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Promoting Inquiry Through Science Reflective Journal Writing

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The purpose of this research paper is to detail how reflective journal writing can be used to facilitate science students' curiosity and engagement in laboratory work. This study advocates reflective journal writing as an instructional tool and a student-created learning resource that can serve additional formative assessment purposes. The researchers tracked a single teacher and his class over a period of five weeks and documented the changes that occurred when reflective journal writing was used to supplement the teaching and learning of specific curriculum items (the usage of scientific equipment and the particulate nature of matter). Findings presented show that the number and quality of students' questions rose over time. While the number of research studies carried out with inquiry as the focus is plentiful, this paper outlines a generative strategy to enhance questioning which constitutes the essential first step in any inquiry process for any particular science content area.

Keywords: Reflective Journal Writing, Inquiry Science, Questioning, Formative Assessment

INTRODUCTION

One of the distinctive characteristics of inquiring learners is their ability to use questioning techniques as they reflect in and on their actions (cf. Chin, 2004). Reflection is a cognitive activity that involves, but is not restricted to, capturing, mulling over and evaluating experiences (Boud, Keogh, & Walker, 1985), looking backwards and projecting forward to the future (Jarvis, 1987) and stepping back from what one is doing in order to achieve some measure of perspective (Ellis, 2001). Yet, while it is important to acknowledge the role reflective thinking can play in the development of 'thinking people' (Dewey, 1933) it is vital for teachers to note two things: the heart of all learning lies in the way students process their experiences, critically, and reflective learning involves recalling from experiences and reasoning out how these connect to present and future 'learning' situations (Kolb, 1984). On these bases, we maintain that reflection can play a key part in promoting inquiry in middle-level science students' learning. We also believe that engagement in reflective activity can be a driving force in bringing about positive changes in laboratories especially in the areas of teacher-student interactions and in breaking away from the notion, where it exists, that scientific facts are absolute or unquestionable truths.

There has been an abundance of, and great enthusiasm for, research activities relating to inquiry science methods over the last decade. Learning science is no longer regarded as remembering the facts of science but should also include the the inculcation of the practice of science among learners. Rather than learning about science, science education is about learning to be scientists. In other words, the goal should be developing skills, attitudes, and knowledge of how scientists do science (Barab & Hay, 2001; Fusco & Barton, 2001). What this implies is that, school science should emulate authentic practices such that students assume the agency of knowledge constructors and interact with phenomena in informed, reflective, and

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critical ways (Rodgriguez, 1998). As such, inquiry science examines the need to allow students to improve their ideas as they encounter new and conflicting evidence (Harlen, 2004). This is similar to activities carried out by working scientists.

Science inquiry is incorporated as part of the science curriculum in many school districts in the United States and notably in all schools in Singapore (CPDD, 2007). According to the National Science Education Standards (NRC, 1996), doing scientific inquiry includes (1) identifying and asking questions; (2) designing and conducting experiments; (3) analyzing data and evidence; (4) using models and explanations and finally (5) communicating findings. When students are equipped with the abilities of scientific inquiry and understandings of scientific inquiry, they will be better prepared to learn the content in science. One of the core abilities identified here is identifying and asking questions and this is the specific skill which we aimed to develop through science reflective journal writing.

To facilitate science students' curiosity and engagement in laboratory work, reflective journal writing can be used as an instructional tool and student-created learning resource that has formative assessment benefits especially in terms of self-assessment (Black & Wiliam, 1998). Reflective journal writing also allows students to identify and record their attitudes and beliefs. It provides an avenue for giving expression to doubts and frustrations about science itself and about learning science. However, it is important to note that reflective writing is not appealing to all. In some contexts, inexperienced or unskilled journal writers have difficulty finding things to write. This point highlights the need for teachers to guide their students in writing regular journal entries. The following section details how this can be done.

PROCEDURE

A small-scale study was conducted with a class of grade 7 girls from an average school, which is partially funded by the government in Singapore. The class, which was noted for its reticence and deference to sources of authoritative knowledge, was involved in learning two units of work in general science: using laboratory equipment (e.g., lighting the Bunsen burner) and the particulate nature of matter. A willing and experienced male chemistry teacher, working in collaboration with academics from a local research center, issued each student with a small notebook measuring approximately 9cm x 14cm. The students, who were of average academic ability and generally reluctant to ask questions openly in class for fear of losing face, were instructed to write their name, class and the title, 'Science Reflective Journal' (SRJ) on the front cover of the notebook. Subsequently, at the end of each lesson or laboratory lesson for a period of half a term (5 weeks), the teacher gave the students five minutes to write their reflections in their SRJ. As the practice of writing science journals was new to the students, the teacher provided three broad headings for their entries:

1. Questions I have about today's lesson
2. Something I have learned today
3. Some thought-provoking incident in class today

At the end of each week, the SRJs were collected and a research assistant compiled the entries on behalf of the teacher. Each entry was read, counted and categorized. A word-processed file containing all of the students' comments was prepared and returned to the teacher for his information and consideration. The SRJs were returned to the students in time for use in the week to come.

The researchers' field notes showed that the teacher was very adept at weaving his responses to the points raised in the SRJs into his regular lesson content without revealing any particular student-author identities. In order not to discourage inquiry, questions that went beyond immediate curriculum matters were not ignored. Instead, every point raised had the potential to lead to a useful learning opportunity. Some questions were answered directly in class but other issues were 'thrown back' to the learners and they were encouraged to source for their own answers in groups outside of class time. To scaffold these extra-curricula investigations, the teacher suggested possible sources of information including the Internet, journals and local libraries. The learners were also encouraged to involve their parents and/or other adults in their follow-up work. The flow chart below (Figure 1) summarizes the process of using the SRJs in study classroom.

OUTCOMES

In this section, we present evidence to show the impact of keeping science reflective journals on the students' abilities to ask questions. At the beginning of the study period, the teacher's topics were laboratory safety, the use of laboratory apparatus and the role of science in society. The specific instructional objectives for the first week's work were as follows:

- Observe laboratory rules at all times in the science laboratories;
- Know the symbols representing different hazardous substances;
- Use the Bunsen burner;

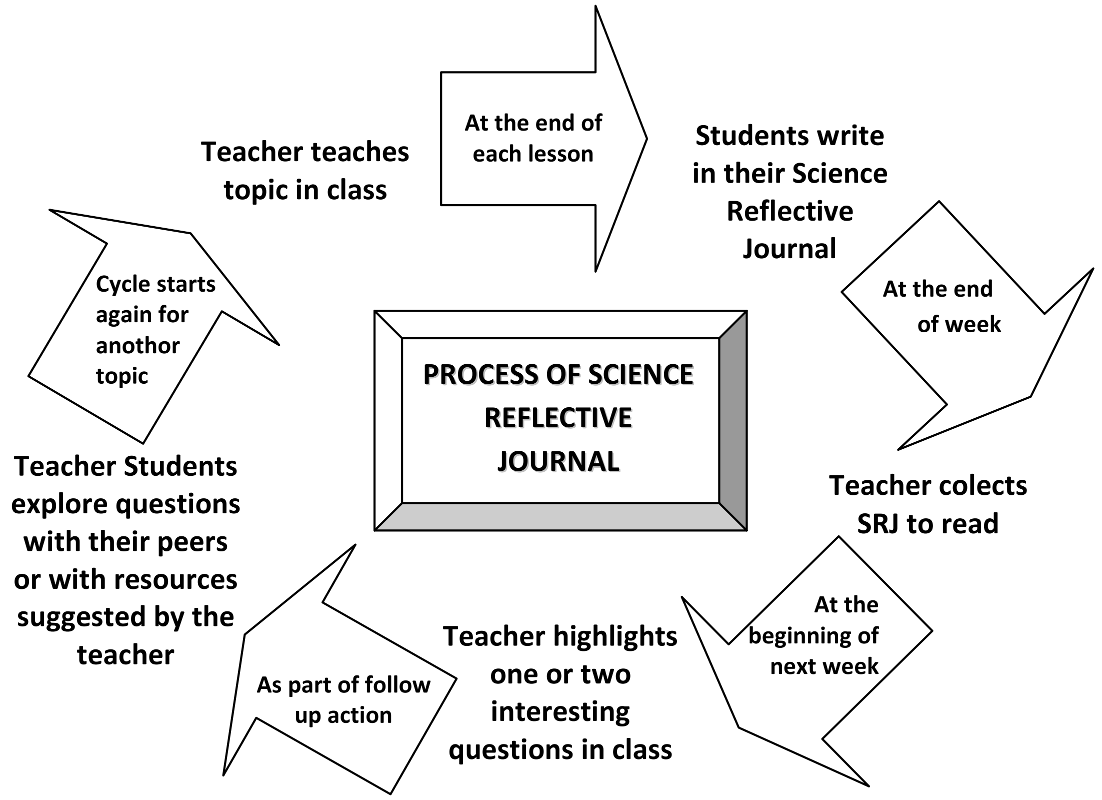

Figure 1. Process of Science Reflective Journal Writing

- Discuss the uses and benefits of science and technology to society;
- Develop an awareness of the limitations of science and technology in solving societal problems; and
- Develop sensitivity to the benefits and abuses of the applications of science.

The students' SRJ entries were largely factual and superficial, although in the instance of the question about biological hazards, there is a positive sign that the student was attempting to connect the world of science in the classroom to her out-of-school life experiences (the numbers in parentheses denote the number of entries along similar lines).

Science Reflective Journal Entries (Week 1, unedited)

1. *Questions I have about today's lesson*
   a. What are basic thinking skills? (2)
   b. How biological hazard does happens? Can it kill? I saw the radioactive sign on a truck? Why is it on the truck?
   c. What is a nuclear reactor?
   d. What are elements?
2. *Something I have learned today*
   a. Benefits of science (19)
   b. Abuses of science (18)
   c. Safety rules in the laboratory (22)
   d. Science process skills such as thinking skills (17)
   e. Signs and symbols (10)
   f. Limitations of science (8)
   g. Safety rules when heating or mixing chemicals, e.g., Point mouth of test tube away from yourself and friends when heating chemicals, Do not place flammable substances near any source of heat, always use test tube holder when heating a test tube (6)
   h. Scientific method of doing experiments (5)
   i. Attitudes of learning science (16)
   j. Science process skills such as define a problem, ask questions, suggest a possible hypothesis, design experiment to test hypothesis, make observations and measurements, communicate the results effectively, interpret the results and draw a conclusion (3)
   k. When experimental results support the hypothesis, it turns to a theory (2)
   l. Different ways of answering questions
3. *Some thought-provoking incident in class today*
   a. We must abide by safety rules to ensure our safety
   b. The abuses and usage of science is interesting as they have been seen in movies but I did not know that they were used in real life
   c. Attitudes are very important in the learning of science
   d. Results in an experiment may not support a hypothesis

e. I know more about the abuses of Science and how some people use their knowledge of Science to harm others. I find the people using drugs, bombs, and viruses to harm or kill to others, very cruel. Even though people are getting smarter, they are more abuses.

The student's question about whether radioactive substances can kill (1b) related directly to the instructional objectives of the uses and benefits of science and technology to society; the limitations of science and technology in solving societal problems and understanding benefits and abuses of the applications of science. This question could possibly serve as a platform for further inquiry-based activities and investigations to be carried out.

After a couple of weeks, the class progressed onto the topic of the particulate nature of matter. The instructional objectives for this topic were:

- Show an awareness that matter is made up of small discrete particles which are in constant and random motion;
- Show an understanding of the simple model of solids, liquids and gases, in terms of the arrangement and movement of the particles; and
- Distinguish among the three states of matter – solid, liquid and gas using the particle models.

It can be seen that by week four, the students' questions and comments became bolder and more adventurous. Features entries from the students' SRJs showing the development of critical, multi-faceted, inquiring scientific minds.

Science Reflective Journal Entries (Weeks 4 and 5, unedited)

1. *Questions I have about today's lesson*
   a. If we put a solid material or a liquid under a microscope, can we see these particles or are they just imaginary?
   b. If particles are present in all matter and they can vibrate, how come we cannot feel the vibration when we touch the matter?
   c. Why is it when we put chemicals like iron into the non-luminous flame, it will change the color?
   d. What is the chemical that causes the flame to change color?
   e. The solid iron can turn into liquid iron if heated to a high temperature. Is it because the particles in liquid can be packed closer than a solid at a high temperature and bombard it?
   f. How is it possible that liquids can taste like acids?
2. *Something I have learned today*
   a. Solid, liquid and gas particles (9)
   b. Reasons for the definite or indefinite shape and volume of solid, liquid and gas (18)
   c. Different colors of flames (16)
   d. Different kinds of chemicals can make non-luminous flame change color (22)
   e. Different way of lighting the Bunsen burner (7)
   f. How to draw models of particles (6)
3. *Some thought-provoking incident in class today*
   a. The burning of powder is used in fireworks
   b. I must be very careful in my observations during laboratory tests
   c. I have learnt to light the Bunsen burner properly and it helped me overcome my fear of fire
   d. I like the luminous flame because when it's dancing it looks beautiful

As can be seen from the questions recorded in Weeks 4 and 5, there is some evidence of complex thinking about the particulate nature of matter. For example, in questions 1a, 1b and 1e, the students considered what they saw (materials versus molecules) and felt (stationary materials versus the vibrations of particles) and made connections between their daily experiences and scientific kinetic theory. Thus, there is support for the claim that the instructional objectives of ensuring that students show an awareness that matter is made up of small discrete particles which are in constant and random motion and also to show an understanding of the simple model of solids, liquids and gases, in terms of the arrangement and movement of the particles were achieved. That said, the SRJ entries also signal that there is scope for a deeper exploration of the kinetic theory as it relates to the topic at hand.

The points raised in question 1e indicated that the student in question was aware of the three states of matter – solid, liquid and gas using the particle models. However, this question also revealed a lack of conceptual understanding of how the model can actually be used to explain phenomena observed in everyday circumstances. This issue could be used as a primer for students to explore alternative ways of explaining the melting of iron at high temperature to better appreciate the completeness and complexity of the particle model.

EVALUATIONS AND IMPLICATIONS

The SRJ exercise provided a channel of communication between the teacher and students involved and there is promising evidence to suggest that its purposes were recognized and valued. In particular, the students' writing allowed for issues to be dealt with by the teacher in the classroom, which may not have surfaced, at all, through any other means. The journals helped the students view the learning of science as an on-going process whereby they stopped at regular intervals to think about what they were doing. The journals also helped the students hone their laboratory skills in two specific ways: (i) they kept records of their experiences, and (ii) they practiced analyzing by thinking about the questions they wanted to ask in relation to their laboratory experiences. These are benefits which can be derived for any science content area using the procedure outlined in Figure 1.

If students can be facilitated in formulating questions about their laboratory learning in writing, there are equally encouraging signs that they can also be assisted in conducting dialogic exchanges with their teacher and peers in classroom interactions. For example, here is an extract from a classroom exchange between the chemistry teacher and the class on another task shortly after the SRJ exercise which demonstrates an interesting transfer effect.

Teacher [to class] Have you finished?

Student 1: I want to ask you the meaning of *constituency*.

Student 2: That means the elements that make up the thing.

Student 3: What thing?

Student 2: The compound or mixture … constituency is the elements that make up either the compound or the mixture.

Student 5 [with hand raised persistently] Mixtures are not chemically mixed, eh, joined together, then how are they joined together?

Teacher: … instead of by chemical means, by physical means. Like when you just pour it into a container and stir it up—that's physical mixing. If there's a chemical reaction, then that's a chemical means.

Mid-level science students have many questions to ask and comments to make about their laboratory learning experiences but may (as is the case in Singapore) fear making mistakes or feel more at ease answering the teacher's questions directly. Given sufficient teacher support and a willingness to respond to students' inquiries, SRJ writing, we argue, can be the foundation for a less intimidating questioning culture in science laboratory learning – one of the essential features of inquiry science. SRJs also have the potential to inform teachers of how students think as they learn science and this can be an invaluable source of information for formative assessment purposes. Overall, the SRJ exercise raised the visibility of students' thoughts in science and helped reduce assumptions made by the teacher about his students' abilities. It also increased the accuracy of the teacher's decision-making in lesson planning and implementation as a crucial result.

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