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FOREWORD

Promoting Thinking through Pedagogical Changes in Science Lessons

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Curriculum Reform to Prepare Children for the 21st Century

Students entering the new millennium will encounter challenges not known to their seniors a decade ago. They must come fully equipped with skills that enable them to think for themselves and be self-initiating, self-modifying and self-directing. They will require skills that cannot be gained by learning content alone. Needed skills go beyond processing capabilities in just fixing problems. Rather they must be visionary and anticipate future challenges and search more consciously for more creative solutions. (Costa, 2001)

The McREL researchers have identified six general thinking and reasoning skills in a majority of the content areas (Kendall and Marzano, 2000):

1. Identifying similarities and differences (found in all subjects)
2. Problem-solving and trouble-shooting (found in 83 percent of the subjects)
3. Argumentation (found in 83 percent of the subjects)
4. Decision making (found in 75 percent of the subjects)
5. Hypothesis testing and scientific inquiry (found in 58 percent of the subjects)
6. Use of logic and reasoning (found in 50 percent of the subjects)

Of the twelve subjects covered in the McREL study, science tops in the share of reference to thinking and reasoning (27.2%). Science has a share of 8.3% for identifying similarities and differences, 11.8% for problem-solving and trouble-shooting, 22.9% for argumentation, 3.1% for decision making, 32.3% for hypotheses testing and scientific inquiry and 21.8% for the use of logic and reasoning. (Marzano and Pollock, 2001)

There is an important emphasis on the study of science in all nations as science and technology lay the foundation for the development of industry, biotechnology, information technology and defence technology for a nation. In the book, *Education for 1.3 Billion* by the former Vice-Premier of China, Li Lanqing, special mention is made on the overhauling of the Chinese science and technology management system.

Among all curricular subjects, science appears to the most suitable subject through which thinking and reasoning skills could be taught and applied. However, the traditional pedagogy of science teaching involving factual information, verification of scientific theories, and application of theories to problems would not foster and develop

in students the higher order thinking skills needed to cope with the unpredictable challenges in the 21st century.

It is necessary for teachers to make pedagogical changes and set thought-provoking tasks and higher-order assessment questions to promote and foster thinking in their students.

Project work with real-world application

Thinking and reasoning should be reinforced with the context of authentic tasks. Teachers should set assignments which require students to do some research, analysis, synthesis and evaluation.

An example of such a science assignment at secondary level is on "Recycling of Waste Materials". Such an issue would sensitize students to the global issue of environmental conservation. The following questions could be used to guide students:

1. Classification of all waste materials and justification for the classifications
2. An explanation of the effects of one selected category of waste on the environment
3. Proposal of a plan on how the selected category of waste in question 2 can be recycled to benefit the society/community.

The above task would require students to employ the following thinking skills:

1. Information gathering
2. Classification
3. Problem-solving
4. Explanation for causation
5. Analysis
6. Synthesis
7. Evaluation.

Emphasis on process skills and metacognitive skills

Teachers have found it convenient to get students fill in the blanks in science practical worksheets. This caters for easy marking. But what kinds of skill can students learn from this set of procedures? Students do not need to apply any conditional knowledge (asking why and when) in the whole exercise. Do students need to understand the rationale underpinning the steps in an experiment? In the spirit of scientific enquiry, students

should be able to explain the scientific concept behind each step taken in a science experiment.

There should be a move away from the focus on results in science practical to that of process skills. Planning, organizing, observing, verifying, interpreting, evaluating and reflecting skills are important skills that science students should acquire. In their eagerness to fill in the blanks with the expected readings, students often ignore the important process skills. Reflection and error analysis are often by-passed when the focus is centred on getting the right answer and not on learning from mistakes.

In order to ensure that students have understood the scientific concepts taught and to discourage rote learning, some science teachers in Singapore have asked students to explain their choice of a response in a multi-choice test. Students are challenged to think through their choices and they realize that guessing will get them nowhere.

Presentation of challenging quizzes and puzzles as out-of-class activities

In the film "Good Will Hunting", Mathematics undergraduates were stimulated and challenged by a complex problem posed outside the lecture hall every week. At the 8th International Thinking Conference in Canada, flash cards with interesting thinking problems were placed all over the conference venue. Participants were encouraged to solve these problems.

Students must realize that thinking skills are not meant to be applied only to academic exercises. They need to and should be encouraged to apply the thinking skills learned to all kinds of situations beyond the classroom. Teachers should provide the opportunities for them to apply their thinking skills.

Use of alternative forms of assessment

Paris and Ayres (1994) felt that for students to be motivated to do their work, new forms of assessment must be created that are sensitive to students' backgrounds, motivation, effort and attitudes. They suggested the use of performance testing or portfolios or work examples where assessment is linked to class curriculum and is part of an on-going process in which students can appraise themselves. Students should regularly reflect on and critically analyze the strengths and weakness of their work, set goals, and identify

ways to monitor their progress towards these goals. They could also review their progress through record keeping via logs and journals.

To develop students' ability to critically self-assess their own answers and to examine and find their own errors, teachers could provide criteria in the form of questions or checklists which students may internalize with practice over time.

Teacher modeling in promoting thinking in the classroom

Teachers have been reminded that they must provide their students with good models in behaviour. In the same way, students will be stimulated to think more if their teachers are consciously and constantly demonstrating thinking and reflective behaviour. The following are some suggestions that teachers may have already tried:

1. Expecting students to explain responses
2. Using "why" questions more frequently
3. Asking "what if " questions
4. Emphasizing on elaboration
5. Asking for alternative solutions to a problem
6. Advising students on good scientific books, knowledge, movies or TV programmes
7. Giving rationale for every step taken in a science practical or in problem solving
8. Encouraging students to challenge statements or observations which are ambiguous or unclear.

Conclusion

In the last decade, we have witnessed financial crises, SARS, avian flu and terrorism. These events arrived silently without warnings and students need to be prepared for future and unpredictable mega-problems. They need to think critically and creatively to solve problems in order to survive. To do this they need broad-based knowledge and thinking skills and science is one discipline which naturally provides the content and opportunities to develop the essential skills.

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