USING OPEN QUESTIONS FOR TEACHING: A CLASSROOM EXPERIMENT

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INTRODUCTION

This is the report of an investigation of one classroom teaching strategy which has the potential to facilitate the achievement of the stated curriculum goals within the constraints of the classroom. There are three criteria which are necessary for any classroom strategy to be effective. First, the strategy must acknowledge the way that children learn the discipline. Second, it must accommodate the sociological constraints operating in classrooms. Third, the strategy must address the content goals of the discipline. These are discussed in the following sections.

THE LEARNING OF MATHEMATICS

The first criterion for a successful classroom strategy is that it must acknowledge the way that students learn. The view of learning as "a process of interactive adapting to a culture through active participation" (Bauersfeld, 1991, p.6) is useful. Learning which is an outcome of a child's exploration of a mathematical task, which highlights connections to existing knowledge, which is dependent in part on the child's own strategies, and which is linked to the child's experiences, is more likely to be useful in the future than learning based on rules or taught procedures.

The classroom interpretation of this is contentious. Obviously it will not be productive if the teacher just "tells" children how to do procedures. There is simply too much mathematics to learn it all by rote, and in any case the mathematics we need is continually changing. If mathematics teaching emphasises rules and procedures, this can create the impression that mathematics is about remembering, rather than working things out for one's self. On the other hand, it is not clear that pupils will experience the full range of mathematics needed for participation in our society solely as an outcome of undirected explorations. For example, we do not expect that all pupils would construct the system of operations with decimal numbers by themselves. There is also considerable risk that structures constructed through undirected exploration may not be adequate (Kilpatrick, 1987). We believe that pupils will need some teacher guidance for their learning to be effective.

This view of learning suggests that teachers must have an active role in planning and reviewing classroom mathematical activity while at the same time allowing flexibility for students to explore mathematical situations and to record their own solutions in their own ways.

THE CONSTRAINTS IN THE CLASSROOM

A second criterion is that the classroom teaching strategy must acknowledge that context can influence both the response of the students and the subsequent actions of the teachers. The implication for teaching is that students reorganise beliefs about the classroom, and about mathematics in particular, to resolve problems which are primarily social rather than mathematical. When asked a question in the classroom, the pupil's short-term goal is to give an answer so that the spotlight will shine elsewhere. Students who primarily seek to satisfy the perceived demands of the teacher have neither access nor motivation to appeal to relevant models or to inconsistencies in their own understandings. Such students could well be reluctant to listen to explanations given by their peers, for example.

It has also been argued that the pupils, in turn, have a major effect on the way that teachers teach. Doyle (1986) argued that the demands of academic work are shaped by a complex negotiated process between teachers and students. On one hand, students try to reduce the risk of failure by seeking to increase the explicitness of task requirements and to reduce the level of accountability, thereby narrowing the demands of the task. Teachers, for their part, tend to react to the response of the pupils by selecting tasks which are familiar and easy. Desforges and Cockburn (1987), in a study of primary classrooms in the U.K., noted the students' capacity to avoid thinking about classroom tasks wherever possible. In other words, any classroom strategy needs to address the pupils' view of the purpose of schooling and how mathematics is learned.

THE CONTENT GOALS OF MATHEMATICS

A third criterion by which any classroom approach can be evaluated is the extent to which the students learn the content which was the focus of the program. The NCTM (1989) described three categories of mathematical content which students should learn. These are empirical concerns, abstract concepts, and higher order reasoning skills. So, while on one hand it is necessary to see the content of mathematics as more than facts and skills, and to recognise that the mathematics used by our society is changing, on the other hand the content, as defined here, forms a critical component of mathematics teaching. It follows that the success of any teaching strategy can be determined, in part, by the extent to which the students demonstrate proficiency at the content of the program.

THE TEACHING STRATEGY

One way to seek to implement such a classroom regime, and to change the students' view of mathematics learning, is by focussing on the questions which teachers ask. This is relevant because questions are the main way in which teachers and pupils communicate (Sullivan and Leder, 1991) and because questions transmit the classroom requirements explicitly. A change in the type of questions asked will, by necessity, change most components of the mathematics classroom.

The particular type of questions which are the focus here are both content specific and open. Sullivan and Clarke (1988) called such questions 'good' questions. 'Good' questions are defined as those which are more than recall, educative and open. Examples of 'good' questions are as follows:

A number has been rounded off to 5.8. What might the number be?
Draw some triangles with an area of 6 sq cm.
Find two objects with the same mass but different volume.
Describe some boxes whcih have a surface area of 94 sq. cm.

Each of these questions requires pupils to do more than recall a set procedure. They provide opportunities for students to learn from the act of working on the question and they allow for a range of correct answers. These features each contribute to the educational potential of the questions, as is discussed in the following sections.

More than recall. Pupils can answer most classroom questions merely by recalling a procedure (Sullivan and Leder, 1991). Education for the future requires more than this.

Classroom questions have, at times, been categorised as high or low level, knowledge or evaluation, convergent or divergent and subjective or objective (Ornstein, 1987). Sullivan and Leder (1991) used nine cells in a two dimensional grid with structured to non-structured on one axis, and from recall to extension on the other. More common is the simple dichotomy of fact questions and higher order questions (Gall, 1984). While research on the effect of higher cognitive questions is not conclusive (Samson, Strykowski, Weinstein and Walberg, 1987), it seems hardly likely that teachers could stimulate higher order thinking if they ask only recall questions.

The level of questions asked also reflects the quality of understanding which the teacher seeks. Basically, pupils will be unlikely to aim higher than their teacher does. Likewise if the context of schooling appears to emphasise the accurate repetition of procedures, that is what the students will concentrate on (Cobb, 1986). Of course, procedural knowledge can be an important component of mathematical learning (Nesher, 1986). Nevertheless, the capacity to develop and expand the base of mathematical knowledge, to link concepts effectively, and to learn in the future will depend on well formed mental structures or schema which are fundamental to learning.

Educative. Perhaps the most important aspect of 'good' questions is that learners can become engaged in the tasks and so learn particular mathematics concepts as a result. Consider, for example, the question:

The perimeter of a rectangle is 30 cm. What might the area be?

Many students see the perimeter and area as linked. Working on this task can allow children to see that even if the perimeter of a rectangle is constant, the area can vary. The students may either find this out for themselves or they might learn it in the review of the questions from the responses of other pupils. In either case, this key measurement concept is addressed through the activity of the pupils rather than the instruction of the teacher.

Open. The third component of 'good' questions is that they are open. Open questions are used in a variety of contexts in education (Cliatt and Shaw, 1985; McGinty & Mutch, 1982; Necka 1989). Open questions can facilitate divergent thinking, imply that a range of possible answers exist, and provoke students to respond at a variety of levels. They require pupils to base their response on their own thinking rather than to mimic their teacher. Owen and Sweller (1985) argued that open questions facilitate learning because the learner is not required to attend to directed goals and so has more processing capacity available to explore the overall situation.

In short, the focus on content allows the content goals of mathematics teaching to be achieved. The openness of the tasks assists in the learning and enhances their applicability to classroom teaching.

THE STUDY

The focus of the study was to determine whether pupils learn substantive mathematics content through the use of content-specific open questions, with no direct teaching. The hypothesis was that pupils would develop the skills and orientation towards seeking multiple answers to open questions if these formed the basis of instruction. It was assumed that this, in turn, would facilitate the learning of substantive concepts by stimulating the development of more robust mental structures. These mental structures would be more accessible because they had been constructed by the learners themselves.

The components of the implementation of the study, namely the subjects, the instruments, the teaching program, and the observations of the teaching, are described in the following sections.

SUBJECTS

The study was conducted in a Catholic primary school in a suburban area of Melbourne, Australia. The school has a high proportion of students from non-English speaking backgrounds and served a predominantly lower socio-economic community. There were two composite grade 5/6 classes. Only the grade 6 pupils participated in the study. These pupils were randomly allocated to two groups prior to any testing. The grade 5 pupils were grouped together and completed a separate program during the experiment.

The experimental group was taught a unit on length, perimeter and area over seven one hour lessons. The control group was taught the same topic. The teacher of the control class was instructed to follow the program presented in the most commonly used text. This was to simulate a standard approach to the topic.

INSTRUMENTS

The purpose of the experiment was to measure the impact on the learning and approach of the students as an outcome of instruction. There were a number of instruments used. These were:

(a) An attitude instrument, prior to and after the teaching.

(b) A content test on the topic of length, perimeter and area. This consisted of 10 items. Three items were written by the class teacher. There were some open-ended items and one 'good' question.

(c) A further instrument of four 'good' questions using a broader response request statement, after the teaching.

The attitude instrument and content test were also administered to six other grade 6 classes to provide some background on typical responses for pupils of that age. After the content test, four pupils from each group were interviewed to allow further examination of the strategies used in responding to the items.

THE TEACHING PROGRAM

Each lesson started with a number drill or game. This was the format requested by the class teacher. The program for the experimental group consisted totally of 'good' questions which addressed aspects of the topic. Examples of the tasks used in each of the lessons are as follows:

- Suppose that we used body parts to measure things. Name something which is the same length as your height . ... the length of your foot.
- John measured the basketball court and said that it was 20 rulers long. Maria measured the same basketball court and said that it was $19\frac{1}{2}$ rulers long. How could this happen?
- What would we use a ruler 1 metre long to measure? ... a ruler 1 cm long?
- What is longer than 1 metre but less than 2 metres in this room? ... not in this room?
- Write down all the ways to describe "how long" that you know.
- *The pupils are given a piece of string.* What shapes might this be the perimeter of?

These tasks formed the basis of the instruction. In each lesson, a task was posed and the students given the materials needed to commence working on the task. Generally the pupils worked in pairs. The teacher moved from pair to pair checking responses, and facilitating the work. Each task was reviewed with the whole class. The students were invited to suggest a response or to write/draw their contribution on the board. Other children were then invited to suggest other responses. When the responses were displayed, the students were asked to comment on the overall pattern or to suggest a way to describe all of the answers. There was no direct teaching in the experimental group.

The format for the control group lessons consisted of an introductory game (15 minutes), teacher demonstration (15 minutes), written applications (15 minutes) and correction of written work (5 minutes). The content included use of formulae to calculate perimeter and area, using regular and irregular shapes. Questions were asked both ways: given a shape with dimensions, find the perimeter and area, and given the area of a shape, to find the length and width. There was a focus on hands-on activities such as measuring and applications such as finding the area of the playground.

THE LESSON OBSERVATIONS

A number of the lessons for each teacher were observed. There were two aspects to each observation. First, an attempt was made to record the teacher's actions. The focus of this was on explanations given, questions asked, and tasks set. A schedule using a similar format to the SCAN notation (Beeby, Burkhardt and Fraser, 1980) was used. A naturalistic record was also made of the lessons and a diary was completed after the lessons observed.

Second, an attempt was made to record the activities of the pupils. The activities of four pupils in each class were recorded at two minute intervals. These provided a record of the extent to which pupils were working on the task or engaged in other activities.

In the five lessons coded in the experimental class, there were no instrumental explanations and only three relational explanations. Eighty-six per cent of the questions in the experimental class were open and 61% were higher thinking questions. Eighty per cent of all set tasks were open and all required more than recall of information. The level of engagement of pupils in the experimental group was high. The students were engaged in listening to the teacher or working on the tasks for over 70% of the observations. An analysis of the students' work showed that they responded to the questions well, and gave multiple responses to the questions. The reports of the naturalistic observations indicated that the pupil adapted to the style readily and that they were engaged in the tasks productively.

In summary, the observations indicated that the implementation of teaching program was as had been designed. There were few explanations given in the experimental group and these were relational. There were few questions asked and these were predominantly open questions which required thinking. The tasks set were open. The pupils were task-oriented. The work produced by the children was good and they seemed receptive to this style of teaching.

RESULTS

The impact of the teaching on both groups was measured by a content test and an attitude instrument before and after the intervention, and by interviews with selected students after the teaching.

Content. The content test was completed by students in both classes. Three of the items were written by the teacher of the control group. There were two components of the content test: eight conventional or closed items on length, perimeter and area and one 'good' question on both the pre-test and post-test. Four additional 'good' questions were completed after the teaching program.

The conventional items on both tests required a single answer. It should be noted that some of the items were difficult for this grade level. There was no difference between the scores of the experimental group and the control group on the pre-test ($t= 0.8$, $df = 32$, $p=0.43$) and no difference on the post-test ($t=1.0$, $df=33$, $p=0.32$). A comparison of the gain in the scores of both groups on these items is presented in Table 1.

Table 1: Comparison of the gains of the experimental and control groups.

	n	mean of gains	s.d. of gains
experimental	16	1.6	2.2
control	16	1.2	1.7
		$t = 0.6$, $p = .54$	

These scores are not statistically different. This is an interesting result since it indicates that the pupils in the experimental group have learnt the skills and concepts as well as those in the control group. As seen earlier, there was no attempt to teach the skills directly in the experimental group. There was less that one explanation per lesson, only one closed recall question overall and no recall level tasks set, yet the students in the experimental group have improved their scores on skill items to the same extent as those in the control.

Since this is an important outcome of the experiment, it is relevant to examine the responses of the students to particular items. Table 2 presents the percentages of correct responses for each group on selected items from the pre-test and post-tests. The responses of 188 pupils at the same grade level from other schools tested at the same time are also presented to provide a context against which the test scores can be interpreted.

Table 2: Comparison of the correct responses (%) between the groups on selected closed items

	Experimental		Control		Other
	Pre	Post	Pre	Post	Schools
	n=18	n=17	n=16	n=18	n=188
Name something which is 10 cm long	56	94	63	72	53
What is the perimeter of this shape? (rectangle drawn here)	33	88	44	83	59
What is the area of that shape?	50	76	25	72	60
A table is the shape of a rectangle 3m long and 50 cm wide. What is the perimeter?	22	41	25	33	43

It is clear that there are children in both groups who have learned to calculate the perimeter and area of a given shape, which was the purpose of the unit. Certainly the experimental group was at no disadvantage on these conventional items.

The study also sought to determine whether the students were able to give better responses to 'good' questions as a result of the experimental program. There was one 'good' question on both the pre-test and post-test and this is used for comparison purposes. Table 3 presents the percentages of students who were able to give at least one correct response to the item.

Table 3: Comparison of correct responses (%) between the groups on a 'good' question

	Experimental		Control		Other
Question	Pre n=18	Post n=17	Pre n=16	Post n=18	Schools n=188
A rectangle has a perimeter of 30cm. What might the area be?	22	53	13	39	27

There were more students in the experimental group who could respond correctly after the instruction. There is a similar gain in the control group. This is a positive result for both groups.

There were no students in either group who attempted multiple answers. It had been anticipated that the experimental group would be able to give multiple or general responses as an outcome of the instruction. Given that this item was similar to those used in the teaching in the experimental group, this result requires consideration. In the class, the students were willing and able to give multiple answers readily to simpler tasks. It is possible that this test item was too difficult, and that processing perimeter and area together requires greater fluency with the concepts than had been developed during the program.

This possibility was explored in the second component of the post-testing. It had been earlier found that students gave more multiple and general answers when the request for more answers was explicit in the question statement (Sullivan, Clarke and Wallbridge, 1990). There were responses at the highest level. There were very few multiple answers. The items with the explicit request for multiple answers were related to the content of the teaching. It seems that the students were willing to give multiple answers if specifically prompted and if the question was easy. It does not appear that the experimental program assisted these students to answer the more difficult question on area and perimeter. This is a relevant issue in that while a significant number of students have learned the basic content, there were few who could respond to the more difficult items.

In summary, the content tests indicate that there were students in both groups who learnt to answer conventional items about length, perimeter and area, but that the students in the experimental group were not able to answer the open questions after the teaching. It suggests that these students were not disadvantaged by participation in the program, but neither did they develop the capacity to tackle the open questions as had been anticipated.

Attitudes and Implementation. The students completed a 14 item attitude instrument before and after the teaching. Students were asked to respond on a five point Likert scale. There were seven pairs of items, one positive and one negative, which sought responses on the students' liking of mathematics, their anxiety about mathematics, how difficult they find mathematics, whether they are interested in mathematics, how confident they feel, their perceptions of their motivation, and their beliefs about the openness of mathematics. By way of example, the stems on the openness of mathematics were:

In mathematics there is always one right answer.
You can sometimes have lots of correct answers to maths questions.

After scoring the responses, there were no significant differences, although the students in the experimental group were slightly less anxious and they considered mathematics slightly more open after the teaching.

Immediately after the post-test, four students from the experimental group and four from the control were interviewed to seek some insights into the thinking of the children. The interviews confirmed the results of the content test. Specifically, three of the students were confident with all aspects of the skills, yet none gave more than one response directly and only one could give a second response even when specificaly requested by the interviewer.

SUMMARY AND CONCLUSION

There is a need to identify teaching strategies which acknowledge the way children learn, which recognise that the way children respond to learning opportunities is influenced by the context of school and the classroom, and which emphasise the substantive mathematics content. 'Good' questions seem to offer one possible teaching strategy. The advantages of such questions are that the mathematical content is explicit, the role of the learner is emphasised, and the development and linking of concepts is facilitated. The basic question of the research study was whether students can learn substantive mathematics content from a program based only on content-specific open questions. It was hypothesised that such a program would stimulate an orientation toward seeking multiple and even general answers.

The study compared a traditional approach with a program based solely on content-specific open questions. Even though the teaching programs were markedly different, some pupils in both groups learnt to respond to conventional items on perimeter and area. The other result was that very few of the pupils in the experimental group had developed the skills necessary to respond to open questions on the content and had not developed the orientation to give multiple or general answers. This result needs further elaboration.

It must be stressed that during classes the pupils seemed to be willing to give a range of responses and they adapted to the style of teaching readily. The openness of the tasks facilitated the constructive activity of the children and allowed the pupils to work productively at their own level. Yet the pupils had consolidated neither the concepts nor the orientation sufficiently to respond to open questions on the test. It had been hoped that the pupils would give multiple or general responses to such questions, yet they did not.

One explanation considered was that the program may not have been long enough, and the pupils may have responded better on the test had they had more experience with open questions, especially at the more difficult end of the topic. Yet the pupils adapted to the style easily, and accepted the approach from the first lesson. Lack of familiarity with the style of questions was not the cause of their inability to respond to the 'good' questions on the tests.

Three aspects which may be more important factors in explaining the failure of the pupils to respond to the tasks were identified. First, it is possible that the 'good' questions asked, especially in test situations, were much more difficult than conventional questions. Second, even though some students learnt the basic concepts, and the gain was similar in both groups, there were still one quarter of the students who did not complete a direct item on area, and less than one half could complete the item where the units were different. Just over one half could give even one correct answer to the 'good' question. It is possible that some skill practice may help the children who could complete the basic items but who had difficulty giving even one answer to the 'good' questions. A third point, which seems obvious post hoc, is that the method used to review the tasks may not have been adequate. In the experimental class, the teaching procedure was to present a task for the pupils to explore, generally in pairs, then to have a whole class review where pupils reported on their findings and results. Often, it was assumed that the statement of a response by one of the pupils would be enough. Clearly it is no better if one of the pupils 'tells' something than if the teacher tells. In other words, the teaching occurs after the pupil activity, not before.

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