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ABSTRACT

This study, conducted in Singapore, was designed to determine pre-service primary teachers' (n=34) behavior in asking operational questions in science. In training the pre-service teachers in asking operational questions, the meaning of operational questions was first illustrated and clarified to them through the use of some examples during group activities. The pre-service teachers were then placed in a new situation in which they had to carry out another activity, make observations, and respond to these observed phenomena. Questioning patterns were identified based on their responses. The study revealed that if proper instruction is given, the pre-service teachers' ability to ask operational questions can be trained and developed further. The study concluded that fostering ability in asking quality operational questions, imparting science content knowledge, and enhancing good observational skills are areas to be addressed. The study suggested that the training should start as early as possible and be extended to pre-service secondary science teachers. (MDH)

PRE-SERVICE TEACHERS' BEHAVIOUR AND TRAINING IN ASKING OPERATIONAL QUESTIONS

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Abstract

This study aims to find out pre-service primary teachers' behaviour in asking operational questions in science. In training the pre-service teachers in asking operational questions, the meaning of operational questions was first illustrated and clarified to them through the use of some examples during group activity. Thereafter, the pre-service teachers were placed in a new situation whereby they had to carry out another activity, make observations and respond to these observed phenomena. Based on their responses, patterns of their questioning were identified.

The study reveals that if proper instruction is given, the pre-service teachers' ability to ask operational questions can be trained and developed further. It is found that fostering ability in asking good quality operational questions, imparting science content knowledge, and enhancing good observational skills are some important areas to tackle. It is also suggested that the training should start as early as possible and can even be extended to pre-service secondary science teachers.

Introduction

The current trend in science education is to place emphasis on the inquiry approach and science processes which would develop in pupils the logical thinking skills and the ability to use some process skills to find solutions to problems.

It is commonly accepted that the process of acquiring inquiry spirit and science process skills involves asking questions by teachers and pupils. But what type of questions should be asked?

Alfke (1974) has come out with a model which systematically directs pupils and teachers to investigate common science phenomena through the use of operational questions, which manipulate variables through: (1) eliminating, (2) substituting, and/or (3) increasing or decreasing the presence of the variable(s). The operational questions imply getting pupils to carry out a task with the materials provided to seek an answer, e.g. "If we use hot water instead of cold water, would the sugar cube dissolve faster?" On the other hand, non-operational questions are those that cannot be easily answered by first-hand experience of the type that young pupils can generate, e.g. "Why can sugar dissolve in water?", "Why is the sky blue?" or "What makes the water go up into the filter paper?". There is no doubt that these higher order questions or reasoning questions have an important role to play in the process of learning science. But "why" or "what" questions frequently give rise to frustration in pupils, especially younger ones who begin to learn some scientific concepts. This is because these questions are too abstract or complex; sometimes even an experienced teacher is also unable to answer them.

Alfke's model has further been investigated by Allison and Shrigley (1986), who advocate teacher modelling with pupils' practising as a more successful means for teaching pupils the skill of questioning.

If teacher modelling has an effect on the number of operational questions pupils could ask, it is apparent to us that the teacher's ability in asking operational questions has an important role to play in the process of science teaching and learning. It implies that training teachers to ask operational questions and finding out teachers' behaviour in asking science questions could have an impact in promoting inquiry learning.

Unfortunately, research work in these areas seems to be lacking. It prompts us to conduct the present study with the following aims:

1. to find out the pre-service primary teachers' behaviour when asking science questions in general and operational science questions in particular.
2. to design an instruction to modify these teachers' behaviour in asking questions.

The subjects

We believe that inquiry learning should start from the young age, because concepts and process skills involved in the primary science are relatively simple, and consequently asking operational questions should not be a complicated process for the pre-service primary science teachers, especially if they have some basic background in science. Hence, a sample of 34 second year pre-service student teachers enrolled in the 2-year Certificate in Education programme were randomly selected. The sample is approximately 15% of the total cohort. The range of their science background is shown in Table 1 below.

Table 1

The subjects have gone through a science methodology course during their first year. In the main, this course deals with the skills in imparting the concepts and processes of science to provide them with knowledge of up-to-date methods of teaching science. In the first year science course, the term 'operational questions' has not been introduced. This study was carried out at the beginning of their second year.

The second year science course is built upon what has been learnt in the first year. It is intended to help the pre-service teachers understand how children learn science and hence improve science teaching at the primary level.

Design of the instruction

Adoption of the proposition that learners are perceived as active agents in the process of constructing meaning (Brown, Collins and Duguid, 1989; Resnick and Klopfer, 1989), we believe in constructivist instruction which employs learning framework and subject matter framework, that emphasize knowledge restructing. Since the concept of Karplus's 3-stage learning cycle (Karplus, 1977) possesses some nature of constructivist instruction and the stages involved are practical and not too complicated to follow, we are of the opinion that it suits our purpose well.

As a result, we came out with the following instruction:

* The first treatment began with the experiment on 'strips and liquids' (Alfke, 1974). Each pre-service teacher was given a strip of filter paper (Whatman No. 1 with a length of 4 cm x 12 cm) and a beaker (100 cm^3) containing about 60 cm^3 of water. They were asked to fold the strip lengthwise and stand it in the beaker containing water. They observed and recorded events for about three minutes. They were then instructed to list any questions which occurred to them as a result of their observations. During that session, they were allowed to discuss in groups of two to three. The outcome of the discussion was presented at the end of the session. At that particular juncture, their responses were used to introduce the concept of operational questions.
* In the second treatment, the concept of operational questions was reinforced with further appropriate examples. Thereafter, the fundamental skills to ask operational questions were introduced. Subsequently, they were placed in a new situation for practising the skills. It was an experiment on placing a piece of sugar cube in about 60 cm^3 of water which was placed in a 100 cm^3 beaker. Again, they were asked to record their observations and questions. At the end of the session, discussion of the concepts involved and the operational questions related to this experiment was conducted.

Data collection

A pre-test and a post-test on 'Burning of Candle' were administered before and after the treatment respectively. The pre-service teachers were asked to write down their observations and questions related to the experiment and their observations. The experiment on "burning of candle" was selected since it was a familiar topic to these pre-service teachers.

Two treatments were then implemented, one for each week. The duration for each treatment was about 3 hours.

About two weeks after the treatment, the pre-service teachers' attitude/opinion towards the skills in asking operational questions was sought. It was in the form of questionnaire (see Appendix 2).

The results

Individual pre-service teachers' responses on the pre-test, the post-test as well as the experiment on dissolving sugar cube from the second treatment were collected and analysed. The following variables were used in the analysis.

- Science standard of pre-service teachers (see Table 1).
- Number of observations given by each of them.
- Number of non-operational questions asked by each of them.
- Number of operational questions asked which were further classified as:
    - correct operational questions.
    - operational questions with language problem(s).

* operational questions with conceptual problem(s).
* operational questions with logical problem(s).
* operational questions focussing on observation only.

Due to the limitation of pages, only the detailed result of the experiment on "dissolving sugar cube" is shown in Appendix 1, in order to provide our readers some ideas how it was done. The following is a summary of pre-test and post-test data on the number of observations, number of non-operational questions and number of operational questions responded to by the subjects (based on the three categories mentioned at the beginning of the section on experiment) in the study.

Table 2

As far as the posttest is concerned, the correlation between the mean values of observation score and the correct operational question score for the three standard groups, i.e. 'A', 'O' and 'O' (HSB), is very high (r = 0.92). For the individuals in the whole group, the corresponding correlation is also fairly high (r = 0.58).

In the case of the second treatment, experiment on "dissolving sugar cube", the results derived from the three categories of pre-service teachers are summarised in Table 3.

Table 3

Here, the data show a similar trend (cf. Table 2). The correlation between the mean values of the observation score and the correct operational question score for the three standard groups is very high (r = 0.99), while the corresponding correlation for the individuals in the whole group is fairly high too (r = 0.52).

In line with the results shown from the quantitative aspect, i.e. in terms of the numbers of good operational questions asked, student teachers with better science background also asked less numbers of operational questions with problems in language, concepts as well as logic, as shown clearly from the data presented in Appendix 1. Hence it seems that the quality of operational questions asked depends also on the subjects' background.

By further examining carefully the responses to operational questions given in the post-test and the experiment on 'dissolving sugar cube', there is evidence that most teachers apply the skills rigidly. Some of them apply the skills so rigidly that the questions seem to be not logical e.g. in the case of 'dissolving sugar cube', question such as 'If we use a smaller beaker of water to melt the sugar cube, would it melt slower?' is asked. Furthermore, almost all the questions asked are not beyond their observations, e.g. only two questions on sweetness of the sugar solution appeared in the responses to the experiment on 'dissolving sugar cube'. In addition, some teachers have missed out certain important observations and hence no questions related are asked, e.g. during the process of dissolving sugar, there is a concentration gradient from where the sugar is being dissolved to the diluted part of the solution. A certain dynamic boundary can be observed. In this case, only one of the teachers has mentioned something like 'wave motion'. In some other cases, it is obvious that due to their lack of understanding of scientific concepts, certain operational questions do not appear in the responses. For example, they have not thought that the bubbles produced could also come from the water. Hence no question related to this aspect has been asked. On top of all these, some pre-service teachers are holding certain misconceptions in science which will definitely affect the quality of operational questions.

With respect to the pre-service teachers' responses to the questionnaire, the following is the summary:

- All the pre-service teachers involved were able to state the definition of operational questions as well as the fundamental skills of asking operational questions correctly.
- They all agreed that asking operational questions is useful for teaching and learning science, especially when the inquiry approach is employed.
- Most of them had the confidence in asking operational questions in science lessons and expressed their willingness to apply the skills during the teaching.

- With regard to other comments, the pre-service teachers pointed out that they had been stimulated and would like to learn more in depth of teaching science.

Discussion and implications for science teaching

1. It is clear that even though student teachers had been taught with knowledge of up-to-date methods of teaching science, almost all of them were not aware of the term and usefulness of operational questions in science, if optional questions had not been informed explicitly to them.

2. However, our introduction of the concept on operational questions with practicing opportunity through the use of learning cycle showed a distinct change of teachers' behaviour in asking questions in terms of the number of operational questions asked. Although the generalization of our results was still too early to be determined, due to the small sample size, the outcome of this stidy did provide some indication that the skills in asking such questions could be trained. The sequence of the training, which began with awareness, followed by definition of the operational questions, seemed to be easily acceptable by the trainees. The discussion and practice on skills in asking operational questions thereafter are able to help the learner to be convinced and to internalize the process of doing it.

3. Although the outcome of the treatment was promising and the teacher's modelling and practising (as also observed by Allison and Shrighley, 1986) would contribute to the success of the treatment, in terms of writing more number of operational questions, we should be cautious about the experimental conditions. The subjects had in general sufficient knowledge of science and the ways of formulating operational questions related to primary science were relatively uncomplicated. Hence, in the process of training, we should not just pay attention only to the format of asking operational questions, but more to the quality of the operational questions.

4. Based on the results of treatment, represented by the experiemnt on dissolving of sugar cubes, the quality of the operational questions asked, in terms of the numbers of operational questions, with problems in language, concepts and logic, seems to relate closely to the subjects' science background, i.e. the higher their science knowledge, the less number of operational questions with problems. Furthermore, the data shown in Table 2 also consistently suggest that there is a direct correlation between pre-service teachers' knowledge in science and their ability to ask operational questions, in terms of the numbers of operational questions asked.

These observations can be intuitively explained as if one has a better understanding of the scientific concepts, one will have more competence and confidence to manipulate the variables with respect to certain phenomena related to the particular scientific concepts.

5. In the post-test, the correlation between the number of observations and the number of operational questions for each pre-service teacher is fairly high (r = 0.58) in terms of the individuals in the whole experimental cohort. It is also very high (r = 0.92) in terms of the three categories of subjects. These data no doubt give an indication that better observational skills can lead to asking more operational questions. Such a pattern also appears to be consistent in the second treatment on 'dissolving of sugar cube'.

6. If the above relationships, mentioned in paragraphs 4 and 5, are put together, the pattern shows in Figure 1 can arise.

Figure 1

Here the solid arrow (——>) shows the action of the former on the latter. It means that understanding of scientific concepts and observational skills in science will both affect the ability to ask operational questions in science. How strong the effect of understanding of scientific concepts on the ability to ask operational questions is not known, since the quantitative data about individual teacher's performance in science are not available. This is however not crucial because more important is its implication to teacher education. The implication here is that the training of pre-service teachers' ability to ask operational questions in science should not just be confined to the skills of asking operational questions. Emphasis on upgrading the scientific content knowledge and on training of observational skills can be helpful in promoting the ability to ask operational questions. If it is generalizabl then the training of pre-service teachers in using the operational questions in science should begin as early as possible, i.e. during the first year science methodology course. This will provide them more chances to apply the skills in setting operational questions in science during the course. However, to raise the quality of the operational questions, demonstration and experiment related to concepts and observational skills should constantly be organised and discussed.

7. Based on the present study, the pattern in Figure 1 exists under the conditions that the pre-service teachers have already acquired the scientific content and skills and learnt how to ask operational questions. But in the context of primary schools, the function of asking operational questions in science is basically one way to promote understanding of scientific concepts and observational skills - certain forms of inquiry. Hence, logically, the direction of the arrows should be reversed

as shown with the dotted arrows (see Figure 2).

Figure 2

Now the problem is how to raise pupils' ability to ask operational questions in science. Research findings (Allison and Shrigley, 1986) show that teacher modelling and the manipulation of certain instructional strategies, are good solutions to this problem. A: a result, Figure 2 can be extended to Figure 3.

Figure 3

Since teacher modelling is one factor affecting the ability of pupils in asking operational questions, the degree of matching the expected curriculum and the intended curriculum in promoting inquiry teaching in our schools could be strengthened with the training of teachers in this aspect. In view of the fact that the primary school pupils are less mature and less knowledgeable about science, the training may require a longer period.

8. In general, the pre-service teachers' attitude/opinion towards asking operational questions is found to be very positive and encouraging. They are convinced, and all believe deeply the usefulness and applicability of this type of questions. They are also very aware of the

modelling effect of teachers in performing the skills. With regard to their confidence in imparting such skills to the pupils, it is interesting to note that most of them are willing to try out using these skills during teaching practice. Although almost all the pre-service teachers involved have accepted the idea of operational questions without fail, there is one teacher making the following comment: operational questions are the type of questions to be directed mainly to primary school pupils, and not secondary pupils and above. Older pupils can be asked operational questions but mostly the type of questions that should be directed to them are those that allowed them to give reasons and facts, not only findings/answers from experiments and observations only.

Such a concern raises an interesting question, whether it is appropriate, at the lower secondary or even at the upper secondary level, to introduce the skills of asking operational questions.

Although at the higher level, with a deeper understanding of the content, the cause-effect questions should be given priority, we believe that the skill of asking operational questions has its role to play even at the higher level.

Such questions will constantly encourage pupils to think of the types of variables, the effects of change of variables and consequently the manipulation of variables which are essential for initiating and conducting project work at the secondary level. Knowing the skills of asking operational questions, a teacher would help pupils overcome the lack of ideas for project work as well as the fear to conduct project work. Hence, acquiring such skills at the higher level will serve as one of the learning strategies for pupils to learn science in a more effective way. Thus, it implies that this type of training can also be implemented for pre-service secondary science teachers.

Conclusion

In short, the present study reveals that if proper instruction is given, the pre-service student teachers' ability to ask operational questions can be trained and further developed. However, fostering ability in asking good quality operational questions, imparting science content knowledge and enhancing good observational skills are important areas to tackle. It is suggested that the training should start as early as possible. Such training can even be extended to pre-service secondary science teachers.

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Appendix 1. Results of treatment 2 experiment on dissolving of sugar cube

Standard	Student Teacher	Science Background	Number of Correct Observations	No. of Non-Operational Questions	Number of Operational Questions with Problems in: Language	Concepts	Logic	Focus on Observation only	No. of Good Operational Questions
	S1	P(A),C(O)	5	0			1	1	8
	S2	C(A),P(O)	6	0					8
	S3	P(A)	4	0	1		1		5
'A'	S4	P(A),C(A)	5	0				3	4
	S5	P(A),C(O)	6	0			1	2	6
	S6	PS(A)	5	1				2	5
	S7	C(A),PS(O)	6	1			1	4	4
	S8	B(O),PS(O)	4	1				3	2
	S9	B(O),PS(O)	2	0					6
	S10	B(O),PS(O)	7	0		1	1		11
	S11	B(O),PS(O)	5	2			1	1	6
	S12	B(O),PS(O)	5	0				1	6
'O'	S13	GS(O)	6	3	1			7	4
	S14	B(O)	4	1				1	4
	S15	CS(O)	7	0			1	2	6
	S16	PS(O)	2	1				1	2
	S17	PS(O)	8	0	1		1	4	6
	S18	PS(O)	2	0	1			2	2
	S19	HSB(O)	5	1					6
	S20	HSB(O)	4	0		2	1		5
	S21	HSB(O)	4	0	1			1	5
	S22	HSB(O)	4	1				1	2
	S23	HSB(O)	4	0					5
	S24	HSB(O)	4	0					7
	S25	HSB(O)	3	0	1	1	1		3
'O'	S26	HSB(O)	4	0		3			1
(HSB)	S27	HSB(O)	3	0	1	1			2
	S28	HSB(O)	9	0		1	2		6
	S29	HSB(O)	4	0					5
	S30	HSB(O)	5	0				2	3
	S31	HSB(O)	3	0			1		5
	S32	HSB(O)	4	0		1		1	3
	S33	HSB(O)	4	0					5
	S34	HSB(O)	4	0					4

* C(A): Chemistry ('A' Level), P(A): Physics ('A' Level), PS(A): Physical Science ('A' Level),
B(O): Biology ('O' Level), C(O): Chemistry ('O' Level),
PS(O): Physical Science ('O' Level), CS(O): Combined Science ('O' Level), GS(O): General Science ('O' Level),
HSB(O): Human and Social Biology ('O' Level).

Appendix 2. Questionnaire on "Asking Operational Questions"

NAME : .... DATE : ....

1. What do you mean by operational questions?

2. How do you ask operational questio: s? Please show us some format(s) you like to use.

3. In asking operational questions, what factors should we consider?

4. Is asking operational questions useful to your science teaching?

5. Are operational questions useful for primary school pupils in learning science?

6. Before attending lecture on "Asking Operational Questions", did you know how to ask operational questions?

7. After attending a lecture on "Asking Operational Questions", have you been confident in asking operational questions?

8. Would you like to use operational questions in your science lessons?

9. Would you like to recommend operational questions to your colleagues who are teaching primary science?

10. Are there any other comments?

Table 1. Range of pre-service teachers' background knowledge of science

Science Background	No of pre-service teachers	Percentage
'A' level	7	20.6
'O' level	11	32.4
'O' level (HSB)*	16	47.0

* HSB = Human and Social Biology

Science at 'A' level refers to pre-service teachers who had taken either pure science subject(s) or physical science at 'A' level. Science at 'O' level refers to those who had taken either pure science subject(s), biological science, physical science or combined science at 'O' level. And science at 'O' level (HSB) refers to those who had taken only Human and Social Biology at 'O' level. The percentages of these three categories in this sample are representative of those in the whole cohort.

The terms 'A' level and 'O' level mentioned here refer to the Advanced and Ordinary Level General Certificate in Education (GCE) Examinations conducted by the Cambridge University Examination Syndicate, United Kingdom.

Table 2. Summary of pre-test and post-test data

Standard	No. of pre-service	No. of observations (mean score)		No. of non-operational questions (mean score)		No. of correct operational questions (mean score)	
		Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
'A'	7	8.7	7.3	5.2	0.7	0.4	6.9
'O'	11	8.1	7.3	5.6	0.8	0.1	5.9
'O' (HSB)	16	7.0	6.8	4.9	0.4	0.0	4.3

Table 3. Mean socres of treatment 2 (experiment on dissolving sugar cube)

Standard	No. of pre-service	No. of observations (mean score)	No. of non-operational questions (mean score)	No. of correct operational questions (mean score)
'A'	7	5.3	0.3	5.7
'O'	11	4.7	0.6	5.0
'O' (HSB)	16	4.2	0.1	4.1

Figure 1

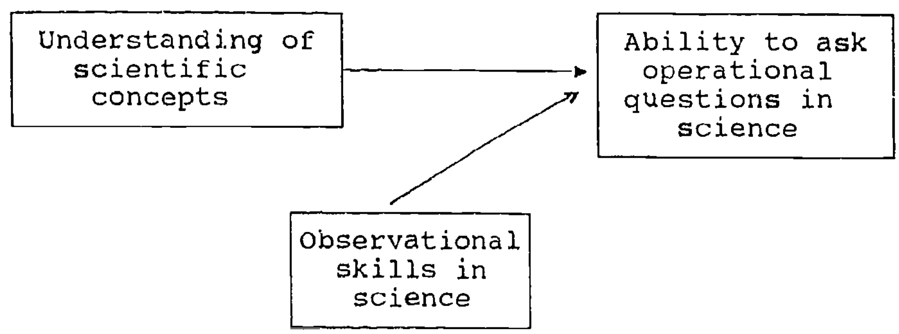

Understanding of scientific concepts
Ability to ask operational questions in science
Observational skills in science

Figure 2

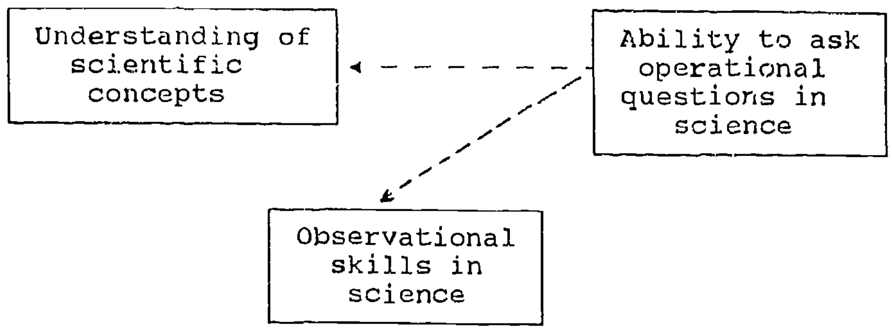
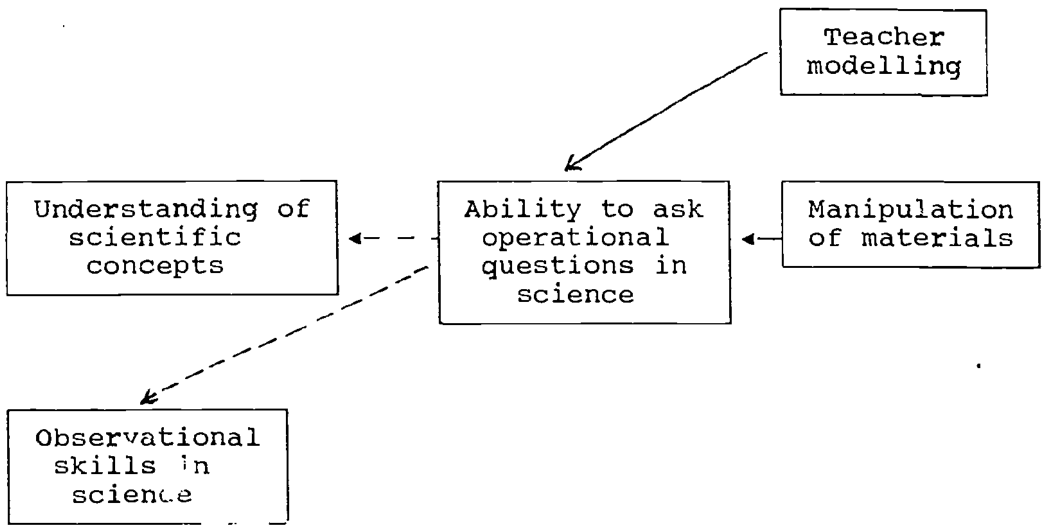

Understanding of scientific concepts
Ability to ask operational questions in science
Observational skills in science

Figure 3


Teacher modelling
Understanding of scientific concepts
Ability to ask operational questions in science
Manipulation of materials
Observational skills in science