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TEACHING CHILDREN SCIENTIFIC THINKING SKILLS

Review by Lucille Lee Kam Wah

INTRODUCTION

In recent years, the Singapore Ministry of Education has placed a great deal of emphasis on teaching thinking skills in schools. Thinking skills can be viewed as a single, unitary intellectual ability or as a collection of smaller, component skills (e.g. observing). Thinking skills are developmental in nature with higher level skills building on more basic ones. There are thinking skills that students can learn to recognise and apply appropriately. If these skills are recognised and applied, students become more effective thinkers (Halpern, 1992).

Thinking skills that are emphasised in science instruction include such process skills as observing, classifying, describing, formulating questions/hypotheses, controlling variables, interpreting data, planning investigations, experimenting, and drawing conclusions. Science teachers are in an ideal position to promote the development of thinking skills, especially the higher-order ones, in students. The higher-order thinking skills include integrated process skills, such as formulating questions/hypotheses, controlling variables, interpreting data, and planning investigation. The purpose of this paper is to review the literature on some methods for and difficulties in teaching higher-order thinking skills. Some implications for teaching thinking skills will also be discussed.

SOME METHODS FOR TEACHING SCIENTIFIC THINKING SKILLS

Selection of a problem-solving model of instruction is one of the critical choices a teacher must make. One important teaching strategy or approach that can improve higher-order thinking skills is the problem-solving approach which includes the processes of acquiring information and recalling knowledge learnt previously, solving novel problems, and evaluating the answers. Halpern (1992) believes that the most important rule in thinking skills instruction is to teach for transfer because the ultimate goal of this problem-solving approach is to develop students who can solve a large variety of novel problems, not just those previously presented in assignments. The use of problem-solving instructional models to teach science influences the problem-solving ability of students. A good deal of research evidence shows that the explicit teaching of thinking skills can improve students' problem-solving skills, students' cognitive development and science achievement (Adey and Shayer, 1993; Huffman, 1997; Preece and Brotherton, 1997).

There are many other problem-solving models proposed by researchers, e.g. Bransford and Stein's (1984) **Identify, Define, Explore, Act and Look (IDEAL)** model; and the **Search, Solve, Create and Share (SSCS)** model created by Pizzini and his co-workers (Pizzini, Shepardson and Abell, 1989). The SSCS model identifies 45 underlying specific process skills such

as brainstorming, predicting, questioning, creating, defining, reporting, verifying, evaluating, etc., to the different phases of the problem-solving model. Harlen (1985) proposes five-steps in planning for an investigation. Questions to be posed in planning are as follows:

- (1) problem question;
- (2) what should be changed in the investigation? (changeable variables);
- (3) what should be kept the same? (controlled variables);
- (4) what kind of effect should be observed?;
- (5) how will the result be used to answer the question?

This planning has to be done at a general and a specific level. The general plan is a useful first stage in planning; the second stage is to translate the general plan into a set of actions to be taken. The teacher functions as a facilitator in a problem-solving model of instruction, assisting students in developing strategies to effectively obtain and process information.

REVIEW OF RESEARCH

Lawrenz (1990) studied the frequency of use of particular teaching techniques and the underlying structure of, and the interrelationships between these techniques. A stratified random sample of seventh and eighth-grade science teachers in Minnesota was asked to respond to a questionnaire about teaching techniques relating to higher-order thinking skills. One hundred and thirty-nine teachers (86%) responded. The results of the study showed

that the teachers emphasised the objective of learning basic science concepts most, followed by becoming aware of the importance of science in daily life and by developing curiosity about natural phenomena. The least emphasised objectives were learning how to design and carry out experiments, and learning what evidence is necessary to constitute proof. In a typical 50-minute class session, 26% of the time (about 13 minutes) would be spent on lecturing, 18% of the time (9 minutes) on discussion, and 16% of the time (8 minutes) working with hands-on materials. The remaining 40% of the time (20 minutes) was spent on completing worksheets, watching demonstrations, and on other science activities like reading, watching movies, etc. None of the teachers reported spending time working with computers in a typical lesson. About 59% of the teachers reported using co-operative groups once or twice a month or more.

The findings of Lawrenz's study (1990) showed that teachers placed very little emphasis on the use of the problem-solving approach as part of their science instruction. They did not spend much time on conducting co-operative hands-on learning which is an important component of problem-solving activities. The teachers did not seem to consider teaching higher-order thinking skills as one of their top priorities.



Sam Cheah

Chin et al. (1994) conducted a study which investigated the extent to which pre-service primary teachers used the problem-solving approach in science instruction during their teaching practice in Singapore schools. The study also sought to identify factors which hindered their efforts in teaching science through this approach. One hundred pre-service science teachers were involved in this study. A questionnaire was used to elicit the pre-service teachers' views on the two above-mentioned aspects. They found that the following factors affected the teaching of higher-order thinking skills in schools (extracted from Chin, et al. 1994; pages 44-48).

- ***Factors pertaining to the teachers***
Some pre-service teachers felt they had limited science content and pedagogical knowledge and thus had difficulty in setting challenging problem-solving tasks for their students.
- ***Factors pertaining to the students***
Students' unfamiliarity with a problem-solving approach and lack of ability discouraged some teachers from using the approach. The teachers felt that their students had been conditioned to learn in the 'traditional' way by being 'spoon-fed' by their teachers and would need a long time to adapt to a new approach. The pupils' weaknesses in language and their lack of ability to co-operate in groups, identify a problem, design an experiment, hypothesise and interpret results were also cited as problems. The students lack of motivation to learn made it difficult to teach higher-order thinking skills to them.

- ***Factors pertaining to classroom management***
The extent to which teachers were able to cope with the disruptive behaviour of their classes affected the efficacy of their teaching. The teachers felt that with problem-solving activities in group work, students would tend to become over-excited and rowdy, and feared that things would get out of hand.
 - ***Factors pertaining to the school system***
Time constraints, limited space in which to conduct science activities, difficulties in getting access to the science room and other facilities, lack of appropriate and relevant activities and materials, and the inconvenience of having to search for such material beyond the prescribed textbook and workbook were also cited as obstacles.
- With regard to assessment Stiggins, Griswold and Wiklund (1989) investigated the extent to which school teachers measured their students' higher-order thinking skills in mathematics, science, social studies, and language. Thirty six volunteer teachers from three schools in northwestern USA, at three different school levels (grades 2-12, high school, middle school and elementary) were involved in the study. A wide variety of assessment documents were analysed, teachers were observed asking oral questions in their classrooms, and each teacher was interviewed. The results indicated that paper-and-pencil assessment documents were dominated by recall questions across all grade levels. However, inferential thinking was also assessed, especially in mathematics. Oral questions tended to tap

recall too, with analysis and inference reflected to some extent. Across grades, subjects, and forms of assessments, comparison and evaluation questions were rare.

The teachers tended to use a lot of recall questions in both written tests and oral questions in the classrooms. The lack of

assessment of higher-level cognitive processes, e.g. analytical skills, made the teaching of higher-order thinking skills difficult. It was recommended that the cognitive process skills of analysis, comparison, inference and evaluation, i.e. the fundamental higher-order thinking skills, be included in any assessment framework.

IMPLICATIONS

In view of the research findings cited above, the following five suggestions can be made for teachers to consider:

1. Teachers need to recognise the importance of teaching higher-order thinking skills (Lawrenz 1990)

Teachers must try to change their mindset from teaching science just as a body of facts. The higher-order thinking skills, which focus on the students' ability to hypothesise, analyse, synthesise and evaluate facts and concepts, are considered important for students to interact effectively with the real world environment of day-to-day problem solving. Teachers are encouraged to employ an inquiry-oriented, investigative approach to teach science.

2. Teachers need to teach explicitly how to plan an investigation

Harlen's (1985) five steps of planning strategy is useful for teaching problem solving. The teaching processes in each step are described with problems related to the dissolution of salt being used as examples:

Step 1 Problem question to investigate

Teachers assist students through brainstorming to identify and refine problem, and to provide tentative answers through formulating hypothesis.

Example:

Problem: Does salt dissolve in other liquids as well as it does in water?

Hypothesis: Salt does not dissolve in other liquids as well as it does in water.

Step 2 What should be changed in the investigation? (changeable variables)

Students identify what things or conditions (variables) should be changed for testing the hypothesis.

Example:

At the general level: the kind of liquid

At the specific level: What are the liquids to be used? e.g. cooking oil, alcohol, etc.

Step 3 What should be kept the same? (controlled variables)

Students identify what things or conditions (variables) should be kept the same for a fair test.

Example:

At the general level: the mass and temperature of the liquids

At the specific level: How much of each liquid should be used?

What should be the temperature of the liquids used?

Step 4 What kind of effect should be observed?

Students identify what to measure and compare in the investigation.

Example:

At the general level: How much salt will dissolve in each liquid?

At the specific level: How the amount of salt dissolving will be measured?

Step 5 How will the result be used to answer the question?

Based upon the result obtained and the process of interpreting it, students make decisions to accept or reject their hypothesis.

Example:

By comparing the amount of salt dissolving in each liquid and water, the results will indicate whether salt can dissolve in other liquids as well as it does in water.

3. Teachers need to play a facilitative role in teaching problem solving (Pizzini et al., 1989)

Teachers assist students in identifying problems and developing strategies to obtain and process information. They could help students by identifying logical errors in their thinking, (such as inconsistencies or unjustifiable inferences), challenging students to consider other possibilities, and pointing out to students when they have over-generalised on the basis of false assumptions.

4. Teachers need to change their mode of assessment (Stiggins et al., 1989)

In order to encourage higher-order thinking in students, the assessment mode needs to be changed. It is suggested that teachers should ask more higher-order thinking questions involving analysis, comparison, inference and evaluation.

5. Schools need to improve science facilities and resources (Chin et al., 1994)

To encourage teachers to teach higher-order thinking skills in science, an increase in the number of science laboratories/science rooms and additional resources, such as teaching materials for conducting hands-on activities, is necessary. At present, supporting laboratory staff at the primary level is lacking. If a problem-solving approach is to be seriously employed by teachers as part of science instruction, they need assistance and support from laboratory staff to cut down the time required in preparing hands-on activities.

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