Using the Predict-Observe-Explain Technique to Enhance the Students' Understanding of Chemical Reactions (Short Report on pilot study)

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ABSTRACT

The grade 10, 11 and 12 Science Curriculum in South Africa places great emphasis on practical activities as tools for learning science. However, resources in schools are limited and some of the teachers are not competent in using the materials needed for practical work. This study investigates the outcomes of a new teaching strategy called Predict-Observe Explain (POE), that can be used to teach practical activities and which is negotiated with science teachers from secondary schools. The main interest in this study is to find out how the POE as a teaching strategy impacts on the students' understanding of redox reactions.

Data sources are students' POE tasks responses, interviews with individual students and the teachers, pre-test and post-test, classroom observation and students questionnaires. The POE tasks are concerned with redox reactions. The data demonstrates how students' prior knowledge can influence their predictions and observations. The results show that the teachers can use POE tasks to design learning activities that start with students' viewpoint. This paper will report on preliminary findings from the study, focusing mainly on students' written responses to hands- on tasks based on redox reactions.

Introduction

The new education system in South Africa is showing slow but gradual progress. However, the percentage of students that complete secondary schooling and enter tertiary education is very small. The failure of black students to meet the entrance requirements for tertiary education can be traced to several weaknesses in the school system such as lack of resources such as textbooks, low qualification of science teachers and ineffective teaching methods.

The objectives of this study are to help teachers diagnose students' understanding of chemical concepts and introduce them to teaching methods that could promote meaningful learning.

While research literature reports numerous studies dealing with students' understanding of various chemical concepts, attention has to be paid to research that promotes effective teaching strategies to minimise the misconceptions or alternate frameworks. Treagust (1987), identified studies on approaches to helping students and teachers diagnose misconceptions), Nidderer (1987), a teaching strategy based on students' alternative frameworks, theoretical concepts and examples and Rosenquit (1987) conceptual approach to teaching kinetic theory.

Teachers were introduced to a teaching strategy called Predict –Observe-Explain that could be used in association with demonstrations or hands-on activities. Teachers participated in four workshops where they were shown what POE strategy is and how it could be used in a science classroom to probe student understandings of chemical concepts.

Predict-Observe-Explain (POE) is a teaching strategy that probes understanding by requiring students to carry out three tasks. First the students must predict the outcome of some event and must justify their prediction; then they describe what they see happen; and finally they must reconcile any conflict between prediction and observation.

Champagne, Klopfer and Anderson (1979) were the first to design this strategy as 'demonstrate-observe-explain' to probe the thinking of first year physics students at the University of Pittsburg . Gunstone and White (1981) reworked the 'DOE' idea into 'POE'. Research studies, which used POE with secondary science children to probe children's understanding of science concepts, have been reported (White & Gunstone, 1992; Liew & Treagust, 1995, 1998; Tao & Gunstone, 1997). Palmer (1995) used the POE strategy with pre-service students.

Over the last two decades a vast body of evidence in the literature has echoed the need for science educators to understand the students' understanding of science concepts, processes and phenomena as a prerequisite to improving teaching and learning in science (Liew & Treagust, 1998). Ausubel's theory of learning takes into account what the learner already knows (Treagust, Duit & Fraser, 1996). Traditional teaching strategies generally do not recognise the learner's conceptions and often fail to take into account the meaning of specific words as used and understood by classroom teachers and students (Mansfield & Happs, 1996). To help the teachers improve their classroom practice various strategies like concept mapping, problem solving, co-operative learning should be modelled in teacher development programmes and their effectiveness evaluated. Another technique developed by White and Gunstone (1992) has been widely used with student groups, is the Predict-Observe--Explain learning / teaching sequence. In Predict-Observe –Explain strategy students are required to predict the outcome of an event or experiment. The experiment is then performed and observations made by students are probed. When predictions and observations are inconsistent with each other the students' explanations are explored.

Studies on chemical education have been described respectively (Anderson & Renstrom, 1982; Pella & Voelker, 1967; Cosgrove & Osborne, 1981; Mitchell & Gunstone, 1984; Garnett & Treagust, 1992a; 1992b; Tan, 2000). Anderson (1986b), Ben Zvi, Elyon and Silberstein, (1987) cited in Tan (2000) found that students cannot understand the interactive nature of a chemical reaction, the concept of atoms rearranging and yet retaining their identity. According to Watson, Prieto and Dillon in Tan (2000), students make no mention of atomic or molecular particles in their explanation of chemical reaction; "students tend to explain phenomena using macroscopic properties". Yaroch (1985), Ben-Zvi et al (1987), Hesse and Anderson (1992) cited in Tan (2000) found that students did not have a sound understanding of what chemical equations represent.

Methodology

This study is an interpretive attempt to generate understanding of chemical concepts. The distinctive characteristic of the interpretive approach is its concern with generating understanding about the significance of what is happening in particular social setting, such as a classroom, from the perspectives of the participants, namely the teacher and the students (Liew & Treagust, 1998).

Data sources in this study include the students' written POE responses, in-class discussions with students and interviews with individual students and teachers.

Participants

Four of the fifteen teachers who attended a training workshop were willing to implement the new teaching strategy (POE). The paper will report on follow up classroom visits of one of these teachers. The study focuses on the use of POE to enhance the students' understanding of redox reactions.

This paper will report on a few preliminary findings from the research study. Some of the questions relevant to this paper are given below: -

What is the impact of using POE as a teaching strategy on students' understanding of redox reactions?

How do teachers implement POE in the classroom?

The teacher who implemented POE in class teaches two science classes one with 25 students and the other with 55 students (mixed classes). Students were first taught how to classify chemical reactions into reaction types, using pen and pencil exercises. This was followed by a series of ten POE tasks on redox reactions. The students were given worksheets with the POE tasks to be performed in class and were guided by the teacher on how to complete the worksheets. I will report on three of the POE tasks that were performed by the grade 11 class with 25 students.

The first POE task was a discrepant event to introduce the students to requirements of POE; it also served to generate discussion in the class.

The second one was based on the reaction that takes place in everyday life –the corrosion of iron and the third one was a syllabus-oriented example, which is found in a grade 11 textbooks.

INITIAL PHASE – Introducing Students to POE

The teacher used the following task to introduce a group of 25 grade 11 (age 16-18) students to the Predict-Observe-Explain teaching strategy: -

Two grapes one peeled and the other unpeeled were each in turn dropped in a glass jar filled with lemonade. The students were asked to first predict what would happen to the grapes and then observe what actually happened. The teacher chose to use this discrepant event to motivate the students and also to acquaint them with the Predict- Observe – Explain strategy. The mode of teaching that the teacher used most of the time is the transmission method. To break away from this mode she needed an activity that was easy to follow and also generate discussion among the students. The students are used to sit and listen passively to the teacher and copy down what the teacher writes on the board.

The experiment was conducted in groups of six students. The unpeeled grape has water repelling properties –hydrophobic-and thus carbon dioxide bubbles from the lemonade can adhere to the surface. The unpeeled grape becomes lighter in weight, because of the adhering bubbles, and rises to the surface of the liquid. There it looses some of the bubbles to become heavier again. It may go down for a while picking up more bubbles, to pop up to the surface. The unpeeled grape lacks the hydrophobic skin and the bubbles from the lemonade have no way of adhering to the grape. This causes the grape to stay at the bottom.

Instructions

The students were then told that this was not a test but their views were sought on their explanation of this phenomenon. Subsequently students were independently asked to write down their answers to the following questions:

1. Predict

> *Predict what will happen to the grapes (one peeled and one with its skin) if they are dropped in a glass jar with lemonade? State and explain your prediction giving reason(s) for your prediction.*

2. Observe and Explain

The next stage of the lesson sequence involved the students performing the experiment in four groups of six.

What happened to the grapes when dropped in the jar with lemonade?

The students were requested to independently write down their observations with reasons.

3. Compare and Explain

> *Compare your observations with your prediction. Are they in agreement or disagreement? Explain giving reasons*.

Finally students within each group discussed their answers to the three questions after which they each wrote down their final reasons and explanations.

Results and Discussion

Prediction and Observations about the behaviour of the unpeeled grape (n=25)

Unpeeled grape Peeled grape

Prediction: Grape will float (18) Grape will float (18)

Grape will sink (7) Grape will sink (7)

Observation: Grape floated (25) Grape sank (25)

18 students predicted that the unpeeled grape would sink because the grape was denser than water, whereas 7 students predicted that the unpeeled grape would float because it was less dense than water.

The students predicted the same for the peeled grape giving the same reasons as mentioned above.

All the students observed that the unpeeled grape floated. Students had to observe closely what was happening in the jar to find an explanation.

The data suggests that these students' prior knowledge and beliefs and hence their expectation of the outcome influences their observation. The students who predicted that the unpeeled grape will sink, to them lemonade was considered to be water as their responses stated that "**because the grape is denser than water**" not taking into consideration the effect of gas bubbles found in lemonade.

To resolve the conflict between the prediction and the observation the teacher took a jar of tap water and dropped the unpeeled grape, and it sunk to the bottom. Students were asked to point out the difference between the two jars. They realised that in the jar with lemonade there were bubbles that adhered to the grape and lifted it up to the surface. When it lost the bubbles it became heavier again. The unpeeled grape has water-repelling properties and thus the carbon dioxide bubbles can adhere to the surface. The peeled grape sinks because the bubbles cannot adhere to the rough surface.

The second and third activities were based on redox reaction. This was meant to bring out students' understanding of redox reactions and ability to use prior knowledge.

Second POE task

The reaction between domestic steel wool and dilute acetic acid (used as vinegar for cooking).

A small ball of steel wool is moistened with acetic acid and placed in a conical flask. The mouth of the flask is covered with an uninflated balloon.

Predict / Explain before the experiment

Predict what will happen to the balloon and what will happen to the steel wool.

State and explain reasons for your prediction.

Observations / Explanation during the experiment

Describe what you saw happen to the balloon and steel wool. State and explain reasons for your observation.

Compare/ Explanation after experiment

Compare your observation with your prediction after the experiment. Is there an agreement or disagreement? Explain with reasons.

Write down the chemical equation for this reaction

…….

What type of reaction is this?

Results and Discussion

Predictions and observations of grade 11 students (n=25)

Though there were 25 students in the class only 17 written responses were available for scrutiny. The other 8 students did not complete their worksheets. They felt that since they were working in groups they would get information from others in their groups.

Total number of students' responses available == 17

Prediction: - Balloon will be inflated (11)

Balloon will shrink (4)

No response on balloon (2)

Steel wool will rust (17)

Gas released (11)

Observations: - balloon shrank (17)

Gas released (0)

Steel wool rusted (17)

The 11 students who predicted that the balloon would be inflated gave a reason that -

'*In this reaction a gas will be released and since hydrogen is light it will fill the balloon'*

Of the 4 students who predicted that the balloon would shrink only one gave the reason that '*oxygen in the flask has been consumed'*.

Two students did not provide a prediction.

All 17 students observed that the balloon shrank, steel wool rusted and no gas was released.

The students' responses suggest that the students' prior knowledge and beliefs as well as their expectations of outcomes influence their predictions.

The data shows that: -

- Most students were of the impression that steel wool will react with vinegar to form salt, hydrogen and water as the products but they observed differently.

' In this reaction a gas is supposed to be released.'

' The reaction was very slow, acetic acid is a very weak acid, and hence I could not seethe gas'.

- Some of the students who predicted an inflated balloon but observed that the balloon shrank tried to justify their predictions

'The balloon did not expand, I think the balloon was very big, may be if we had a small …balloon'………

' The balloon was not inflated as expected, as there was not enough gas.'

The students in grade 10 have been taught that an acid reacts with a metal to form salt and hydrogen gas as the products. The POE task showed that students are holding to prior knowledge even though they have observed a different phenomenon. Students also made an error to say that water is one of the products in a reaction between an acid and a metal.

Students' existing ideas are often strongly held. Students may undergo instruction in a particular science topic and yet do not change their original ideas pertaining to the topic even if these ideas are in conflict with the scientific topic they are taught (Fetherstonhaugh & Treagust, 1992). This is attributed to students being satisfied with their own conceptions and therefore seeing little value in the new concepts (Duit & Treagust, 1995). Another reason proposed was that the students look at the new material "through the lenses of their pre-instructional conceptions" and they may find it incomprehensible.

As the students gave many different answers they did not find it easy to represent the reaction by means of a chemical equation. It was confusing to the students what the reactants were in this reaction. They regarded the vinegar and the steel wool as the reactants. To take the matter further the teacher made the students do a number of activities to investigate factors that support corrosion.

The third POE task

Reaction between copper and concentrated sulphuric acid

1 g of copper turnings is placed in a test tube. 2 ml of concentrated sulphuric acid is added and the test tube is heated.

Prediction / Explanation before the experiment

Predict what will happen when copper is heated with concentrated sulphuric acid. State and explain the reasons for your prediction.

Observation / explanation during the experiment

Describe what you would see happen when copper is heated in concentrated sulphuric acid and give reasons

Explanation

Compare your observation with your prediction after the experiment

Write down the chemical equation to represent the reaction

……
……..

What type of reaction is this?

……
……

This was followed by discussion on their answers

23 students predicted that a gas would be liberated. 15 of the students were specific in their reporting that the gas was hydrogen, whereas the 8 students simply said –a gas without being specific.

The reason given for the prediction was that an acid reacts with a metal liberating a gas.

2 students predicted that there would be no reaction. One gave a reason that it has something to do with redox potential while the other did not give a reason.

All students predicted the formation of a blue solution due to the presence of copper ions in the solution.

Contrary to expectations the gas given had a choking smell which hydrogen does not have. To convince the students that the gas was not hydrogen, they had to perform a test for hydrogen. Students had to use their books to find out what gas was liberated in the reaction.

Some students experienced some difficulty in representing the reaction by means of a chemical equation.

Reflection

The effectiveness of POE depends on how the teacher implements the strategy. The teacher should make use of students' views or misconceptions to plan teaching sequence. The teacher must be able to assist the students reconcile the inconsistency between the students' predictions and observations.

Students at first were scared to express their views in writing, what if they wrote a wrong answer. The students do need to be encouraged to take charge of the learning and not look up to the teacher as the fountain of knowledge.

The use of POE has implications on curriculum developers and inset planners, to make materials available so that teachers could continue using POE in their teaching. As the use of POE is entirely new in South African schools teachers do need support and teaching materials for all topics in the syllabus. For the teacher in the research the POE worksheets were available for the topic redox only. When she teaches other topics she may not continue using POE as a teaching strategy.

Even though a POE may be designed with an intention to provide an obvious and clear observation outcome there will still be a variation in students' observations.

The results imply that POE tasks can be used by teachers to design learning activities and strategies that start with students' view points rather than the teacher's or the scientist's.

Using POE may appear to be a slow way of teaching but can enhance students' critical thinking skills.

Summary and conclusion

To find the impact of POE on students' understanding of redox reactions the study will also look at the students' understanding of chemical change and how they interpret chemical equations.

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