Alternative Conceptions in Physics among Secondary School Students

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Abstract

Considering the explorative nature of Physics and its intricate disciplinary characteristics, science educationists were always curious to explore how children learn Physics. It is a well-acknowledged fact that concept acquisition is a very active process wherein learners identify essential attributes and construct new conception integrating with already built conceptions in the mind. During the process of acquisition of concepts, learners may view the world in the form of concepts which are deviant from accepted notion of knowledge which are termed as alternative conceptions. If the alternative conceptions are not dealt at the secondary level, the probability of sustaining those alternative frameworks of conceptions may continue at higher learning too. This research paper attempts to identify alternative conceptions in Physics among secondary school students of D.M. School of Regional Institute of Education (RIE), Bhubaneswar, Odisha. All 9th standard students of D.M. School were considered as the sample. A two-tier concept attainment test and a semi-structured interview were used to collect the data. The data was qualitatively analysed with specific intention to explore students' alternative conceptions in the themes—Motion, Force, Sound, Light and Electricity. The findings suggest that a well-constructed system of pedagogical design is to be integrated in the teaching-learning process so that alternative conceptions in Physics could be redirected to conceptual change among learners.

INTRODUCTION

Physics is an exciting intellectual endeavour which tries to explore knowledge about nature and is an inevitable component of school science as a part of integrated science at secondary level and as a disciplinary study at senior secondary

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stage. However, a disturbing concern at senior secondary stage students is a negative perspective about learning Physics among students. Researches indicate that one of the major causes of this phenomenon is a lack of understanding about basic Physics concepts or students' misconceptions in Physics (Halim, Young and Meerah, 2014). Despite repeated instruction and explanation, students continue with their own understanding of the physical world which is not consistent with well-researched and validated scientific explanations. There are empirical researches pointing to the fact that children's ideas are deviant from scientific explanations (Pathare and Pradhan, 2005; Temiz and Yavuz, 2014; Woldron, 2013) and those ideas which are deviant from scientific conceptions are termed as alternative conceptions.

Wide researches revealed that they are not random guesses, rather they have a deep-rooted mental framework of conceptions underlying in it. Children's ideas have been shown to exhibit a degree of coherence and persistence which suggests links to underlying structures or conceptual frameworks (Driver and Bell, 1986).

Understanding the root cause of these alternative conceptions is also equally interesting. A person's expressions of alternative conceptions are derived from his/her alternative framework of thinking. Learners' prior knowledge interacts with the knowledge presented in formal instructions, resulting in a diverse variety of unintended learning outcomes. In this case, if the alternative conceptions are not dealt at the secondary level, the probability of sustaining the alternative framework of conceptions would continue at higher learning. These are too strong to overcome and can inhibit the process of teaching and learning (Gunstone, 1995). Initial ideas held by students are very difficult to change by teachers despite being presented with scientific concepts (Tsai, 1999; Sencar and Eryilmaz, 2004). Wandersee, Mintzes and Novak (1994) claimed that alternative conceptions have their origins in diverse sets of personal experiences including direct observations and perceptions, peer culture and language and in teachers' explanations and instructional material. It is also claimed that these are tenacious and resistant to extinction by conventional teaching strategies. In this context, it becomes highly necessary to identify those alternative conceptions and attempt for conceptual change considering their significance from the perspective of teaching-learning process.

Genesis of the Study

The significance of 'understanding the learner' in the process of learning necessitates the need for researches on concept formation of learners. Especially in a discipline like Physics, wherein the concepts are closely related to daily life experiences, there is a high probability of developing alternative conceptions.

The research done by Lee et al. (1992) suggests that there are three ways in which alternative conceptions among children differ from generally accepted concepts. First, children have difficulty with the kind of abstract reasoning used by scientists. Second, children are interested in unique explanations for specific events; unlike scientists, they are not concerned with the need for coherent and non-contradictory explanations for a wide variety of phenomena. Third, the everyday language of our society often leads children to have views that are different from those of scientists, and common speech is often at odds with the precise language used by scientists. Once these beliefs are enrooted in the mental structure of the learner, there is a high chance that they might impede future learning, unless provided with very conscious intentional conceptual change experiences. Hewson (1981) proposed two models to explain how alternative conceptions are overcome — either an alternative conception is suppressed and replaced by a correct understanding (conceptual change), or students retain both views.

To bring conceptual change among learners, identifying their alternative conceptions in a reliable and valid way would be the first and foremost step. There were many attempts in the last few decades to diagnose alternative conceptions using different tools/ strategies. However, considering the need for a comprehensive study of alternative conceptions in Physics, the present study has been taken up. Demonstration Multi-purpose School (D.M. School) at Bhubaneswar is one of the model schools of NCERT and is of concern here. In this context, the present study is aimed at understanding indepth, the alternative conceptions possessed by secondary school students in Physics.

Methodology

An explorative study was conducted to identify alternative conceptions in Physics of secondary school students. Both quantitative and qualitative techniques were employed in data collection and analysis.

Sample

The sample of the study were Class 9 students of D. M. School. In total, 97 students including 46 girls and 51 boys participated in the study. A two-tiered test was administered to all the 97 students whereas seven randomly selected students participated in the interview.

Tools

A two-tier concept attainment test consisting of structured multiple choice questions was used to elicit the alternative conceptions among students at secondary level. The first tier includes multiple choice items, followed by a second tier of explanation and justification for choosing the option as the right answer. The advantage of using this approach is that it considers students' reasoning and interpretations behind

their responses. It also reveals the link of their choice to the alternative conceptions that they possess. The test was conducted at Kendriya Vidyalaya, Unit IV of Bhubaneswar on Class 9 students. Content validity of the tool was established and the Cronbach alpha coefficient of reliability was found to be 0.7. The test consisted of 20 items chosen from the themes of secondary school Physics such as Motion, Force, Sound, Light and Electricity. Seven students of Class 9 of D.M. School also participated in a semi-structured interview.

Data Analysis

Although quantitative data was collected and processed in terms of frequencies of the different multiple choice options of students, the main thrust of data analysis for this study is centred on the qualitative data generated from students' justifications for their answers/ responses to the interview questions. The meanings from the statements and explanation given by the students are identified and interpreted in the following section.

Findings and Discussion

The result of the study is categorised under five themes—alternative conceptions in motion, force, sound, electricity and light. The two-tier test and the interview responses were analysed and the interpretations are presented together. In addition, Science textbooks were also analysed with specific consideration to the identified alternative conceptions.

The study revealed that alternative conceptions do exist among students in the just mentioned themes of Physics. The alternative conceptions identified are presented below under various themes with a detailed discussion.

Force

The analysis of the responses obtained to an item wherein students need to explore the forces acting on an object which is at rest on a table reveal that students consider gravitational force as the only force which keeps an object at rest. Their limited understanding of gravitational force is that it is a force which holds objects without allowing them to fly off. The students extrapolate the limited explanation/ examples given in the classroom or textbook to all the situations and ignore the effect or presence of other forces such as frictional forces or normal forces on a body at rest on a table. It leads to a conceptualisation that since gravitational force is acting downward, the object is at rest on a table. This further constraints their understanding about the balanced forces as well. In addition, a few students have another alternative conception that gravitational force acts only on falling objects. It indicates that students' idea of gravitational force is also limited to gravitation due to earth, negating the universal law of gravitation. This alternative conception is also evident from the

responses of a few other students that "there is no gravitational force on moon".

In addition, one of the students thought that there is no net force acting on the book which is at rest on a table, the interpretation given is that *"the book is at rest and therefore no velocity and therefore no force"*. It is apparent that the students relate velocity with force, and not with acceleration. From the response of one of the students, it is clear that the student has an alternative conception that frictional force acts only when objects are in motion. In addition, it is also revealed that students use 'force' and 'pressure' synonymously which indicates that there is no clear differential understanding of these conceptions. It is in agreement with the findings of the researches such as Hestenes, Wells and Swackhamer (1992).

Interpretations to the responses to the item wherein students were supposed to identify what happens to the ball if it is kicked and rolled over the ground for some time, reveal various alternative conceptions of the concepts of 'motion', 'force' and 'energy'. The response—*The ball will move with constant velocity as there will be no force acting on the ball*—reveal that the student could not identify any of the opposing force to change the state of motion of the ball. Since they could not identify any other forces to oppose the motion of the ball, the conception that it moves with constant velocity emerged.

The other response, *"the energy given to the ball by kicking, gets finished and therefore the velocity gets decreased"*, is in contrary to the law of conservation of energy. This indicates an alternative conception that energy is something which gets finished. This might have emerged from the phrase which is commonly used in day-to-day life such as "I lost my energy doing work". At the same time, it reveals students' difficulty in identifying an opposing force to change the state of motion of the ball as well. The response that *"its velocity will be decreased as it is getting frictional force, after sometime the force at which the ball was kicked will be consumed by the frictional force so it will stop at a point or reduce its speed"* also reveals students' idea of opposing force as something which is intended to 'consume' the force applied. Another common alternative conception is that since applied force is reduced, the velocity gets reduced or the ball stops. Students could not identify the presence of opposing forces in this case as well.

Sound

In the study, it was found that students have alternative conceptions about the concept of 'vacuum'. The response of the students such as "inside a balloon, there is vacuum"also points to their alternative framework of thinking. Majority of students have an understanding that sound requires medium to travel, however a few of them responded that the sound cannot

travel in water. The response *"there is no medium in water, only vacuum and sound do not travel through vacuum"* indicates that students' conception of medium and vacuum is vague. Majority of students selected the right choice that we cannot hear the sound when an alarm clock is covered in a glass shell in which air is extracted out, a few of them gave the justification that since glass shell blocks the sound, we are unable to hear the sound. The alternative conception identified is that sound cannot go through the surface of separation of two different media. This is also in corroboration with that of findings of Periago, Pejuan, Jaén and Bohigas (2009) related to students' alternative conception that sound cannot go through the surface of separation of two different media. There are many examples given in Class VIII NCERT textbook (pp. 161–63) to illustrate that sound needs medium to travel. However, lack of examples showing propagation of sound through the surface of separation of two different media might be one of the reasons to sustain the alternative conception developed because of students' day-to-day life experiences.

Electricity

It was found that students have alternative conception about open/ closed circuit. They also think that when the switch is on, current flows to the first bulb, then the second one and so on. The simultaneous glowing of bulb is not reasoned out by students. This is indicated by their response "Since all bulbs A, B, C and D are connected to each other through a wire. If current cannot reach to bulb A (bulb A is fused), then it cannot reach to other bulbs". The direction of electric flow/ current also seems to be misunderstood by a few students. It is also found that students perceive that the bulb which is close to power supply glows first as the current reaches that point first. It confirms the findings of many other researches. The bulb which is farther away from the power supply is dimmer than the closer bulbs (Heller and Finley, 1992; Peşman and Eryilmaz, 2010; Sencar and Eryilmaz, 2004). They have an alternative conception that current moves from positive terminal of battery then to different bulbs and then reaches the negative terminal. Some of the sentences given in the textbook of Class VI (p. 116) such as "A torch has a bulb that lights up when it is switched on" and "Electricity to the bulb in a torch is *provided* by the electric cell". They possess an understanding which is inconsistent with scientific explanation that an electrochemical cell can be a source of charge in a circuit and the charge that flows through the circuit originates in the cell and is used up as it flows through a circuit.

Light

The responses on the first law of reflection reveal that students

have alternative conception that the law holds true only in the case of plane surface. In reality, the laws of reflection are obeyed in the irregular reflection case as well. Only the difference is that because of the irregularities in the surface, the reflected rays are not parallel. The response such as *"light travels in straight path not in rough path"* indicates that students possess an alternative conception that the first law of reflection holds true only in the case of regular reflection. It is evident that students have the conception that reflection happens only in smooth plane surfaces, and not at a rough surface. This kind of misconception can be categorised as 'induced incorrect generalisation'. Mohapatra (1988) attributed the students' failure to generalise the concept of reflection from plane mirror to curved mirrors to a "misconception" process known as induced incorrect generalisation. When the textbook was analysed, it was found that while discussing about irregular reflection, an assertive point is given on page 202 (Textbook for Class VIII) that "remember that the diffused reflection is not due to the failure of law of reflection". However, considering the above-mentioned alternative conception, it is suggested that the concept is explained with a diagram in the textbook on laws of reflection.

Implications

The findings of this study may provide impetus to teachers and curriculum developers for designing classroom activities and teaching strategies that could address students' alternative conceptions in Physics and textbook writers to provide ample visualisations, graphs and explanations to bring more conceptual clarity to the readers. These inputs might be helpful for the science teachers to use various strategies such as conceptual change model to transact the concepts and subsequently science learning of students may be optimised. These results may be considered while planning in-service training programmes to science teachers at the secondary level.

Conclusion

It is highly essential to understand how students process knowledge and conceptualise knowledge structures in the mind. Any effort to identify alternative conceptions in any subject has its significance. For a discipline such as physics, with its complex interwoven concept structures, it is all the more significant to examine the alternative conceptions of learners and its impeding role in concept formation. This consideration suggests that, it is crucial to consider the logical structure of the subject matter and its conceptualisation. Therefore, curriculum planners, the textbook writers and the teachers need to be extra cautious in this aspect and area of research in general.

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