TEACHING SCIENCE THROUGH INQUIRY

PEARLY NG
Sunway College Johor Bahru

ABSTRACT

Learning is a process of acquiring knowledge and skill through practice, training and accumulation of experience. Teaching is thus an act of imparting knowledge and skill. The most conventional way of teaching science has been through lecturing. In a typical lecture setting, the audience is expected to listen and follow a set of notes without much questioning. Such a method seems to contradict the learning of science, which builds on prior knowledge and advances through curiosity. As a result, this one-way transmission of knowledge has induced dry memorization and very little interest in exploring science by the students. The dullness in learning science could be due to the lack of development of quantitative and analytical skills that come with conventional teaching. This gives rise to the stereotypical perception that science is cryptic, difficult and can only be understood by very smart students. The National Science Teachers Association (NSTA) has suggested that science teachers employ the method of inquiry-based teaching to overcome the inefficacy of conventional teaching. Inquiry-based teaching is much more desirable and effective in teaching science subjects because it follows more closely the scientific method of experimentation. This paper aims to explore the potentials of assimilating inquiry-based teaching into the current conventional method. Hopefully by adopting a more effective teaching method, we can engage more learners in shaping the education they receive and inspire them to become the creators of knowledge themselves.

Keywords: Inquiry-based teaching, constructivism, scientific method, structured inquiry, guided inquiry, open inquiry.

INTRODUCTION

Inquiry-based learning has a long history, dating back to Socrates and his method of leading students to self-knowledge through aggressive questioning. John Dewey, an American educational reformer during the first half of the twentieth century, pointed out that the authoritarian, strict, pre-ordained knowledge approach of modern traditional education was too concerned with delivering knowledge, and not enough with understanding students' actual experiences (Neil, 2005). His active and relentless reform of the educational system eventually led to the first inquiry-based learning methods in the United States. Inquiry-based education is deeply intertwined with the theory of constructivism. Constructivism argues that people construct their own understanding and knowledge through their own experiences (Liepolt *et al.* 2004). When people encounter new things, they reconcile them with their previous ideas and experiences. This may result in changing what they first believed, or discarding the irrelevant new information. To achieve this, people ask questions, explore and assess what they know.

Science, on the other hand, involves observation and experimentation. Science builds upon prior knowledge and progress depends on curiosity. According to Norman Budnitz, cofounder of the Center for Inquiry Based Learning (CBL) and training director at Teachers and Scientists Collaborating (TASC) based in North Carolina, science is a process of asking questions. In an interview, Budnitz says,

> "*If the question you're asking requires observation, it's making careful long-term observations. If the question requires experimentation, it's designing careful experiments that will address the question that you're answering. It is understanding cause and effect, and being able to see cause and effect when it is there, and being able to understand that what you see may not be cause and effect, when it's not. It is an ongoing process*" (Harrell, 2005).

The conventional way of teaching science has been through lecturing using textbooks across all levels of education. In a typical lecture setting, there is a very clear distinction of roles between the teacher and the students. The audience is expected to listen and follow a set of notes without much questioning. Such a method seems to contradict the learning of science, which builds upon prior knowledge and advances through curiosity. Not surprisingly, this one-way transmission of knowledge has induced dry memorization and very little interest in exploring science by the students. The disinterest in learning science due to the lack of development of quantitative and analytical skill that comes with the conventional teaching method gives rise to the stereotypical perception that science is cryptic, difficult and can only be understood by very smart students. The National Science Teachers Association (NSTA), an association of science teachers in the United States and the largest organization of science teachers worldwide, has recommended that science teachers employ the method of inquiry-based teaching to overcome the inefficacy of conventional teaching (NCSES & ANRC, 1996). In fact, inquiry-based teaching is much more desirable and effective in teaching the science subjects because it encourages the scientific method of experimentation and exploration.

PERSPECTIVES OF INQUIRY-ORIENTED SCIENCE INSTRUCTION

Inquiry-oriented science instruction has been espoused from a variety of perspectives over the years. It emphasizes the active nature of student involvement, assimilating inquiry into hands-on learning, experiments and activities. Some associate inquiry with a discovery approach or with development of process skills, which correlate with the scientific method. From a science perspective, inquiry-oriented instruction engages students in the investigative nature of science. Novak suggested that inquiry involves behaviours of people struggling for reasonable explanations of phenomena in which they are curious about (Haury, 1993). Hence, inquiry in this perspective focuses on the active search for knowledge or understanding to satisfy a curiosity. There are a few methods a teacher can use in an attempt to engage students to actively search for knowledge. These include structured method of guided inquiry, provision of few instructions, as well as the use of heuristic devices to aid skill development. Whichever the method is employed, the focus on inquiry always involves collection and interpretation of information in response to wondering and exploring (Haury, 1993).

From a pedagogical perspective, inquiry-oriented teaching reflects mostly the constructivist model of learning, in contrast to the traditional expository methods. The science educators today often refer to it as active learning. Students are encouraged to make meaning of what they have learnt and in the process, they are involved in developing and restructuring their knowledge schemes through experiences with phenomena, exploratory

talk and teacher intervention. In fact, research findings show that if students work directly with natural phenomena, using their senses to observe and using instruments to extend the power of their senses, they are more likely to better understand the natural world.

The fundamental of these two perspectives - science and pedagogy - is that inquiry-based teaching engages students in investigations by constructing mental frameworks that adequately explain their experiences. This implicates that inquiry-based learning begins with curiosity stimulation or wonder provocation (Haury, 1993). Indeed, should there be no curiosity strong enough to trigger an inquisitive mind to seek for an answer, solution, explanation or decision, there will never be significant learning or genuine investigation.

Inquiry and the Scientific Process

Inquiry may seem to be multifaceted but its basis is about asking questions. In an inquiry-based science lesson, students formulate their own questions and answer questions through their own exploration. Inquiry-based lessons allow different students to solve problems in different ways, capitalizing on their individual strengths instead of supposing that there is only one answer (Harrell, 2005).

Students acquire a deeper understanding when they question, debate and explore things that they learn. By discovering principles and not just memorizing them from any textbooks, students learn not just what it is, but how it is and why it is important. Inquiry involves students and challenges them, and maybe the teachers too. Hence, teaching this way is hard. Thinking this way takes a lot of effort too. Most people learn better by doing things. In one California school district where the students are taught based on inquiry approach for four years, they showed steady improvements in tests of both science achievement and writing proficiency compared to their counter parts (Harrell, 2005). This clearly shows that inquiry-based teaching is able to strengthen students' understanding in science and helps them to better appreciate the principles of science in the long run.

TYPES OF INQUIRY

So far, we have established that inquiry-based teaching engages students in the processes of formulating predictions, organizing and interpreting data, and communicating results using science terminology. The approach has great potential to enthuse and inspire students, but requires preparation and planning for successful implementation. The method employed must be able to appeal to students' natural curiosity about the world around them and develop science process skills simultaneously.

Inquiry-based teaching takes on the approach from teacher-led to student-led processes (McGraw Hill, 2009). These can be categorised into the following approaches:

- Structured inquiry: Students follow precise instructions from the teacher to complete a hands-on activity.
- Guided inquiry: Students develop a set of procedures to investigate a question selected by the teacher.
- Open inquiry: Students generate a list of questions about a topic selected by the teacher and plan their own investigation.

Structured inquiry

In this approach, students use the process provided by the teacher to solve a given question. Teachers guide students step-by-step through the scientific process. This is one of the approaches commonly practiced at the secondary and pre-university levels. The suitability of this approach depends on the topics taught. In topics that involve answering standards-based questions using a method which is not intuitive or which involves the use of specialized instruments, structure inquiry strategy seems to be appropriate. Examples of questions that can be constructed by the teacher are:

- Do plants require sunlight to perform photosynthesis?
- What is the relationship between mass and inertia?
- What is diffusion?

Such lessons are bound to familiarize students with inquiry methods and allow them to develop science process skills, perhaps at a superficial level. Students get to practice common techniques such as food testing, acidity or alkalinity testing and reaction rate calculations. On top of that, the types of questions that students are most likely to raise may be easily predicted and thus, teachers are able to prepare points of discussion with more ease.

Despite the advantages, structured inquiry strategies may not be able to trigger genuine interest from students. Hence, students are least likely to develop in-depth understanding and high-level critical thinking skills from the lessons.

Guided inquiry

This strategy involves the teacher posing a question and providing the students only with materials to be used in their investigation. In this way, the students design the experiment themselves by deciding the methods to be employed based on the materials provided. They also explore and do research on their own based on the questions provided, with some guidance by the teacher.

Guided inquiry approach works well for most standards-based topics. The questions asked will trigger careful observations under a given condition and require good analysis and deduction skills, coupled with the ability to recall and apply prior knowledge. Examples of questions a teacher might provide include:

- What happens to a steel bar when it is heated up?
- What are the differences between a prokaryotic cell and a eukaryotic cell?
- What will happen to a green plant if it is kept in a dark room for a week?

Such an approach requires students to be familiar with the main steps of scientific inquiry and thus, is suitable for upper secondary or pre-university students in which they are equipped with sufficient exposure of the scientific method.

Open inquiry

Open inquiry is, undoubtedly, the hardest among the three types of inquiry-based teaching. In this strategy, teachers provide the materials or a problem statement for students to investigate. In order to solve the problem, students must come up with a list of questions and formulate methods for investigation. Students need to ask the questions to lead to the most probable answer and be able to identify relevant information for their solution in their research. Critical thinking skills and in-depth understanding are required of students in the process of forming a solution.

Teachers may provide students with the following objects and allow students to formulate questions about them.

- A light bulb, battery and wire.
- A bag of red beans, green beans and soya beans.
- An animal cell and a plant cell.
- A problem statement concerning a diarrhea patient and oral rehydration salts.
- A problem statement concerning a natural phenomenon.

Such problem-based learning allows students to follow their own paths of questioning for problem solving. Therefore, it is harder to reconcile this approach to standards-based topics. When choosing a topic for assessment, teachers must ensure that students are able to identify information clearly from the object or problem of investigation. To assist students in mastering this strategy, the teacher can do the following:

- Provide carefully planned inquiry-based assessments.
- Create well-established classroom rules for interaction and the handling of materials.
- Offer guidance to students who may be lost in the investigation.
- Prepare guided questions following the activity that tie into standard ones.

Many times, teachers feel uneasy with the method of open inquiry compared to structured inquiry. However, with ample preparation and an appropriate topic, this approach can be more exciting to both students and teachers and encourage more participation from the students as compared to conventional teaching with a textbook. This strategy triggers genuine interest from the students and provide a great opportunity for students to develop critical thinking and inquiry skills. In the process of defending their own solutions, students are forced to employ their scientific reasoning using their prior knowledge and improve their articulation and confidence of scientific terms. In comparison with textbook teaching that stresses on regurgitation of facts during examination, such an approach will ensure that students' learning will come with a good understanding that will last a long time.

ADVANTAGES OF TEACHING THROUGH INQUIRY

Studies of inquiry-oriented teaching and inquiry-based programs in the 1960s have been

generally supportive of inquiry-based approaches. Students in middle school have been found to improve in performance through inquiry-based programs, particularly in the area of laboratory skills, graphing and interpreting data. In addition, evidence has shown that inquiry-based teaching is useful in nurturing scientific literacy and understanding of science processes, vocabulary knowledge and conceptual understanding, critical thinking, positive attitudes toward science, higher achievement in test of procedural knowledge and construction of logico-mathematical knowledge (Haury, 1993).

In some findings, inquiry-based teaching seems to be especially valuable for many under-served and underrepresented populations. In fact, language-minority students were found to acquire scientific ways of thinking, articulating and writing mainly through inquiry-based teaching. In another study, inquiry-based science teaching was reported to promote development of classification skills and oral communication skills among bilingual third graders. Experiential instructional approaches based on daily life experiences are also considered to be more attuned with American viewpoints than are text-based approaches. On top of that, deaf students tend to be more receptive when they are taught to actively explore the world of science (Haury, 1993).

Despite the emphasis on inquiry-based teaching, it does not necessarily disqualify the use of textbooks or other instructional materials. The Biological Sciences Curriculum Study materials are examples of those that incorporate an inquiry orientation. According to Duschl, textbooks can be used to support inquiry-based science teaching and are not mutually exclusive (Haury, 1993).

CONCLUSION

In its essence, inquiry is the ability to ask questions and identify problems and solutions. In most colleges and universities, science lessons are traditionally planned on acquisition of content than on triggering real interest and understanding from the students. As a result, many students tend to memorize scientific principles wholly rather than understanding and appreciating how they work. Hence, it is the responsibility of the teachers to engage students in inquiry-based learning early in their education. When children are exposed to scientific methods at a young age, they can better assess if a career in science is a suitable one for them.

The ability to listen and to ask effective questions during teaching are skills that are not easy for most people to master, especially when the educators themselves were taught in the conventional way. It may be hard to let students puzzle through problems and make mistakes and the teachers may not be used to presenting problems without one right answer. However, if the inquiry approach can be incorporated into the teaching of science, it will definitely help them to understand the laws of science and eventually gain better appreciation of what they have learnt. The principles learned will be more significant and ingrained, which will be able to last them a lifetime.

A big paradigm shift is necessary for inquiry-based learning to be the norm in the world of education. But hopefully by adopting a more effective teaching method, we can engage more learners in shaping the education they receive and inspire them to become the creators of knowledge themselves.

REFERENCES

Harrell, Waverly. (2005). *A perspective on inquiry*. Retrieved 10 April 2009 from http://www.learnnc.org/lp/pages/806.

Haury, David L. (1993). *Teaching science through inquiry*. ERIC/CSMEE Digest, Columbus, Ohio.

Liepolt, Werner & Wilson, Sue Young. (2004). *Constructivism as a paradigm for teaching and learning*. Retrieved 1 Apr 2009 from http://www.thirteen.org/edonline/concept2class/constructivism.

McGraw Hills Education. (2009) What is inquiry in science? Retrieved 30 May 2009 from http://teachingtoday.glencoe.com/howtoarticles/what-is-inquiry-in-science.

National Committee on Science Education Standard and Assessmen; National Research Council. (1996). *National Science Educational Standards*. The National Academic Press, Washington.

Neil, J. (2005). *John Dewey, the Modern Father of Experiential Education*. Retrieved 28 May 2009 from http://wilderdom.com/experiential/ExperientialDewey.