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Exploratory Study of Misconceptions of Grade VII Students in Science[1]

K. M. Rajan

Abstract

New learning is intertwined with what already exist in learners' cognitive structure. Learners are more likely to construct an interpretation that agrees with their notions of reality and or misconceptions. The objective of the present study is to shed some light on the misconceptions of seventh-grade students more specifically on the concepts related to force, motion, structure of matter, properties of matter and light. A 10-item two-tier multiple-choice test was developed and administered to 404 grade seven students from twelve schools. The results indicated that seventh grade students among several misconceptions hold that a rolling ball will continue to roll only if a force is applied on it continuously. To teach children successfully, teacher requires an understanding of how children think and construct scientific knowledge. The role of teacher as a diagnostician is important in this context. Recent research has revealed that students' misconceptions interfere with, rather than enhance learning

Pupils have naïve conceptions (descriptive and explanatory systems) about scientific phenomena that develop before they experience formal study of science. Naïve conceptions that students bring with them to the classroom are persistent. Naïve theories and the distortions they engender in students' comprehension are among the principal causes of students' failure to achieve understanding in science (Champagne, Gunstone & Klopfer, 1983).

The naïve propositions such as - 'heavier objects fall faster than lighter ones' - is common among learners. This is generalized from their experience that stones fall faster than leaves. However, the 'contaminated' form as - ' heavier objects fall faster than lighter ones because gravity pulls harder on heavier objects' - is the result of information learned in science that is inappropriately linked to an existing naïve conception (Champagne, Gunstone & Klopfer, 1983). Thus, a learner selectively adds (assimilates or/and accommodates to use the Piagetian terms) those aspects of formal science to his/her naïve conceptions. However, naïve conception is different from prior knowledge which is explained in the following section.

Prior knowledge may be defined as a combination of knowledge and skills accumulated from previous experiences (Hewson, 1986). However, there is an abundance of terminology used by researchers to refer to what seems to be the same construct – prior knowledge. These include background knowledge, pre-existing knowledge, previous knowledge and existing knowledge. In this paper all these terms are used to mean prior knowledge. The term here denotes that the knowledge is based on some experience and not notions of reality. Prior knowledge exists not only at the level of "concepts," but also at the levels of perception, focus of attention, procedural skills and modes of reasoning.

Prior knowledge is like a conceptual frame to which new knowledge is incorporated. Prior knowledge may facilitate or obstruct/interact with new learning. New knowledge does not replace prior knowledge; rather new knowledge re-uses prior knowledge. Re-use is made possible by a process in which prior knowledge is refined, and placed in a more encompassing structure. The Piagetian assimilation and accommodation are not discussed here for those who treat learning as a one-directional process.

Learning Difficulties

New learning is intertwined to what already exists in the learner's cognitive structure. Learners are more likely to construct an interpretation that agrees with their naïve conceptions/prior knowledge. Learners hold a wide range of ideas about many scientific topics that often contradict the science that they will have to learn in schools. Teachers should not assume that their students will come to classes without any perceived ideas about a topic. The nature of learners' ideas varies across a number of dimensions. Some of the ideas appear to be quite specific, while others are more general. Sometimes learners' ideas are easily labile but others are very stable. Certain conceptions seem to disappear rapidly under the effect of teaching. For example, many beginners who are asked to light a bulb using a battery and wires consider that a single wire is enough to carry the current from the battery to the bulb, without the circuit needing to be closed with another wire. But this conception disappears with a single encounter with the topic (Dupin & Joshua, 1987).

The overwhelming weight of evidence has forced informed educators to fundamentally change the way science is taught. Traditionally, it has been assumed that the naïve conceptions/prior knowledge that students already possess will facilitate further learning (Champagne, Gunstone & Klopfer, 1983). Emphasis was on the role of facilitative function (positive transfer) of these in learning. That is, the facilitating effect of knowing something on learning a new concept. Recent research has revealed that students' misconceptions interfere with, rather than enhance learning. This has raised a new problem of identifying and confronting (if needed) with misconceptions so that science knowledge presented in the instruction can be successfully learned and applied.

Students' conceptions of natural phenomena are very content-and context-dependant. Conceptions guide observations (Duit, 1991). Students (as do human in general) tend to see what they want to see. There is a tendency among students to "observe" only the aspect of experiments that support their own view. Sources of students conceptual frames are: (1) sensual impression, (2) everyday language, (3) innate structures of brain, and (4) learning in students' social environment and instruction (Duit, 1991). For example, "the sun rises in the East" leads to the idea that sun is moving and not the Earth. The sensual impression and everyday language contribute to naïve concepts.

Role of a Science Teacher

Recent studies have highlighted the importance of teachers' understanding of how children learn. To teach children successfully, teacher requires an understanding of how children think and construct scientific knowledge as well as a thorough understanding of science (Alsop, 2003). There are several ways to ascertain different views held by their pupils such as questionnaires, informal discussions and interviews. As a medical practitioner diagnoses the cause of a symptom before attempting to alleviate it, so the teacher needs to diagnose the viewpoints of her/his pupils before deciding how to set about modifying them towards more scientifically acceptable ones. Where pupils' views are completely unknown, an awareness of the significance of pupil's views can in itself lead to the discovery of some important factors in children's present thinking about the topic concerned. For this to occur regularly, however, a systematic recording of interesting comments made by pupils in the class will have to be analyzed.

In ordinary classroom interactions, it is not possible to explore any one pupil's ideas in depth. For example, when an inappropriate or unexpected answer is provided by a pupil in a teacher-led discussion, a few moments can be spent attempting to find out why the pupil gave that answer. So, often in class, the inappropriate answer is ignored and the teacher moves the question on to another pupil in constant pursuit of the 'right' answer. To discover or to diagnose children's existing knowledge, teachers must provide plenty of opportunities for pupils to express their ideas, whether in small groups or in whole-class settings. Teachers, need to ensure a classroom climate where children's ideas are valued and listened to. The role of teacher as a listener is inherent in the role of 'teacher as a diagnostician' (Osborne & Freyberg, 1985).

Several researchers have investigated misconceptions related to various topics in Physics and Chemistry such as Light (Kaewkhong, Mazzolini, Emarat & Arayathanitkul, 2010; Yalcin, Altun, Turgut & Aggul, 2009; Sahin, Ipek & Ayas, 2008), Force (Sharma & Sharma, 2007; Trumper & Gorsky, 1996), and Force & Motion (Bayraktar, 2009). However, the nature of misconception depends on several factors and hence a study on seventh grade students on a few selected concept is warranted. So the study is titled - - "Exploratory Study of Misconceptions of Grade VII Students in Science." The objective of the present study is to shed some light on the misconceptions of seventh grade students, more specifically on the concepts related to force, motion, structure of matter, properties of matter and light.

Tool

There are several techniques and instruments such as - - (1) interview about instances and events, (2) prediction-observation-explanation, (3) drawings, (4) paper and pencil tests based on multiple-choice items and (5) two-tier multiple choice tests that can be used in identifying naïve conceptions/prior knowledge/misconceptions. Of these approaches, two-tier multiple choice item is the most common tool that has acquired strong support. However, open-ended two-tier tests allow teachers to explore each student's reasoning patterns and misconceptions.

A test with a total of 10 items was developed. Five questions were 'Yes or No' type and five questions were two-tier multiple choice questions with diagrams. The items in two-tier multiple choice diagnostic tests were designed to identify students' preconceptions and misconceptions. The tool developed is comparable to the format of *'Test of Logical Thinking'* (Tobin & Capie, 1981)

Sample

A 10-item two-tier test was administered to 404 grade VII students from eleven schools of Kottayam Revenue District, and one school from Thrissur Revenue District, taking into account the type of school - government, government aided and unaided.

Results

The questions and students' responses are given below.

Question No. 1

Sound travels at a greater speed in air than in objects like wood.

Of the 404 seventh grade students, 112 students (27.72%) responded that the statement is wrong. This concept was further probed by the item given below.

Examine the figures given below. In Figure 1, sound is passed through a thread using match boxes. In Figure 2, sound is passed through a PVC pipe.

Figure 1

Figure 2

Of the two, through which sound passes at a greater speed? [Put a tick mark (✓) against the selected answer]

(i) In Figure 1 -(_ _ _)

(ii) In Figure 2 (_ _ _)

Only 64 (15.84%) students out of the 404 students selected the Figure 1 as the right answer. Students were further asked to explain why he/she selected the answer as the right answer. One of the typical response was that sound travels through air to reach our ears.

Question No. 2

Even though a chair is at rest, a force is acting on it.

Out of the 404 students, 257 students (63.61%) students agreed to the statement. However, students were given a figure to examine their propositions.

A book is kept on the table. Which of the following inferences are true?

(A) The book exerts a force on the table

(B) The book does not exert a force on the table

(C) The table exerts a force on the book

(D) Gravitational force acts on the book

Which are the correct statements? Indicate your choices with a tick mark (✓).

(i) A and C -(_ _ _)

(ii) C and D (_ _ _)

(iii) B and D (_ _ _)

(iv) A, C and D (_ _ _)

Explain why you have selected the answer

166 (41%) students out of the 404 students asserted that the table does not exert a force on the book.

Question No. 3

Force is not necessary to maintain the speed of a ball moving in a straight line. 200 (49.5%) students agreed to this proposition. This was further clarified with the following question.

When no external force is exerted on a rolling ball, it will [Put a tick mark (✓) against the selected answer]

(i) Continue to roll (_ _ _)

(ii) Stop after a while (_ _ _)

(iii) Slow down (_ _ _)

(iv) Stop (_ _ _)

Explain why you have selected the answer.

Only 25 (6.19%) students responded that the ball will continue to roll. "After some time the ball will drop its strength and will require some external force."

Question No. 4.

The size of the image of an object depends on the diameter of the mirror.

Only 92 (22.77%) students believe that the proposition is wrong. This was further probed with a figure. Carefully examine the figures given below.

Figure 1 Figure 2

In Figure 1, a pencil is fixed in front of a small mirror. In Figure 2, a pencil of the same size is fixed in front of a big mirror. Of the following which is the correct Inference? [Put a tick mark (✓) against your choice]

(i) The image formed by the big mirror will be bigger than the image formed by the small mirror. (_ _ _)

(ii) The image formed by the small mirror will be bigger than the image formed by the big mirror (_ _ _)

(iii) The images formed by both mirrors are of the same size. (_ _ _)

Only 250 (61.88%) of the students selected the answer that the images will be of the same size irrespective of the size of the mirror.

Explain why you have selected the answer.

Question No.5

Particles in solids do not have freedom of movement.

96 (23.76%) students agree to the proposition that particles in solids do not have freedom of movement. This was further clarified by another question.

5. Which of the following inferences are correct? [Put a tick mark (✓) against the answer selected by you]

A) Water molecules are in motion. In steam, the movement is very fast, in water it is slow and in ice it is very slow (_ _ _)

B) Water molecules are in motion in water and steam, but in ice they are still (_ _ _)

C) Water molecules are in motion in steam, but, they are still in water and ice (_ _ _)

D) In water, water molecules are in motion. But in steam and in ice, they are still (_ _ _)

Expalin why you have selected the answer.

Only 109 (26.98%) students selected response A. 200 (49.5%) selected response B. 50 (12.38%) selected response C. 64 (15.84%) selected D. Some students have selected more than one response hence the total will not add to the total number of respondents. This will require a detailed examination of their explanations which is beyond the scope of the present study.

Discussion

The results of the exploratory study indicated that students do possess misconceptions about concepts in science. The students' conception of force and motion may be interpreted in terms of their prior knowledge contributed by the experiential base. Moreover, students' concept of force and rest are associated with motion. For students, where there is no motion there is no force. Clement (1983) has also examined the origin of persistence of the preconception "motion implies force." The belief that force "dies out" or "builds up" are common among students to account for changes in an object's speed. Brown and Clement (1989) investigated the instance of "a book resting on a table." They used a bridging strategy to deal with the misconception that 'the table does not exert an upward force on the book.' However, the concept of speed of sound was absent which may be attributed to lack of experiential base to relate the concept speed. The concept of particulate nature of matter of VIIth grade students in this study is comparable to those of XIth and XIth grade chemistry students (Benson, 1991).

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A Science Class in a California School

K. M. Rajan

A combination physical science class with students from grades 9-11 was observed in a multi-ethnic school for a period of three weeks. The investigator observed and audiotaped seven class periods, each of 59 minutes duration, interviewed three science teachers, and collected documents such as seating charts, student grade reports, work sheets, question papers, etc. There are two major themes that can be inferred fairly accurately from the study. (1) Classroom processes can be conceived to have three distinct phases - - the opening phase, the instructional phase, and the closing phase. (2) Teacher's philosophy and personality are translated into teacher's behavior and transpired in classroom management.

The Holy Angels High School is located in San Pedro, California. San Pedro is a rapidly growing area and the school is in its third year of existence. The school looks like a typical suburban high school. The glass windows of the front red brick building have a lot of posters on it. One yellow poster cautioned every visitor: "Kinds Zone" enter with care and love. There are several other posters regarding '*Cinco de Mayo'* (a Mexican festival) celebrations.

The school is a 9-11 multi-ethnic high school offering college preparatory, general education, and vocational courses. The total enrolment in the school is approximately 1500. The student body consists of approximately 53% White, 24% Hispanic and 16% Black students, and the remaining 7% is Asian and students of other origin.

Throughout the school, there is a great concern for discipline and order. As students move from one class to another, campus supervisors are on duty in the corridors to ensure orderly movement. A total of nine staff members - - two vice-principals, one dean, and six campus supervisors, provide for the disciplinary function. Disciplinarians move around with walkie-talkie/radio and count loudly: ten, nine, eight…. go. Before counting 'one' the student should get to the class. One of them was following a group of three girls asking: "Where are you supposed to be?" Students walking in the campus after the bell, were holding up the "yellow card" (the card showing permission) establishing their legitimacy to move around. Disciplinary staff is asking for the "yellow card" from students who are still at the lockers where they keep their personal belongings such as books, back-packs, shoes, and sports items.

One police vehicle is invariably at the 'bus loading zone,' the no parking area, during the third period. A female police officer is meeting with four students. The disciplinary staff who was keeping those students in the lunch area, for the officer to come, was listening to the conversation and was nodding his head. The two soft-drink vending machines near the lunch area are without any customers. As students pass between classes, many of them are searching for something in their lockers. The cluttering sounds of the locker doors indicate the beginning of the next period. The metal lockers reinforce the institutional feeling of the school campus (Lipsitz, 1991, p. 109).

At the time of the study, the staff of the Holy Angels included sixty-eight regular education teachers, one principal, two vice-principals, one dean, three counsellors, one librarian, six campus supervisors, and other non-teaching, administrative, custodial, and cafeteria staff. Each of the regular education teachers served a maximum of 165 students per day. Most of the regular education teachers are working in a area of their specialization. In an interview with Mr. Charles, the science teacher, asserted: "Physical science only that is the only thing that I can teach."

Mr. Charles is a physical science teacher with four years of teaching experience. He has a chemical engineering background with fifteen years of experience in that field. He is a religious man who attends Bible study classes to which he refers to occasionally during his instruction. For example, he mentioned about one of his ailing friends, a cancer patient, who attends the same prayer group, while he was discussing radiation therapy in the class. On another occasion, during group work, he explained to Mary, a student, the different backgrounds of authors of the four Gospels. Mary was reading the Gospel according to St. Mattew while the teacher was lecturing.

Mr. Charles demonstrated a strong sense of ethics. He discussed with the class how his daughter, Nancy, fell off from bed (suspected child abuse) while she was with the baby sitter on the previous day. His daughter had bruises on both cheeks, which resembled four finger prints, and two bumps on the forehead. Antony, a student in the class, suggested: "Mr. Charles, you can quit you job (a big laughter) by taking the case to the court." Mr. Charles responded quickly: "Making money out of my daughter's bruises and cuts! I am not for that."

Mr. Charles is teaching a combination physical science class with students from grades 9, 10 and 11. The students in the class are not college bound. The teacher remarked: "This science class is a graduation requirement." This indicated that the students are not there because they wanted to take the course (Jackson, 1990, p.9)

The chairs in the classroom were arranged in seven rows and five columns. There are tables on the three sides, close to the wall, with air and gas taps and electrical outlets intended for the laboratory work. There are storage cabinets fixed to the wall above the tables. At the back of the class there are four new consignments of teaching-learning kits from M/s. Learning Technologies Incorporated. During an informal conversation, Mr. Charles remarked: "The administrators do not know much about the science learning kits and I have no problem in getting whatever I wanted to get."

The teacher's desk (lecture cum demonstration table) is an organized mess of several requisites – – a 350 ml conical flask fitted with a one-holed cork and a delivery tube; two plastic trays, one labeled "work sheets' and the other labeled "current events." There are two sinks at either end of the table with air and gas outlets.

On the first day as I entered the classroom, I felt that the class had been prepared by the teacher to receive the new "observer." In the subsequent days I became one among the students. Two students Jesse and Joe were sitting on the table. Jesse was on the back table, and Joe was on the side table. When I aked about the seating arrangement Mr. Charles explained his outlook

> "Jesse sits in the back on the table instead of in his seat. I still don't hassle him. You know, I figured if he is sitting back there and paying attention, which he is, I will let him sit on the table, ah uh they don't give me any grief for the most part, and they are listening, they are paying attention and whether they are not sitting in their seats with their hands folded, you know, that doesn't make any difference to me."

Each of the seven lessons that I observed seems to have three phases (Mehan, 1979, pp. 73-75). The phases are: (1) The opening phase, (2) the instructional phase, and (3) the closing phase. The opening phase usually started with announcement:

> "Any one interested in attending a water-polo camp in summer, (Eric-Ooo that sounds fun) good luck ( ) for information – one of the best camps in the nation … If you believe, you qualify for a perfect attendance, pick up your form from the attendance office and turn it to Miss. Anderson, May 6th . … Applications ( ) uh for summer residential programme at U.C. Riverside are here, students interested in participating see Mrs. Moreno/Mrs. Schumacher at …. Students accepted to attend will be notified by June 3rd, all those students selected will stay at the U.C.R. campus.

The opening phase is very time consuming and is a waste of time (ranging from five to seven minutes) Mr. Charles suggested:

> "If I could, ideally, I would like to have uh, you know, two or three hour blocks, but not everyday. You know may be Monday, Tuesday, Thursday have three hours each day, something they; wouldn't spend ( ) because we lose so much time counting the students, getting the stuff out, and it a sort takes

a while getting into the frame of mind of working and once we can get them in the frame of mind, we can let them work and keep working productively for a period of time and then do the clean up ( ) ah uh, you know, this I think would make the teaching more efficient time-wise. And I think it also keeps it from being so sporadic, I mean a little spot here, and a little spot there sort of thing. They get it bite-size pieces and actually think about ( ) and accomplish something in that time."

The instructional phase is teacher dominated and a question (which should more like a statement) rose by the teacher serves as a preface to the subsequent explanation:

> "How many of you have heard of the archaeologists will dig something out? ( ) and they will say use ( ) Carbon dating and so many ( ) so old, ( ) yeah, that's ( ) its, that's what they are doing. They are measuring radioactivity."

Teacher and student questions are rare in the classroom instruction. If there is a question at all, the question is not sustained for a possible response. There is no wait time as the question serves only as a lead to the explanation to follow. Another category of question (three to four in a class period of 59 minutes) that dominated instruction is that which requested responses from 'sharp' students: "What do we need to convert A.C to D.C.? What do we need Joe? Jesse, what should happen to gravity?"

Most of the students in the class are 'emotionally flat' as Goddlad (1984) has observed. Mr. Charles is aware of students' disengagement and uses a point system to ensure attention. During the lesson, Mr. Charles often takes his grade book and walks around the class to note down students' names. "Let me get names of the people who are sleeping here, (Mr. Charles counts in low voice) one, two, three, four ( ) O.K. all those six. Ah, yeah, Seirah, are you not getting to sleep at home?

On another occasion, Mr. Charles noticed that some students are putting their heads down and not paying attention, and he took his grade-book to note their names. "There are a bunch of people losing their points." There are specific days on which Mr. Charles checks whether students are bringing books to the class. This is also a part of the point system.

During class, Lori, a student, waited so long to be called on, with her hands up. The teacher was discussing about the "solar power system" with Michael and Eric. She tried four times to get teacher's attention and finally asked for a clarification: "What does 'retrofit' mean?" This is because of the fact that the teacher usually expects questions from the 'sharp' students. During and after the instruction phase, four to five students seem to have more access to the teacher. Eric usually works at the teacher's desk after the lab. Joe invariably meets the teacher after the class to say: "Goodbye, see you tomorrow."

Characteristics of the closing phase are different, depending on the nature of the activity in which the class is engaged - - watching a film, doing lab experiments, group work, etc. But, there is one thing common to the closing phase, that is, students' signaling the teacher to quit instruction. The process of student signaling is characterized by lack of attention, students moving their chairs and whispering, girls taking out their make-up kit, turning in their work-sheets, and students getting their back-packs. Mr. Charles' response to these behavours was as follow:

> "We got (..) What (looks in the watch, since the wall clock in the classroom is not working) ten minutes? We get out here at fifty – nine, I have got about ( ) thirteen minutes. Why don't you, why don't we go ahead and finish this lab today. We got plenty of time. Make sure that it is nice and neat. Yeh, you got lots of time. Finish it up; it will be fresh in your mind. Make sure, your names are on there." (Teacher is looking for coils, galvanometer, and magnets) Eric, I got three of them. Teacher: You got three of them? How many coils? Eric: Four. Teacher: "O.K., and three galvanometers, Uh. As you finish, you can drop the work-sheets in the tray. One last thing, don't forget . . ." (inaudible, students are moving to the door)

Between the student signaling and the bell (end of the period), there is an average of seven to ten minutes. This is the time for the 'sharp' students to interact with the teacher. They move to teacher's desk to do experiments, to ask questions, or to help teacher to organize the lab equipments. In an interview, Mr. Charles described the 'sharp' students as follows.

> ". . . so, sharp student is ( ) a student that can stay with me while I am talking, like on the transformer thing today, like you pointed out, you know, Jesse asked some questions that told me he understood what was going on. And Joe does too, Joe doesn't have the uh, he frequently won't speak up, he had a ( ) he took Biology or Chemistry, one of, I think Chemistry and dropped out of it, he wasn't doing well. So he is got a kind of wounded his self image right now, so if you ask him, he will say, he is not a good student in science . . . and Eric seems to have a genuine desire to try to figure things out. Eric is, ( ) is not the sharpest student, I mean, I have a number of other students that can figure things out faster and easier than Eric can. But they don't have that natural curiosity."

The characterization of 'sharp' students by both the science department chair, Mr. Jim, and another science teacher, Mrs. Lucy are comparable to that of Mr. Charles. They describe 'sharp' students as more motivated, getting beyond the concept, demanding, wanting more explanation; investigate on their own, etc. But the grade reports show that all the three students described as 'sharp' students by Mr. Charles were scoring below 80%.

The generalisations drawn from this study are valid to the extent that they are based on seven hours of classroom observation, three teacher interviews, and an analysis of a few records, and hence shold be treated cautiously.

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