Probing Primary School Science Teachers' Conceptions of the Experiment in an In-Service Course

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ABSTRACT

This qualitative study discusses the development of teachers' conception of scientific inquiry, particularly, that of the experiment, in a science process skills in-service course in which the nature of science and scientific inquiry are embedded and explicitly taught as well. As a result of the course teachers' incoming conceptions of the experiment changed to a more scientific one.

INTRODUCTION

This study arose from observations obtained from an in-service course on science process skills for 35 primary school science teachers conducted by one of the researchers. The course was intended to improve the mastery of the 12 science process skills which were taught at the primary school level and designed to equip pupils to carry out scientific investigation systematically. The process skill 'to experiment' is placed highest on the hierarchy and encompasses all the other skills. Out of interest, the researcher had prepared a short written questionnaire in which participants were tested on their understanding of what constitutes a scientific experiment. (see appendix 1) They were presented with 7 situations and required to determine which were experiments and to explain why. The questions were adapted from those used by Driver et al (1996) in a study on school students' images of science.

According to the Malaysian primary school science syllabus (1993), 'to experiment' is to carry out an investigation to test a hypothesis using all the other science process skills. An analysis of the answers revealed that almost all the teachers were not able to distinguish correctly between a true scientific experiment and a non- scientific one. In many cases, all the situations were considered experiments. Further analysis of the explanations given by teachers for situations 5 and 7 revealed that some teachers explained that a hypothesis was tested and so these were considered experiments.

The results suggested that while teachers might have knowledge about scientific process skills and be able to define the skill 'to experiment' as the testing of a hypothesis, they had difficulty in deciding what constituted true scientific enquiry from a scientist's point of view when presented with examples of investigations in different contexts. It has been the government's aspiration that science teachers prepare a more scientifically literate citizenry besides preparing students for vocations in the science fields. If teachers do not have a clear grasp of the scientist's way of working and thinking then the teaching of process skills will not be carried out in a meaningful manner. Therefore, there is a need to find means of improving teachers' conceptions of what constitutes scientific experiments. Could the in-service course content and delivery be modified to help towards this end?

Driver et al (1996) suggested that an understanding of the nature of science promotes the learning of science concepts and argued for the inclusion of the teaching of nature of science in the science curriculum. This study will explore this suggestion for teachers. A subsequent process skills course was modified and 'value added' to include content on the nature of science and scientific enquiry

PURPOSE OF THE STUDY

The purpose of the study was to describe teachers' developing conceptions of the experiment in an in-service course on process skills which also included content on the nature of science and scientific inquiry.

Significance of the study

This study will provide insights to teacher trainers and curriculum writers about teachers' understanding of scientific experimentation and ways to improve their understanding.

Research question

More specifically the study seeks to answer the following research questions:

1. What are teachers' conceptions of the experiment?

2. What are the effects of the teaching about the nature of science, scientific inquiry and process skills on conceptual understanding of what is scientific experimentation?

REVIEW OF RELATED LITERATURE

Understanding the nature of science and scientific inquiry

There has been an increasing number of studies done recently on students' and teachers' epistemological perspectives and the ways in which these might influence learning and teaching in science. Driver, Leach, Scott and Wood-Robinson (1994) refer to epistemological beliefs as being one of the major dimensions along which students' conceptual knowledge grows. Epistemological beliefs are beliefs about the nature of knowledge and the way we come to know things. For science, it might include positions on what constitutes a satisfactory explanation, what a theory is and what characteristics of a good theory are, the purpose of experiments in science and the way in which theory relates to science, and whether knowledge is constructed, discovered or something in between. These issues are not dealt with science curriculum in schools nor teachers' training colleges in Malaysia.

Driver, Leach, Millar and Scott (1996) reviewed work such as those by Scott (1993), Tytler (1994) and also coordinated a large number of studies on students' images of science and argued on the basis of their findings that an understanding of the nature of science supports successful learning of science content. They strongly favoured the inclusion of explicit teaching about the nature of science into the science curriculum.

In their work they developed a framework which identified three different epistemological representations along which students seem to develop. These are:

(a) Phenomenon- based reasoning
In this representation, students see scientific inquiry simply as looking and seeing what is, or trying things out and seeing what happens. Explanation is treated as an unproblematic portrayal of how things are and there is no distinction made between explanation and description.

(b) Relation based reasoning
In this representation, explanation and evidence are distinguished, but involve relationships between observable features or features that are taken for granted as existing in the natural world. There is no room in this view for conjecture concerning theoretical entities. Explanation is seen to emerge from data in an inductive way. Relationships between variables are taken to be true and theories are able to be 'proved'.

(c) Model-based reasoning
The main feature of this representation is explanatory modeling. Scientific inquiry involves the evaluation of conjectures models in the light of evidence. Theories are the product of creative human endeavour, and are in principle provisional. There is a clear distinction between the language in which theories and explanations are described, and that in which observations are described.

In a study with secondary school students by Carey (1992) also discovered these categories of representations. Gess – Newsome (2002) has carried out some work in which explicit teaching on the nature of science was carried out for teachers. She found that incoming conceptions of science as primarily a body of knowledge changed to a more appropriate view of science as a body of knowledge generated through the active application of scientific inquiry.

Techniques for probing conceptions

A variety of techniques have been developed by researchers to explore students' understandings of science phenomena and particularly alternative conceptions. White and Gunstone (1992) discuss the range of techniques available for monitoring students' developing conceptions in the classroom. These include interview about instances, interview about events, survey instruments, concept maps and predict-observe-explain (POE). The interview about instances technique is applicable to the exploration of the meaning held by individuals of particular concepts. The purpose is to explore the range of events that form part of the student's framework of understanding, and the criteria used to define inclusion

METHOD

This research is conducted in the interpretive, qualitative research paradigm

Participants

25 primary school teachers from various schools in a certain town in Sarawak attended a 2-day science process skills in-service course. Many had not received specialist training in science but were required to teach the subject in their schools. A sample of 5 participants were selected randomly to be interviewed. Their informed consent was obtained prior to the interviews.

Instrument

The instrument consisted of interview questions in the Malay language designed to probe teachers' epistemological understandings (refer appendix 2). The questions were similar to the ones in the written questionnaire in appendix 1. However it was decided that interviews would yield richer data than the ones obtained through the questionnaire. The type of interview referred to above is the 'interview about instances' (White and Gunstone,1992) which is often used for the exploration of meanings held by participants on particular concepts, in this case, the concept of the experiment. The interviews were recorded on audio tape and transcribed.

Procedure

The procedure consists of three steps

1. Pre- course interview
2. Course Input - A two -day science in-service course in which the nature of science and scientific inquiry including science process skills were taught and delivered using the constructivist CLIS model (see appendix 3)
3. Post- course interview

Analysis of respondents' answers to interviews

The answers were categorized according to inherent emerging ideas about what constitutes true scientific experiments. They were analysed on the different views about the nature of science implicit in the explanations and compared with the different epistemological representations according to Scott (1993) and Driver, et al (1996). Following that, a comparison between conceptions before and after the intervention were made.

RESULTS AND DISCUSSION

The five participants interviewed are given fictitious names in this report:
Cikgu Ali, Cikgu Sami, Cikgu Lily, Cikgu Renai and Cikgu Chin

Different views about the concept of the experiment before course input

(a) Phenomenon based reasoning

In this representation, respondents see scientific inquiry simply as looking and seeing what is, or trying things out and seeing what happens. Explanation is treated as an unproblematic portrayal of how things are and there is no distinction made between explanation and description. This type of reasoning is illustrated by respondents who answered incorrectly that the following situations were examples of experiments

Situation (a) Baking a cake by following a recipe
Situation (b) Following a teacher's instructions to make a crystal from salt
Situation (c) Taking a radio cassette player apart to find out why it doesn't work

Four respondents i.e. Sami, Renai, Lily and Chin determined that situations (a), (b) and (c) were experiments with the following reasons:

Cikgu Sami (Situation a) : Boleh dikatakan satu eksperimen. Sebabnya, dalam setiap satu kek ada berlainan dia punya kandungan, Jadi, dia nak tahu hasilnya

(Situation b) : Sebab murid melakukannya. Dia buat ujikaji ..dia lihat perkembangannya dan hasilnya

Cikgu Renai (Situation c) : Saya rasa itu eksperimen. Perlu mencatat apa yang rosak

(c) Model based reasoning (with a qualification)

The main feature of this representation is explanatory modeling. Scientific inquiry involves the evaluation of conjectures models in the light of evidence
This type of reasoning is illustrated by respondents who described the following situations as representing experiments.

Situation (e) Testing the idea that the smaller the grains in sugar, the quicker it will dissolve
Situation (g) Dropping a tennis ball and a cricket ball to test the idea that heavier objects fall at the same rate as lighter objects

All the five respondents correctly identified situations (e) and (g) as experiments.
However only some demonstrated the model based reasoning in their explanations.

Cikgu Sami (Situation e) : Nak mengesahkan kenyataan tadi.. dia betul atau tidak

For other respondents, key words or phrases in the process skills vocabulary played the more important role as prompts in distinguishing between an experiment and a non-experiment.

Renai	(Situation e)	:	Ya , yakin… kerana ia mempunyai bukti, bukti yang kukuh Semakin ….semakin…. Itu merupakan bukti eksperimen
	(Situation g)	:	Kerana saya selalu buat aktiviti ini untuk budak tahun 6 saya. Kita mengkaji ketinggian dan keberatan sesuatu bahan.. Kita mengkaji dari paras mana, berat/saiz bahan itu dan masa….

Lack of consistency in the type of reasoning

In general there was a lack of consistency in the reasoning used across all 7 situations posed. for four of the respondents respondents.

Other criteria used

If the inquiry-discovery approach was used in investigation, where students looked for answers themselves, it was an experiment.

Cikgu Lily (Situasi c)	:	Ya, ini eksperimen sebab dia mencari bukti itu sendiri mengikut inkuiri penemuan. Sekarang dia buka, dia akan cuba satu per satu untuk menentukan mengapa radio tak berfungsi

Comparison of views before and after the course input

Answers to interview questions show some improvement

For interview questions, Situation (a), (b) and (c) – Three of the four respondents who had answered incorrectly before were able to state that the situations were not examples of scientific experiments. The exception was Chin who maintained responses which showed no clear consistent criteria before and at the end of the course.

Cikgu Lily

Post course interviews revealed better conception of the experiment shown below

(Situation g)

Interviewer	:	Dari mana datang hipotesis ini?
Cikgu Lily	:	Hipotesis ini datang dari jangkaannya, pemerhatiannya
Interviewer	:	Apakah yang menghasilkan jangkaan ini?
Cikgu Lily	:	Pemerhatiannya
Interviewer	:	Apakah pemerhatiannya?
Cikgu Lily	:	Objek yang berat dan ringan dijatuhkan.. sebiji buah dan Sehelai daun.. jatuh dengan kadar berbeza
Interviewer	:	Macam mana sekiranya hipotesis tadi tapi pemerhatian

yang didapati berlainan?
Cikgu Lily : Hipotesis itu salahlah

Cikgu Ali
This respondent had given correct answers on all the situations before and after the course. However there was a more developed view of inquiry as can be seen by his answers to the interview. In the post course interview, Ali used more scientific criteria to differentiate between exemplars and non –exemplars of experiments, with less reliance on the use of key word by rote.

Situation (e): (pre-course) Ya, memang. Selalu kita buat hipotesis macam itu lah. Semakin Kecil butiran gula, semakin singkat masa/cepat dia larut. Jadi. another… how I use the formula to teach my students. Jika kecil butiran gula…. I use jika…. ia larut… maka singkat lah masa untuk ia larut…

(post-course) : Sebab dalam hipotesis terdapat pembolehubah.. maca lebih kecil, lebih besar.. pembolehubah yang dimanipulasi. Cepat larut, lambat larut …dia adalah pembolehubah yang bergerakbalas

Situation (f) : (pre-course) Boleh dianggap sebagai eksperimen sebab tujuan kita menguji adalah untuk mengetahui tentang kebolehan bahan pencuci itu sendiri bukan? Sebab dalam eksperimen kalau ada istilah menguji, ia boleh dianggap sebagai eksperimen kerana apabila budak ditanya "Apakah tujuan penyiasatan ini?", dia akan jawab, untuk menyiasat" Tadi puan kata menguji. Menuji sama dengan menyiasat bukan?

(Post-course) : Kerana jenis-jenis serbuk pencucui tergolong dalam pembolehubah yang dimanipulasi. Sudah tentu kita nak lihat dia punya kesan basuhan dan jadi ini boleh dilihat sebagai satu eksperimen.

In the following exerpt Cikgu Ali improved on his truncated answer by integrating ideas beyond the formularic ones used before.

Situation (a) : (Pre-course) Bukan. Ini bukan eksperimen. Dia ikut langkah-langkah saja yang diberi.

(post-course) : Ikut resipi tapi bukan menguji. Kalau ikut saja bukan menguji samada resipi betul atau salah.
Interviewer : Macam mana resipi boleh betul/salah?
Cikgu Ali : Yang tulis resipi itu tahu tulis betul jumlah bahan, sudu Gula.. 5 sudu ..Anggap itu satu hipotesis. Definisi eksperimen –satu kajian yang dilakukan untuk menguji

samada teori yang dipegang saintis itu betul atau tidak.

Cikgu Chin

Cikgu Chin maintained responses which should no clear consistent criteria before and at the end of the course. Earlier on for situations (a) to (d) she had explained they were experiments Using a variety of criteria which were not very related, not even to process skills. The following excerpt illustrates that she was not able to show better development of her conception of scientific inquiry at the end of the course.

Situation (e)

Cikgu Chin	: Ya, ini eksperimen. Di sini ada hipotesis.
Interviewer	: Dalam kes-kes tadi, tak ada hipotesis?
Cikgu Chin	: Ada juga eksperimen tak ada hipotesis, dia juga Eksperimen.

SUMMARY AND CONCLUSIONS

Pre-course interview results showed that at the beginning of the course phenomenon based reasoning was the basis for answers to situations posed which were not couched in familiar laboratory type contexts. The criteria given for distinguishing exemplars and non-exemplars of experiments included the systematic nature of the procedure, the discovery of new knowledge and the uses of certain process skills. In this instance, scientific inquiry consisted of looking and seeing what is, or trying things out and seeing what happens.

There was a lack of consistency in the use of criteria to distinguish between exemplars and non-exemplars. The shift from phenomenon based reasoning to model-based reasoning with questions where the situations posed were in the laboratory context and had the familiar phrases " the smaller.. the quicker.." referring to variables shows the importance of the use of key phrases from the syllabus as prompts to the teachers. This is consistent with research (Tytler 1994) who found that students lacked consistency in their use of conceptions when contexts differed, giving scientific answers in some and reverting to unscientific answers in other.

Post course interviews revealed that all the respondents except one were more consistent better able to use the testing of conjectured ideas/hunches/hypotheses and control of variables as the main criteria for distinguishing between experiments and non-experiments

The respondent Encik Ali who at entry level displayed a more sophisticated and confident understanding of scientific inquiry showed marked flexibility and skill in his answers at the end of the course. Cikgu Chin however was an example of a teacher who was not yet able to organize her fragmented understanding to develop a coherent conception of the experiment

Limitations of the study

The findings are peculiar to the context of the participants of the course but may provide insights to teacher trainers in their own practice.

Implications of the study

This study suggests that exposure to the theoretical basis of scientific thinking may enhance teachers understanding of experimentation and scientific inquiry. However an experimental design could be used to research the effectiveness of the teaching of the nature of science in improving teachers understanding of experimentation.

Science teachers with specialist training in the discipline and pedagogy have a far better grasp of scientific inquiry. However, the ‘value-added’ short in-service courses on science process skills may be of use to improve teachers’ competence and understanding where schools face constraints such as non-specialist teachers teaching science.

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Appendix 1

Written Questionnaire

In your opinion, which of the following represent scientific experiments?
Give reasons for your answer.

1. Baking a cake by following a recipe
2. Following a teacher's instructions to make a crystal from salt
3. Taking a radio cassette player apart to find out why it doesn't work
4. Keeping a diary to test a hunch that it rains on more days in January than February
5. Testing the idea that the smaller the grains in sugar, the quicker it will dissolve
6. Testing to see which brand of dish washing detergent works best
7. Dropping a football and a volleyball to test the idea that heavier objects fall at the same rate as lighter objects

Appendix 2

Interview Questions

1. In your opinion, which of the following would be a scientific experiment? Give reasons for your answer.

    a. Baking a cake by following a recipe
    b. Following a teacher's instructions to make a crystal from salt
    c. Taking a radio cassette player apart to find out why it doesn't work
    d. Keeping a diary to test a hunch that it rains on more days in January than February
    e. Testing the idea that the smaller the grains in sugar, the quicker it will dissolve
    f. Testing to see which brand of dish washing detergent works best
    g. Dropping a tennis ball and a cricket ball to test the idea that heavier objects fall at the same rate as lighter objects

Translation

Yang manakah daripada berikut merupakan eksperimen?
Beri alasan bagi jawapan anda

a. Membuat kek dengan mengikut sesuatu resipe
b. Mengikut arahan prosedur guru membuat satu hablur daripada garam
c. Membukakan radio untuk menentukan kenapa ia tidak berfungsi
d. Menyimpan rekod dalam diari untuk menguji idea bahawa lebih banyak berhujan pada bulan Januari daripada bulan Februari
e. Menguji idea bahawa lebih kecil butiran gula lebih cepat ia terlarut
f. Menguji yang mana jenama serbuk pencucui lebih berkesan
g. Menjatuhkan sebiji bola tennis dan sebiji bola 'cricket' untuk menguji idea bahawa benda yang lebih berat jatuh dengan kadar kelajuan yang sama dengan benda yang lebih ringan

Appendix 3

Two Day In-service Science Process Skills Course

Course Outline

1. Introduction to process skills
2. Basic science process skills –activity based
3. Integrated science process skills –activity based
4. What is science? The scientific method. What is a fair test?
5. Counting letters of the alphabet
6. The fruit fly experiment
7. The story of vaccination against small pox
8. The fair test :designing your own investigation – The paper spring experiment

Content

1. Science process skills
Basic process skills – observing, inferring, measuring and using numbers, using space- time, predicting, communicating
Integrated science process skills –operationally defining, interpreting data, controlling variables, hypothesizing, experimenting

2. Nature of science and scientific inquiry

- What is science? - (one of a variety of ways of knowing the world)
- Purpose of scientific work – purpose of experiments in science and the way evidence relates to theory in science
- The scientific method (and critique)
- Nature and status of scientific knowledge
  (what constitutes scientific forms of inquiry, nature of explanations in science, what constitutes a satisfactory explanation, relationship between explanation and evidence, tentative nature of explanations in science)
- Whether knowledge is constructed or discovered or something in between
- Science as a social enterprise

Teaching Strategy

Content of the whole in-service course on science process skills was taught with a hands-on,activity based constructivist approach using the CLIS model (Driver 1988)

Orientation

↓

Elicitation of ideas

↓

Restructuring of ideas

↓

Application of ideas

↓

Review change in ideas

The content of the nature of science and scientific inquiry was presented through strategies and methods also consistent with constructivism**.** However, a modified form of the CLIS model is used in which teachers' ideas about what constitutes an experiment are not challenged directly. Instead, scientific ideas were presented and allowed to grow alongside until their greater usefulness was recognized. This was carried out through activities, facilitator- student small group discussions, examination of historical account of scientific experiments etc.