

## PRIMARY SCHOOL TEACHERS' UNDERSTANDING OF SCIENTIFIC CONCEPTS

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*This paper reports on the understanding of scientific concepts of a group of 45 non-graduate teachers from 10 randomly selected schools in Singapore. The data was obtained from an "interview-about-situations" technique, adapted from Osborne and Gilbert (1980). The findings show many teachers do not have accepted scientific views and brings into question the conceptual level at which primary school teachers need to understand concepts in order to convey them correctly when they teach.*

### INTRODUCTION

Over the past decade there has been a marked shift from the so-called process approach to primary science to one that increasingly identifies a role for understanding of science concepts. The process approach emphasizes scientific activities such as observing, forming hypotheses, subjecting them to 'fair test' experiments, and so on, and is a philosophy underpinning the science curriculum of the 1970s and 1980s. These have given way in the 1990s to the more pressing concern for understanding of science concepts as the curriculum focus, with a "Thinking Schools, Learning Nation" framework. This does not mean that the process approach has been abandoned. Rather both these aspects are deemed important, the process approach providing the framework for inquiry learning, while the other understanding of science concepts, the framework for constructivist teaching. This paper focuses on the latter.

Teachers are central to the whole process of education. The main obstacle to the improvement of science teaching can be attributed to the lack of understanding of science knowledge of the teachers (Cheung & Toh, 1992). This underlines the need to quicken the pace for more graduate science teachers in primary schools. Ignoring the inadequacies in mastery of scientific knowledge of many primary school teachers is counter-productive in the long run. Many have noted this problem, and generally too little attention has been paid to helping the large base of practising teachers identify their own levels of understanding in science (Whittaker, 1983).

It is recognized that teachers will have ideas about science concepts; that these ideas will, at times, differ from accepted scientific views. The views they hold will have been constructed through life-long attempts to make sense of the everyday world. The validity of the teachers' views is now discussed with respect to:

- concept of forces and their effects, and
- changes in materials.

### CONCEPT OF FORCES AND THEIR EFFECTS

The concept of force is an interesting one and the conceptual level at which primary school teachers need to understand the topic in order to teach it well is a contentious issue. Using the technique of interviews-about-situations (Osborne & Gilbert, 1980), 45 non-graduate teachers from 10 randomly selected primary schools involved in teaching science were interviewed concerning the following two scenarios presented to them on cards:

1. A man is pushing his car, but the car is not moving.
2. A beach ball is rolling down a slope and picking up speed.

The report from the 90 interviews obtained reflected the uncertainty that many teachers are having, when their beliefs were subjected to close scrutiny. These responses can be grouped into two categories.

*Category A:* This is the category of teachers whose understanding of forces is a mix of life-world beliefs and partial understanding of scientific concepts. Explanations provided by the teachers are likely to be of a superficial nature, lacking in internal rigour or consistency, and rejected by the scientific community. Three examples illustrating this follows.

**Interview with Teacher 2 when shown a card of a man pushing a stationary car**

*Interviewer:* What do you know of the word force?

*Teacher:* I'm not sure, scientifically speaking, what you mean by the word force.

*Interviewer:* I'm interested in what people understand by the word force.

*Teacher:* Sources of energy, I suppose.

The discourse above, showing the teacher equating force with energy, epitomises a lack of understanding for both the concepts of force and energy. The evidence points to an ignorance of the meanings for both these concepts.

**Interview with Teacher 20 also shown a card of a man pushing a stationary car**

*Interviewer:* What forces are acting on the car?

*Teacher:* It's gravity that's keeping it static. The weight of the car, I suppose.

*Interviewer:* Is the weight of the car a separate force from gravity?

*Teacher:* Yes, I think it is.

Teacher 20 has some idea of force but is still unable to provide a coherent explanation for weight and force from gravity. The teacher is in need of help if she teaches science.

**Interview with Teacher 41 when shown a card of a beach ball rolling down a slope**

*Interviewer:* The ball is picking up speed. What are the forces acting on it?

*Teacher:* Forces are turning the ball. That is why it is picking up speed.

*Interviewer:* What is a force? If you exert a force on something what do you do?

*Teacher:* When you push something, you turn it. You wind it up and let it go, you make it move. A force makes something move.

Teacher 41 provides a better answer than Teacher 20, but the answer is still far from perfect. The association of force causing motion, makes his explanation closer to the scientifically accepted view.

The sample of responses from the report of the 90 interviews shows that teachers in this category have some exposure to formal study of science during their school years. However, these teachers imperfectly understood the scientific view, resulting in their adopting a hybrid of their formal learning and that of the life-world knowledge. They resort to the use of language of formal science either incorrectly or without full comprehension. When encountering a situation where their viewpoints conflicted with scientific views, or show up their logical inconsistency, these teachers are likely to resort to half-understood scientific explanations, or come forward to admit that they are unable to offer an alternative explanation.

*Category B:* The teachers in this category have mastered their formal science well, providing correct or almost correct explanations. Answers at this level rarely regress to the life experience explanations. This category of teachers will fit into the label of expert teachers and should move around with relative ease between the symbolic-world of scientific concepts and life-world knowledge. The following is an example for this category:

**Interview with Teacher 11 when shown a card of a man pushing a stationary car**

*Interviewer:* What is the force exerted by him?

*Teacher:* Well, the car is stationary. He has not caused the car to move. No movement, therefore no net force.

*Interviewer:* But he has put in some effort, isn't it?

*Teacher:* His effort is in vain, I guess.

**CHANGES IN MATERIALS**

The three scenarios presented on cards to probe the primary school teachers' understanding of changes in materials were:

1. Water is boiling in a transparent electric kettle and you can see into it.
2. A lighted candle has some wax dribbling down its side to the bottom. Hours later the candle is shorter, with quite a bit of it having disappeared.
3. Sugar is put into some warm water and stirred. The sugar disappeared.

Another 135 interviews were carried out in connection with these three scenarios. The responses obtained again reflected the uncertainty that many teachers have when their beliefs were subjected to close scrutiny, corroborating the outcomes of the interviews concerning their understanding on concepts of forces. These responses can also be grouped into the same two categories.

*Category A.* As before, teachers tend to resort to life-world beliefs for their explanations. Also their inadequate knowledge of scientific views are reflected in the following interviews:

***Interview with Teacher 4 on disappearance of sugar in water***

*Interviewer:* What has happened to the sugar?

*Teacher:* It's been absorbed into the liquid.

*Interviewer:* How does this absorption take place?

*Teacher:* It has become much smaller particles. Sugar is a crystal; it's made up of tiny bits with air in between.

*Interviewer:* What happens to the bits when sugar dissolves in the water?

*Teacher:* They go soft when dissolved.

***Interview with Teacher 16 on boiling of water in a kettle***

*Interviewer:* What does boiling mean?

*Teacher:* The water has reached 100 degrees. It is throwing up particles of water into the atmosphere.

*Interviewer:* Can you describe what happens when boiling takes place?

*Teacher:* The electric current produces heat energy. It makes the water molecules move.

*Interviewer:* This heat ... does that change the way the molecules move?

*Teacher:* Yes, they move faster and faster.

***Interview with Teacher 37 on a burning candle***

*Interviewer:* What's happening to the wax?

*Teacher:* Just melts. It has become a hot liquid.

*Interviewer:* So what happens after that?

*Teacher:* They're burnt away. Ends up in the atmosphere as smoke.

*Category B.* A response for this category is obtained with a teacher on the burning candle scenario.

### **Interview with Teacher 15 on the burning candle**

*Interviewer:* What is happening to the wax very close to the flame?

*Teacher:* The wax melts, and becomes a liquid. The wax is sucked up on the wick and burns.

*Interviewer:* What happens with the burning?

*Teacher:* The burning is an irreversible process. It is a chemical reaction.

### **SUMMARIZING THE RESEARCH FINDINGS**

The findings from the total of 225 interviews-about-situations conducted on the sample of teachers, suggest that all the primary school teachers interviewed were exposed to formal models of science during their schooldays and had retained, to a varied extent, this symbolic way of looking at the world. However only a very small minority of them had retained sufficient expert knowledge to explain all the instances correctly in scientific terms. This is evident from the gaps or omissions in the answers they provide to the interviewer's questions.

Examples of this gap or inadequacies in their mastery of scientific knowledge are reflected in (*incorrect*) statements like:

- Energy is what makes things move.
- Energy is a force.

Some of these statements can also be found in textbooks being used, a probable source for such statements. The incorrect statements should be corrected as follows:

- A force is what makes things move. [Energy does not make things move!]
- Energy is not a force.

Teachers in Category A do not have accepted scientific views for forces. The deficiencies in understanding of energy are also evident. It brings into

question the conceptual level at which primary school teachers need to understand concepts in order to convey them correctly when they teach.

Similar conclusions can be drawn from the teachers interviewed for changes in materials (on boiling, evaporation, burning and dissolving). Many of the explanations by teachers in Category A contain gaps, showing flaws in their understanding of phenomena. The explanation of sugar going soft when it dissolves can be likened to that of melting ice changing into water. This is not unlike the reasoning one might have observed proffered by children. The teachers interviewed did not often refer to molecules and very few incorporated molecules into a conceptual model and explanation in terms of energy does not come spontaneously.

This study is an eye-opener. It is difficult to see how teachers without a deeper understanding of the processes involved can appropriately lead their charges along the experiential path. Can conceptual science be taught by teachers who themselves do not fully understand science concepts? The crucial question is whether in-service training can provide sufficient expertise. The authors believe this is possible, and that is the reason for the Ministry of Education's continuous support for in-service training of the teaching workforce.

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