Fifth grade students engaged in a cooperative learning environment: Evaluating their ability to determine the status of their own conceptions about matter

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Abstract

This study integrated cooperative learning methods in classroom instruction to investigate the effects on achievement and conceptual change in matter concepts involving 70 fifth grade students after 10 weeks of instruction. Data obtained from the administration of two achievement tests indicated that there were significant differences between the pretest and posttest mean scores on the Matter Unit Test as well as on the Matter Diagnostic Test. Since the notion of status is fundamental to the Conceptual Change Model (Posner, Hewson, Strike & Gertzog, 1982) this study also investigated student's ability to determine the status of their own conceptions. Analysis of student's use of written descriptors provided varied evidence of their ability to use technical language (intelligible, plausible, or fruitful) and effectively determine the status of their own conceptions.

Introduction

In addition to the problem of teaching the facts and processes of science, teachers also have to unteach the intuitive conceptions that students develop outside the classroom (Guzzetti, 2000; Harrison & Treagust, 1996). Research indicates significant conceptual differences between intuitive science (alternative conceptions) and scientists' science (Driver, Squires, Rushworth & Wood-Robinson, 1994; Taber, 2001). Therefore, while school science educators are confronted with the issue of academic achievement they must also become aware of students' alternative conceptions in science (Duit & Treagust, 2012).

The concept of cooperative teamwork was introduced in the science classroom and laboratory in the late 1970's (Denrell, 2005; Miller & Brewer, 1984) in an effort to enhance academic achievement and increase scientific literacy. Cooperative learning is a different learning organization in which the classroom is structured into cooperative teams of learners (Lazarowitz & Hertz-Lazarowitz, 1998; Levitt, 2002; Lin, 2006; Treagust, 2007).

Theoretical Framework

The fundamental principles of science education research employed by this study are embedded in the theories of cooperative learning conceptual change. There is significant evidence to indicate that a cooperative goal structure can have the most powerful impact in promoting achievement and productivity (Johnson, Johnson & Smith, 2007; Johnson, Maruyama, Johnson, Nelson, & Skon, 1981). The cooperative learning instructional strategy capitalises on students' propensity for interaction (Lundgren, 1994) and promotes positive gains in the area of self-esteem, intrinsic motivation, and partiality for the subject matter (Kagan quoted in Burron, James, & Ambrosio, 1993). Cooperative learning necessitates positive interdependence (a sense of sink or swim together), individual accountability (each of us has to contribute and learn), interpersonal skills (communication, trust, leadership, decision making, and conflict resolution), face-to-face interaction, and processing (reflecting on how well the team is functioning and how to function even better) (Johnson, Johnson, & Holubec, 1993). Supported by prior research meta-analysis validates the findings that cooperative learning increases student achievement, and promotes positive student interactions and relationships.

Conceptual change is difficult to investigate and assess. However, a conceptual change model developed by Posner, Hewson, Strike and Gertzog (1982), and researched comprehensively by Hewson and Thorley (1989), describes learning as a process that involves the interaction between new and existing conceptions with the outcome being dependent on the nature of the interaction. Learners use their existing knowledge to determine whether a new conception is intelligible, plausible, and fruitful. If the new conception satisfies all three criteria and is integrated with existing conceptions, then conceptual change learning has taken place by a process of assimilation (Treagust, Harrison, & Venville, 1996).

This study embraced the design used in a case study lasting nine weeks conducted by Hewson and Hennessey (1991). Students were given tasks which consisted of a questionnaire that asked them, for each of four instances to select an explanation from the list of options, give reasons for their choices, and comment on the intelligibility, plausibility, and fruitfulness of their choices and other options. Cooperative learning methods were integrated in science classrooms and laboratories to promote academic achievement in science within a peer context. Research on the use of laboratories in science education indicate that the achievement goals of school science depend on student active involvement in practical work integrated throughout the program, and that the laboratory is both a means and an end in science education (Arzi, 1998). The objective of laboratory activities can be subsumed under four broad categories: they are technical skills, scientific inquiry, scientific knowledge, and attitudes (Hegarty-Hazel, 1990; McRobbie, Fisher, & Wong, 1998).

Research questions

This research is distinctive in the area of conceptual change because it represents one of the few studies that examine the effects of cooperative learning using the conceptual change model (Posner, Hewson, Strike & Gertzog, 1982) to evaluate elementary school students' ability to determine the status of their own conceptions. Many past researchers have only looked at the outcome of cooperative learning on achievement (Slavin, 1995; Slavin, Hurley & Chamberlain, 2003), but undoubtedly changes in students' conceptions are strong indicators of the effectiveness of cooperative learning strategies on students' understanding of concepts in addition to achievement. This research examines two areas of concern:

Research question 1: How does a cooperative learning science class influence fifth grade students' understanding of matter concepts?

Research question 2: How effectively can fifth grade students determine the status of their own conceptions about matter?

Methodology

Research design

Since conceptual change research involves probing student's cognitive models by observing what they do, listening to oral communications, and reading written responses, the quality of the data obtained is correlated to the quality of the experimental design. Subsequently, the design is influenced by the profile of the problem, the questions it proposes and the desired end product (Harrison & Treagust, 1996).

Within the context of case study research, an approach was selected that was both exploratory and descriptive in character (Marshall & Rossman, 1995). Case study research as explained by Merriam (1998) is fastidious in that it concentrates on one phenomenon, is descriptive, providing rich illustrations, and heuristic, further investigating the phenomenon. Employing Merriam's theory, this research focuses on fifth grade students' ability to acquire and implement cooperative learning skills and correlates its effect to achievement, and students' ability to determine the status of their own conception. The study is descriptive in nature because it provides rich illustrations of students' insight on the status of their conceptions. In addition, the research is also heuristic because it provides information that can be used to enhance teaching and learning in elementary school science. This study utilized the case study method and quasi-experiments, triangulating information from the case study with data from the two-tier multiple-choice Matter Diagnostic Instrument (MDI) and the Matter Unit Test (MUT) to make imperative contributions (Punch, 1998), and enhance the credibility, dependability, and confirmability of the findings (Guba & Lincoln, 1989).

In order to facilitate student interaction, the tables in the science laboratory were arranged to accommodate groups of four students. The students faced each other as they worked together. The groups were mixed socially, racially, and ethnically, by gender and learning abilities because heterogeneous groups emulate the world which encompasses meeting, accepting, and appreciating differences (Lundgren, 1994). The groups remained the same during the ten week teaching period. Since the Laboratory classes where approximately one hour every week the advantage of not changing the groups gave students the opportunity to really know the group members, and build successful cooperative skills together.

The teachers were trained in cooperative learning strategies and guided in the implementation of the desired instructional approaches of the laboratory activities. The training consisted of four, one hour meetings, during which cooperative learning strategies where introduced and guidelines for implementation discussed. The teachers had six weeks to trial cooperative learning strategies in their science laboratory classes prior to the research. Since the students had little experience working in small groups, the teachers started with short, highly structured laboratory activities during the trials. Teachers were assisted in establishing norms to develop a respectful and safe classroom community. In addition, the teachers modeled positive interpersonal skills, gave students the opportunity to practice the skills, and encouraged them to reflect on how successfully the skills were used. This arrangement ensured that the teachers were competent in the successful implementation of the cooperative instructional approach and the students were comfortable working in cooperative groups.

During the 10-week duration of the study, each class participated in hands-on science activities in the science laboratory for one hour per week in addition to the two and a half hours of science instruction in the homeroom class each week. The total duration of the study was over a period of 35 hours.

Sample

This study was conducted at a coeducational elementary school in Miami-Dade County (MDCPS), located in Miami, Florida, USA. A total of 70 fifth grade students from three heterogeneous classes (DO5, HO5 and SO5) taught by two teachers. The three classes consisted of 30, 29 and 11 students, respectively. The teachers were trained in cooperative learning strategies in four one hour sessions and were guided by the first author in the implementation of the desired instructional approaches for the laboratory activities.

Instruments

Two instruments that were developed by the first author were used in this research to assess understanding of relevant concepts about matter. They were the two-tier multiple-choice Matter Diagnostic Instrument (MDI) (Appendix A) that was developed using the procedure proposed by Treagust (1988, 2006) along with the Matter Unit Test (MUT) (Appendix B). The MDI consisted of 12 two-tier multiple choice items; the first tier required students to select a content response, while the second tier required them to select a reason for their response in the first tier. Each item was scored '1' for correct responses to both tiers and '0' for incorrect response to the first tier, giving a maximum score of 12. The MUT consisted of 12 multiple-choice items, and 2 short-response (SR), questions with a total score of 20 points, one point for each correct multiple choice question and four points for each correct short response question. Both tests were administered as pretests prior to instruction on the unit to determine student's prior knowledge and as posttests at the conclusion of the unit after 10 weeks to ascertain students' improvement in understanding of matter concepts.

Concepts included in instruction

A list of 22 propositional knowledge statements was compiled (see Figure 1) to guide classroom instruction and in the construction of the items in the MDI and MUT to assess understanding of the associated concepts.

Propositional knowledge statements			
1.	An object will sink in a liquid if the object's density is greater than the density of the liquid.	12.	Volume measures how much space matter takes up.
2.	Mass is a measure of the quantity of matter in an object.	13.	A change in the size, shape, or state without forming a new substance is a physical change.
3.	All matter is made of tiny particles.	14.	Solutions are mixtures that are blended completely and look the same throughout.
4.	An object on the moon has less weight than it does on earth.	15.	Compounds are produced by chemical combination of two or more elements to form a single substance.
5..	The mass of an object divided by its volume is the density.	16.	An element is a pure substance that cannot be broken down into simpler substances.
6.	The Earth has a greater mass than the moon; therefore the force of gravity is greater on the surface of the Earth.	17.	Homogeneous mixtures, such as sugar dissolved in water are uniform in appearance.
7.	The tiny particles in a gas are widely spaced making gases less dense than liquids and solids.	18.	Heterogeneous mixtures are not uniform but have physically distinct components.
8.	Weight is a measure of the force of gravity between a planetary body and an object.	19.	A Chemical change produces a new substance with different properties from the original components.
9.	An object's weight depends on its location in the universe.	20.	Ice is less dense than water therefore it floats, but more dense that alcohol so it sinks.
10.	Matter is anything that has mass and takes up space.	21.	A physical change occurs when the components of a mixture are added to each other and when the components of a mixture are separated.
11.	If the upward push of water is strong enough compared to the object's weight the object will float.	21.	Matter exists in three states, solid, liquid and gases.

Figure 1 List of propositional knowledge statements relevant to selected topics on matter

Determining status of students' own conceptions about matter

The Posner et al. (1982) conceptual change model emphasises the view of status as being fundamental to the learning process, arguing that in order for a new conception to be incorporated into a student's schema, the status of the conception must fulfill a number of conditions. The conditions essential for conceptual change to occur are *dissatisfaction* with existing conceptions, *intelligibility* or minimal comprehension of the new competing concept by the learner, *plausibility* or satisfactorily believable for the learner to apply the new concept to problems previously solved, and *fruitful* if the new conception is both intelligible and plausible for the learner and provides new opportunities for inquiry.

During the first seven weeks students learned how to use the descriptors for the technical terms associated with the conceptual change model (see Figure 2) that was developed by Hewson & Hennessey (1991). This use of the descriptors was accomplished through small group work to help identify students' preliminary understandings, while whole class discussions gave them the opportunity to share their ideas and use the technical terms shown in Figure 2.

Descriptors for the technical terms in the CCM	
For an idea/concept to be: Intelligible to me	
I must know what the concept means • The words must be understandable • The words must make sense **I should be able to describe it in my own words** • Examples that belong • Examples that do not belong	**I can find ways of representing my ideas to others** • by drawings or illustrations • by talking about or explaining it • by using idea map (concept map)
For an idea/concept to be: Plausible to me	
It must first be intelligible **It must be believable** • it must be true • it must fit my picture of the world	**It must fit in with other ideas or concepts I know about/believe it is the way** • I really see things about me • I see things work
For an idea/concept to be: Fruitful for me	
It must first be intelligible **It should be plausible** **I can se it as something useful** • It can help me solve problems • It can help explain ideas in a new way	**It gives me new ideas for further investigations/exploration** **It is a better explanation of things** • It is a new way of looking at things

Figure 2 Descriptors for the technical terms in the conceptual change model (CCM) (Hewson & Hennessey, 1991)

During the middle and end of the 10-week unit data were obtained from a task performed by students working in cooperative groups. Responses to the tasks were collected in written form, which students completed individually following group completion of the activity. Students were allowed to refer to the handout describing the Conceptual Change Model (CCM) descriptors (similar to Figure 2) as they completed the worksheet.

CCM task: Air as matter

The task investigated students' understanding of the definition and physical properties of matter, as well as of the states of matter. The instructions, diagram, and question is presented in Figure 3.

Instructions

Place a piece of paper towel in a beaker. Push it down to the bottom of the beaker.
Place the beaker upside down in a bowl.

The arrows in the diagram below show where the force if any, is coming from that prevents water from filling the cup and the paper towel from getting wet.

Question

Which picture do you think best shows where the force if any, is coming from that prevents water from filling the cup and the paper towel from getting wet? Circle the letter (A, B, C or D)for the correct answer.

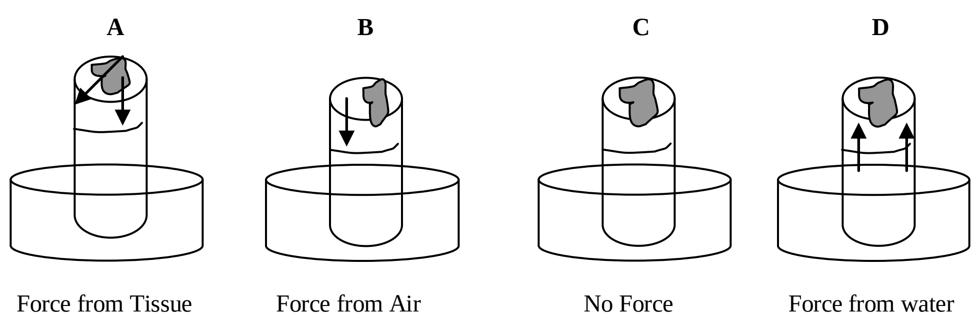

Figure 3 The CCM task to evaluate status of students' conceptions of matter

Results

Understanding of matter concepts

The two sources of data used to assess cognitive achievement were the two-tier multiple-choice Matter Diagnostic Instrument (MDI) and the Matter Unit Test (MUT). The internal consistency for the pretest and the posttest administration of the two instruments were established by computing the Cronbach's alpha coefficient (Cronbach, 1951). These values are summarised in Table 1.

Table 1 Pretest and posttest Cronbach's alpha reliability values for the cognitive assessment tests (N = 70)

Cognitive assessments	No. of items	Cronbach's alpha reliability values	
		Pretest	Posttest
Matter Unit Test (MUT)	12	0.28	0.73
Matter Diagnostic Instrument (MDI)	12	0.51	0.63

The relatively low reliability values were most likely due to the relatively high difficulty of the tests (Mehrens & Lehman, 1991; Sattler, 2001). The mean posttest scores for both tests were higher than the mean pretest scores (see Table 2). T-test analyses confirmed that these differences were significant at the $p = 0.01$ level suggesting that the cooperative learning strategy was successful in facilitating students' understanding of matter concepts in response to Research question 1 (How does a cooperative learning science class influence fifth grade students' understanding of matter concepts?). The strength of the difference between the pretest and posttest mean scores for each test may be determined by computing the effect size, Cohen's *d*. Cohen (1988) has defined the effect size as being small when $d = 0.2$, medium when $d = 0.5$ and large when $d = 0.8$. In this case, the large effect sizes for the MUT and MDI (2.80 and 1.40, respectively) shown in Table 2 further attest to a significant improvement in understanding of matter concepts by the fifth grade students as a result of the cooperative learning environment that was facilitated during instruction.

Table 2 Pretest and posttest descriptive statistics and paired samples t-test comparisons for the two cognitive assessments (N= 70)

Tests	Pretest Mean (SD)	Posttest Mean (SD)	t-value	Effect size (Cohen's *d*)
Matter Unit Test (MUT)	6.66 (3.27)	17.51 (4.39)	16.59**	2.80
Matter Diagnostic Test (MDT)	3.69 (2.22)	7.10 (2.63)	8.32**	1.40

** $p < 0.01$

The posttest scores for the MUT showed an average increase of 41%, while posttest scores for the two-tier diagnostic test (MDI) showed an average increase of 28% (Table 3). Comparison of class performances on the MDI indicated that class D05 had a lower gain score than the other two classes.

Table 3 Percentage pretest and posttest mean scores and gain scores for achievement tests (N = 70)

Class	Mean percentage					
	Matter Diagnostic Instrument (MDI)			Matter Unit Test (MUT)		
	Pretest	Posttest	% Gain	Pretest	Posttest	% Gain
H05	34	62	28	34	76	42
S05	33	63	30	30	70	40
D05	20	47	27	21	62	41
Overall mean	29	57	28	28	69	41

Analyses of responses to CCM task

Selection of responses to CCM task

This task (responded to by 66 students) investigated student's understanding of the definition and physical properties of matter, and of the states of matter. The instructions, diagram, and question were presented earlier in Figure 3. The data in Table 4 indicate that 82% of the students selected the correct response B, suggesting that the tissue did not get wet because the air in the beaker takes up space and pushes down on the surface of the water thus preventing it from filling the beaker and wetting the tissue. Answer A was selected by 3% of the students who suggested that the tissue did not get wet because the tissue paper exerted a downward force that prevented water form entering the jar. Response D was selected by 15% of the students who suggested that the water exerted an upward force that prevented it from filling the jar.

Table 4 Student's responses to the CCM task shown in Figure 3 (N = 66)

	Classes				
Task answers	H05	D05	S05	Total	Percentage
A	1	-	1	2	3
B*	15	14	25	54	82
C	0	0	0	0	0
D	6	0	4	10	15
Total no. of students	22	14	30	66	100

*correct response

Students were asked to explain in writing the reason for their choice of answer to ascertain their understanding of the associated concept. The question was, "*Please explain the reason for your choice. In other words why do you think letter___ best shows the force, if any* *acting on the water preventing it from filling the jar and wetting the tissue?"* The student's rationales for their selection varied and are shown in Tables 5 and 6.

Table 5 Students' rationale for selecting option B in response to the CCM task

CCM task answers	Students' written explanations for their choice "Which picture do you think best shows where the force if any, is coming from that prevents water from filling the beaker and the paper towel from getting wet? Circle the letter of the correct answer."
B (Force from air)	-Air filled the beaker and when you put it in the water the air took up space and water can't share the space with air. -I chose B because air takes up space. -The tissue doesn't have force. Also the water isn't pushing it. It's the air because of its gravitational pull. -I think B because the air is pushing the water down. -Because the force from the air, so the air doesn't let the water come in. -Because the pressure from the air pushes the water down so the tissue does not get wet. -I think it is B because the little beaker has air inside and air takes up space and has mass. -I think it is B because when you push the beaker down it brings air into the jar and the air took up space. -I think that it is B because if it was C or D the force of the water will get it wet with no force it also will get wet and a is because its still get wet. -I think my answer B is correct because the air is holding the water down so the water cannot touch the tissue paper. -Force from the air pushes the water away; what I mean is that the air takes up space and causes the tissue to not get wet. -I think the answer is B because it's the only possible force why the tissue did not get wet because of the force from the air. -I think my answer is B because the force from the air is pushing down on the water so no water is getting to the tissue. -Because when you push the beaker down all the air comes inside the beaker and then that's when it goes down in the water and the air stops the tissue from getting wet.

Table 6 Students' rationale for selecting options A and D in response to the CCM task

Task 1 answers	Students' written explanations for their choice
A (Force from tissue)	-I think it's A because paper floats in water and so does a tissue paper, and the tip may probably sink down. -I choose this one because this is not wet, all the other ones look wet.
D (Force from water)	-I think my answer is D because of the force from the water. -The tissue is actually taking all the force of the beaker. -It is possible because the force of the water pushed up and it got wet and contains mass and it takes up space. -The force from the water helps the tissue not to get wet because the water is heating up the tissue. -The water is the only possible force that could produce a force against the paper tissue. -I choose D because the force of the water is not making the paper towel get wet. -I think it is because the force of the water is pushing into the beaker but since air is partly occupying the beaker the water doesn't completely get in.

These results show that the majority of students understood the concept and provided precise scientific explanations for their responses. However, a small percentage of students identified the correct response but the reason for their selection was incorrect. Only 2% of the students did not provide an explanation supporting the reason for their choice of answer (B).

Table 7 Summary of students' written explanations for selecting answer B. (N = 54)

	Class				
Response	D05	H05	S05	Total	Percentage
Correct	13	21	13	47	87
Incorrect	3	3	0	6	11
None	0	0	1	1	2

Status of students' own conceptions about matter – Intelligible conceptions

In response to the question asking students to decide whether or not their answer seemed intelligible, of the 54 students who selected the correct response B, 94% responded positively. Table 8 shows the percentage of students using language associated with descriptors specific to the "intelligible" status. The idea or concept was intelligible because 100% of the 54 students indicated that they "know what the concept means," and 90% could "describe it in their own words." Even though most of the students stated that they could give examples or represent their ideas only 4% actually provided written examples and 20% either represented their intelligibility of the concept using illustrations or further clarified the concept.

Table 8 Summary of students' responses using descriptors to support their notion of the concept being intelligible

Descriptors	Class			Total	Percent
	D05	H05	S05		
Know	14	20	20	54	100
Describe	12	16	21	49	90
Example	1	0	1	2	4
Represent	10	1	0	11	20

Examples of students' written responses illustrating that they know, can describe the concept, give examples or represent it by explaining it is shown in Table 9.

Table 9 Examples of students' written responses supporting their notion of the concept being "Intelligible."

"Intelligible" Descriptors	Students' written responses
Know	-Yes, because I can explain it in my own words and understand what is happening. - Yes, it is intelligible to me because air is matter and it takes up space and it's understandable to me. - Yes because I really understand the experiment. It is very possible. I believe there is a force pushing it. It's very useful when I grow up.
Describe	- Yes, because the air is the only thing that is in there that could push the water down without the water hitting or touching the tissue. - The answer I chose seems intelligible because the water can't make the tissue wet because of the air pressure separating them.
Example	- Yes, because the air takes up space like in a balloon. - Yes it is intelligible because I understand it. It makes sense. I can give examples.
Represent	- It is intelligible to me because the air has mass and takes up space. The air blocked the water from wetting the tissue since it takes up space. - Yes, because when you put the beaker in the water the force from air is in the beaker. So that is why the water does not go in.

Status of students' own conceptions about matter – Plausible conceptions

The written responses of the 54 students were evaluated to determine whether or not they supposed their knowledge to be plausible. Based on students' use of descriptors attributed to a concept being identified as "Plausible" 93% believed that it is true, 33% understood that it fit a picture of the world, 13% supposed that it fit with other ideas or concepts they knew about or believed, and 30% stated that it is the way they see things about them and see them work as depicted in Table 10 (Hewson, & Hennessey, 1991). Approximately, 7% of the students acknowledged that the concept was not plausible to them for various reasons.

Table 10 Summary of students' written responses supporting their notion of the concept being recognized as "Plausible"

"Plausible" Descriptors	Class			Total	Percent
	D05	H05	S05		
Not plausible	1	1	2	4	7
Believe/True	16	16	18	50	93
Fits picture of the world	8	7	3	18	33
Fits other ideas/ concepts	4	3	0	7	13
See things about me/see things at work	5	5	6	16	30

The students clearly articulated their ideas to support the notion that the concept was either plausible or not plausible to them as shown in Table 11.

Table 11 Examples of students' written responses supporting their notion of the concept being "Plausible"

"Fruitful" Descriptors	Students' written responses (Plausible)
Not plausible	-My answer doesn't seem plausible because I really can't see a clear picture in my head. -No, because I don't feel the force of air, just water. -No, because I don't think it is going to be plausible. -No, because I don't think that it could help the world.
Believe/True	-Yes, because I can explain it and I really believe that it is true. -Yes, because I believe that it is true and B is the possible answer. -I believe it because I understand it. I can explain it to someone which they can understand too.
Fits picture of the world	-Yes, it is plausible because there is air in this room right now and air is outside so that makes it true. -Yes, because it is fitting my picture of the physical and logical extensions of my picture of the world.
Fits others ideas/concepts	-I think that it is true because the air is taking up space because when I breathe my lungs get filled up with air that takes up space. -Air takes up space and has mass, like when you blow up a balloon the air takes up space, that's the reason why I think its plausible.
See things about me/See things work	-Yes, I can solve a problem because I do see things about me that seem true and the reason for that opinion is because I see it in the real world. -Yes because when the inside of the soda opens all the air comes out. -Yes because if you blow up your cheeks you have air taking up space.

Status of students' own conceptions about matter – Fruitful conceptions

A concept fulfills the status of being fruitful to a student if it is intelligible and plausible, as well as enabling the learner to solve problems, explain ideas in a new way, apply it to other ideas, provide a better explanation or is perceived as being useful. A review of the 54 students' written statements indicated that 85% suggested that the concept was fruitful (useful) and used the descriptors 'true' or 'believe' in their statements. The descriptors that students used to support the notion that the concept was fruitful to them indicated that while most suggested that the concept was useful, many did not state or give examples as to how the concept was practical (Table 12). Perhaps the students did not give examples because the question did not instruct them to do so. More specific descriptors were used to support the status of fruitful with 85% relaying that it was useful, 30% stating that it helped them solve problems, 15% conveyed that it helped to explain ideas in a new way, and 7% thought that it provided a new way of looking at things as indicated in Table 12. Notably, 15% of the students did not perceive the concept as being fruitful to them.

Table 12 Summary of students' written responses supporting their notion of the concept being recognised as "Fruitful"

	Class				
Descriptors	**D05**	**H05**	**S05**	**Total**	**Percent**
Not fruitful	1	5	2	8	15
Fruitful (useful)	10	17	19	46	85
Solve problems	4	6	6	16	30
Explain ideas	2	6	0	8	15
Apply it to new ideas	2	1	0	3	6
New ways of looking at things	2	1	1	4	7

One student was able to articulate how he was able to apply the concept to new ideas when he stated, “I think it can help me with everyday problems because I will understand what’s happening in scientific terms” (Table 13). A small percentage of the students conveyed that the concept was not fruitful to them and provided some interesting reasons. In response to the question, “Does the answer seem fruitful to you?” one student stated, “No, because fruits aren’t involved.” This response seems to imply that the student did not understand the terms intelligible, plausible, and fruitful as they relate to the conceptual change process. Another student clearly communicated why the concept was not fruitful in her written statement, “No, because it cannot help me solve problems, I can’t understand it, and it’s not a new way of looking at something because I have seen it before.” Students’ comments in support of the status of their conception either being fruitful or not fruitful are found in Table 13.

Table 13 Examples of students’ written responses supporting their notion of the concept being “Fruitful”

Descriptors	Students’ written responses (Fruitful)
Not fruitful	-No, because fruits aren’t involved. -No because I can’t solve problems. -The answer doesn’t seem fruitful because it is just intelligible and not plausible. -No, because it cannot help me solve problems and I can’t understand it and its not a new way of looking at something because I have seen it before.
Useful	-Yes, because I believe and I know I can use this in everyday life. -Yes, it is useful.
Help solve problems	-Yes, my answer seems fruitful because it can help me solve problems. -I think it can help me with everyday problems because I will understand what’s happening in scientific terms.
Explain ideas	-Yes, because it is a way to explain to a person that the air has mass and takes up space. -Yes, because I can explain it in my own words and it is a new way of looking at things.
Apply it to new ideas	-It can help me solve problems. It can give ideas in a new way. -Yes, because when I go to the pool I have air in my mouth because I know that I can’t breathe under water that’s why I need to take in air.

Conclusions, implications and recommendations

The effect of a cooperative laboratory class on fifth grade students’ achievement in the topic relating to matter concepts was ascertained by analysing data obtained from the administration of the Matter Diagnostic Instrument (MDI) and the Matter Unit Test (MUT) as pretests and posttests to 70 fifth grade students (of ages 10-11 years), in three classes at an elementary school in Miami-Dade County, Miami, Florida, USA. The paired samples t-test for differences between the pretest and posttest mean scores were significant for both tests ($p < 0.01$). The Cronbach's alpha coefficient which is a measure of the internal consistency of the instrument was 0.28 and 0.51 on the pretest for the MUT and MDI respectively, and 0.73 and 0.63 for the MUT and MDI posttest. The small sample size (70) may have contributed to the lower alpha reliability values. The large effect sizes for the MUT and the MDI were 2.80 and 1.40, respectively. In response to Research Question 1 (What is the effect of a cooperative laboratory class on fifth grade students' achievement in physical science?) all these results attest to a significant improvement in understanding of matter concepts by the fifth grade students as a result of the cooperative learning environment that was facilitated during instruction. These findings support the view the nature of laboratories encourages and permits students to cooperate at higher levels than other instructional methods (Chang & Lederman, 1994).

"Learning for conceptual change is not simply accumulating new facts or learning a new skill. In conceptual change, an existing conception is fundamentally changed or even replaced, and becomes the conceptual framework that students use to solve problems, explain phenomena, and function in their world" (Davis, 2001, p.1). According to Posner et al. (1982), the conditions necessary for conceptual change are dissatisfaction with existing ideas, intelligibility, plausibility, and fruitfulness of the new competing conception often referred to as conceptual status. Subsequently, in order to determine how effectively fifth grade students are able to ascertain the status of their own conceptions, data were obtained from a matter conceptual change task (see Figure 3) completed by students working in cooperative groups, during the middle and end of the nine week unit.

The task examined students understanding that air is matter and therefore, takes up space and has mass. Following completion of the task (in which students had to place a piece of tissue in a beaker and invert it in a bowl of water). The first question required students to select a multiple choice answer and explain the reason for their choice. The results for the task showed that 82% of the students selected the correct response (Table 4). The students gave reasons for the answers that indicate that they understood the concept. The remaining questions on the task sheet required students to evaluate their knowledge relative to their conceptual status. In response to the question, "Does the answer you chose seem intelligible to you? If so, why? If not, why not?" all of the students stated that the concept was intelligible and rationalised that they could describe it (90%), were able to give an example, (4%), and were able to represent it (20%) (see Table 8).

The status of plausibility was addressed by students' answers to the question, "Does the answer seem plausible to you? If so, why? If not, why not? For the task, 93% of the students stated that the concept was plausible, while only 7% acknowledging that it was not plausible. Using the descriptors provided, 93% conveyed that they believe it is true, 33% stated that it fits their picture of the world, 13% believed that it fits in with other ideas or concepts, and 30% thought that it enabled them to see things about them or see things work. An assessment of data obtained from responses to the final question, "Does the answer seem fruitful to you? If so, why? If not, why not? indicated that 85% of the students thought that the concept presented in task was fruitful. A small proportion of students (15%) identified the concepts as not being fruitful. Students' use of conceptual change descriptors revealed that 85% said that the concept was useful, 30% thought that it could be used to solve problems, 15% said that it could be used to explain ideas, 6% could apply it to new ideas, and 7% communicated that it gave new ways of looking a things.

There are several conclusions that can be deduced from this study about students' conceptual change. First, the fifth grade students have provided written evidence of their ability to use technical language to identify the status of their conception. It was noted, however, that often when students referred to a concept as being useful or stated that it helped them solve problems they did not however explain how it was useful or how it helped them solve problems. Perhaps, students did not give this information because the question was not specific in requiring them to do so. Second, as students articulated the status of their conceptions, it was noted that if the concept was not plausible, it was also not fruitful. This observation is consistent with the conceptual change model (Posner et al., 1982). Third, the students' statements seem to indicate that they experienced conceptual exchange.

To conclude, in response to Research Question 2 (How effectively can fifth grade students determine the status of their own conceptions about matter?)**,** assessment of student's use of descriptors provides varied evidence of their ability to use the technical language and effectively determine the status of their own conceptions.

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Appendix A
Matter Diagnostic Instrument

Name: ______________________ Teacher: __________________ Date: ___________

INSTRUCTIONS

This test consists of 12 questions which examine your knowledge of the nature of matter. Each question has two parts: A Multiple Choice Response followed by a Multiple Choice Reason. You are asked to make one choice from both the Multiple Choice Response section and one choice from the Multiple Choice Reason section for each question. There are 12 questions on this test.

1. Read each question carefully.
2. Take time to consider your answer.
3. Circle your answer for each question on the test.
4. Read the set of possible reasons for your answer.
5. Carefully select a reason which best matches your thinking when you work out your answer.
6. Circle the letter that represents your answer.

1. When an astronaut travels from Earth to the Moon, which of the following changes?

A. Weight

B. Mass

The reason for my answer is:

1. It is a measure of the force or pull of gravity on the mass of an object.
2. It is the amount of matter in an object.
3. It is a measure of the volume of an object.

2. Can air be classified as matter?

A. Yes

B. No

The reason for my answer is:
1. Air cannot be seen or touched.
2. Air takes up space and has mass.
3. Air does not have mass but it takes up space.

3. Take a look at the containers below. Each container has the same volume. If each egg has the same mass, which container would have the greatest density?

Container J Container K

A. Container J

B. Container K

The reason for my answer is:
1. The greater mass will result in an increase in density.
2. The lesser mass will result in an increase in density.
3. The eggs in container K are packed closer together.
4. The eggs in container J are packed further apart.

4. A cup of peanuts is placed in a blender and ground to a fine paste that we call peanut butter. This is an example of a ________________.

A. Physical change

B. Chemical change

The reason for my answer is:
1. The peanuts changed from a solid to a semi –liquid.
2. Grinding the peanuts caused it to look different and form a new substance.
3. Although the paste looks different to the peanuts, peanut butter has most of the same properties as peanuts.

5. Mary added Kool-Aid and sugar to water and made a refreshing drink. This drink is an example of what kind of solution?

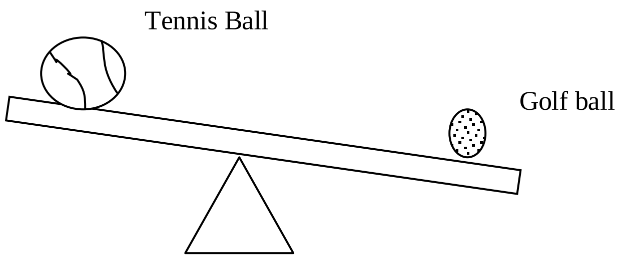
A. Heterogeneous

B. Homogeneous

The reason for my answer is:

1. This solution is uniform in appearance because all the parts are blended together.
2. This solution is not uniform in appearance and is only partially blended.
3. This solution has a jelly-like appearance.

6. A tennis ball and a golf ball were placed on a scale as shown in the picture below. The scale was originally balanced until the balls were placed on it. Which ball has the greater mass?



A. Tennis ball

B. Golf ball

The reason for my answer is:

1. The golf ball has the lesser mass and causes the scale to be unbalanced.
2. The tennis ball has the lesser mass and causes the scale to be unbalanced.
3. The tennis ball has the greater mass and causes the scale to be unbalanced.
4. The golf ball has the greater mass and causes the scale to be unbalanced.

7. Jerry found an iron nail, sugar cube and a gold ring in the kitchen drawer. Which one of these objects is a compound?

A. The gold ring.

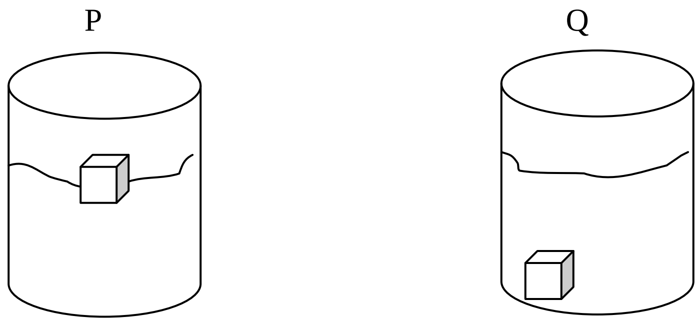
B. The sugar cube

C. The iron nail.

The reason for my answer is:

1. The sugar cube is made of carbon, hydrogen and oxygen.
2. The gold ring is made of the element gold.
3. The iron nail is made of the element iron.

8. Picture P shows an ice cube in water while picture Q shows an ice cube in alcohol. In water the ice cube floats, in alcohol it sinks. Why does this happen?

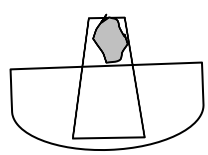


A. Ice is denser than water and less dense than the alcohol.

B. Ice is less dense than water but denser than the alcohol.

The reason for my answer is:
1. The upward push of the water is greater than the weight of the ice cube, so the ice cube floats in water.
2. The upward push of the water is less than the weight of the ice cube so
3. the ice cube floats in water

9. Mr. Josiah placed a piece of tissue paper in a cup and placed it upside down in a bowl of water as shown in the picture. What do you think happened to the tissue paper?



A. The tissue paper will get wet.

B. The tissue paper will not get wet.

The reason for my answer is:
1. Air takes up space and prevents the water from filling the entire cup.
2. Air does not take up space therefore the water fills the entire cup.
3. The tissue paper pushes down on the water and gets wet.
4. The tissue paper pushes down on the water and does not get wet.

10. When vinegar (a liquid) is mixed with baking soda (a solid), bubbles of gas rise through the liquid. This gas produced is carbon dioxide. Mixing baking powder and vinegar is an example of a ___________________change.

A. physical

B. chemical

The reason for my answer is:

1. A new substance is formed.
2. A homogeneous solution is formed.
3. A change in the appearance occurs but the substance does not become different.

11. Venus placed a metal ball in a beaker containing 50 ml of water. After the ball was placed in the water she noticed that level of the water in the beaker increased to 58 ml. What physical property was she measuring?

A. Mass

B. Weight

C. Volume

The reason for my answer is:

1. It is a measure of the amount of mass in an object.
2. It is measure of the force of gravity between the earth and the object.
3. It is a measure of the amount of space an object takes up.

12. Everyday Johnny uses a bar of soap to wash his hands before dinner. After each use he notices that the soap gets smaller and smaller. He realizes that a ________________change has take place.

A. physical

B. chemical

The reason for my answer is:

1. A change in original substance has taken place.
2. A change in the size or shape has taken place without forming a new substance.
3. A change resulted in the formation of a new substance.

Appendix B

Name: ______________________ Date: ___________ Teacher: __________________

Matter Unit Test

For each item, circle the letter that indicates the most appropriate answer.

1. An example of a gas is
- A. helium
- B. apple juice
- C. water
- D. copper

2. Why does ice float in water but sink in alcohol?
- A. Ice is denser than water but and denser than alcohol.
- B. Ice is less dense than water but denser than alcohol.
- C. Ice and alcohol has the same density.
- D. Ice and water has the same density.

3. Matter that has a definite shape and volume is a(n)
- A. gas
- B. liquid
- C. solid
- D. metal

4. Two or more elements put together form a(n)
- A. silver
- B. gold
- C. iron
- D. compound

5. Which of these units is used to measure mass?
- A. litre
- B. gram
- C. Newton
- D. metre

6. Winston Scott weighs more on the earth than he does on the moon. How can this be explained?
- A. The mass of the astronaut stays the same, however his weight changes due to the difference in the force of gravity on the earth and on the moon.
- B. The mass of the astronaut changes and his weight changes due to the difference in the force of gravity on the earth and on the moon.
- C. The mass of the astronaut changes however the force of gravity on the earth and the moon is the same.
- D. The mass of the astronaut stays the same as well as the force of gravity on the earth and the moon.

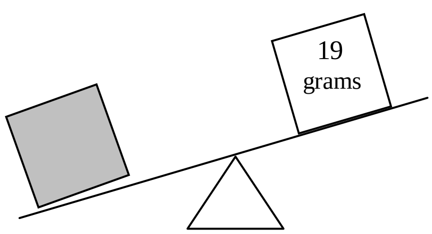
7. What is the smallest particle of matter called?
A. compound
B. a particle
C. an atom
D. a property

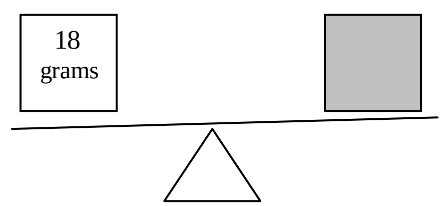
8. An example of a compound is
A. salt
B. carbon
C. oxygen
D. hydrogen

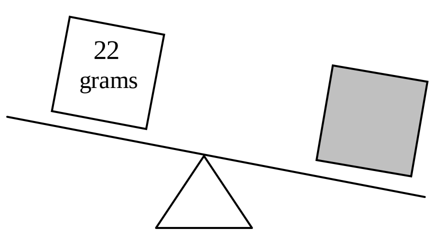
9. Changing state is an example of
A. chemical change.
B. physical change.
C. chemical reaction.
D. chemical interaction.

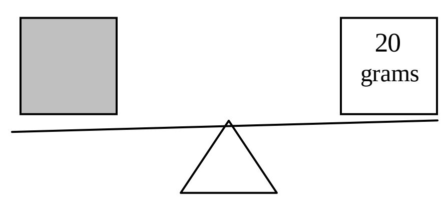
10. Oxygen and iron can combine to form
A. water.
B. carbon dioxide.
C. air.
D. rust.

11. Jennifer is measuring the mass of four different boxes shown in the pictures. Which box has the least mass?

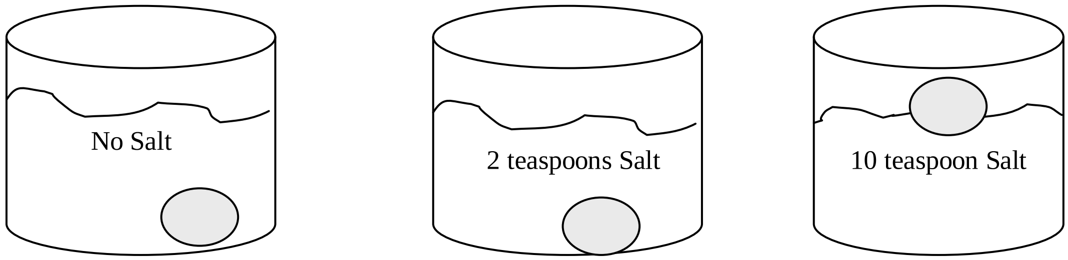
A. 

B. 

C. 

D. 

12. Jennifer is conducting an experiment in which she is trying to float an egg. She adds the amounts of salt shown in the pictures to one cup of water. How can the results of the experiment be explained?



A. The water changed the density of the egg.
B. The water changed the density of the salt.
C. The salt changed the density of the water.
D. The salt changed the density of the egg.

13. What happens to solids such as water when heat is applied? (4 points)

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14. Students in your science class do not believe that air is matter. Think about the definition of matter and using items shown in the picture design a simple experiment to illustrate that air is matter. (4 points)

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