Science Talk in the Inquiry Classroom: An Analysis of Teachers' Questions and Their Purposes

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Teachers' questions in the inquiry classroom not only explore and make student thinking explicit in the class but also serve to guide and scaffold it. Several studies analysing teachers' questions and their categories have been reported; however need for a fine grained analysis has been felt (Chin, 2007) especially in the inquiry setting (Erdogan & Campbell, 2008; Roth, 1996). This study attempts a fine-grained analysis of the variety of teachers' questions and their roles in an inquiry science classroom, which are illustrated with vignettes from our classes. We also examine, through teachers' self-reports and lesson plans, their motivations for questioning. This work leads to a characterisation of inquiry in the science classroom that, we believe, would be helpful for teachers interested in moving towards more constructivist teaching practices.

Keywords: Inquiry classroom, Teachers' questions, Typology of questions

Introduction

Teacher's questioning is a significant aspect of classroom talk. Teachers' questions have the potential to elicit and stimulate student thinking and provide feedback to the teacher. This is especially true for inquiry-oriented science teaching. The kind of questions teachers ask and the way in which they are asked can, to a large extent, influence the nature of students' thinking as they engage in the process of constructing scientific knowledge (Chin, 2007) and can become indices of quality teaching (Carlsen, 1991).

In this paper, we present a qualitative analysis of teachers' questions and the patterns of questions that emerged in the inquiry classrooms we studied, juxtaposing them with those asked during traditional teaching. We examine these questions for the different roles they play for transacting science as inquiry. We also present teachers' self-reports on their purposes for using questions in their classes.

Literature on Teacher Questioning

Teachers' questions and their kinds

Several categories of teachers' questions have been proposed. Well known among these are lower and higher order questions (Bloom, Englehart, Furst, Hill, & Krathwohl, 1956), and open and close-ended questions (Graesser & Person, 1994). Lower cognitive, corresponding to close-ended questions, are those that invite brief answers and place few cognitive demands on the student while open-ended or higher-cognitive questions invite extended answers, may have several acceptable answers and place more demands on the learner. It has often been reported that traditionally teachers spend most of their time asking low-level cognitive questions (Harlen, 1999).

Some other researchers have suggested categories of questions that move away from this typical division. For example, Watts and Alsop (1995) illustrated instructional, conceptual and transactional questions; Elstgeest (1985) described productive questions that were: attention-focusing, exploring how and why, forging comparisons, problem solving and prompting actions. However, such broad categories may paint many aspects of teacher questioning with too broad a brush; need for a fine-grained analysis has been felt (Chin, 2007). Chin's (2007) categories of questioning-based approaches is such an attempt. She describes three approaches (namely socratic questioning, semantic tapestry and framing) and several strategies within these approaches that encourage student responses and thinking.

Teachers' use of questions in inquiry

Previous studies have shown that the purpose of teacher questioning in traditional science classes is to evaluate what students know and the predominant pattern of discourse is IRE (Dillon, 1988b; Lemke, 1990) in which the teacher typically initiates an interaction with a question (I), a student responds (R) and the teacher evaluates (E). However in inquiry-oriented science classrooms the role of teachers' questions is to encourage true dialogues (Lemke, 1990) aiming at conceptual understanding.

Erdogan and Campbell (2008) and Roth (1996) have pointed out that there exists a limited amount of literature investigating teacher questioning in constructivist learning environments and have attempted to describe the complexity of these questions. Roth (1996) described a case-study where the teachers' questioning was designed to draw out students' knowledge and scaffold students' discursive activity. Erdogan and Campbell (2008) found, using categories of open and close-ended questions (modified from Graesser & Person, 1994) that teachers facilitating classrooms with high levels of constructivist teaching practices not only asked a significantly greater of number of questions but also more open-ended questions.

In this study we attempt to explore and describe the rich diversity of roles teachers' questions play in transacting science as inquiry.

Methodology

Setting and participants

This study is part of an ongoing larger project that aims to investigate the outcomes of inquiry science teaching. Students of Grade 7 were invited to attend science classes after their school hours. Participation in all classes was voluntary; the sample was a convenience sample. The students belonged to an urban school in a cosmopolitan setting, coming from a varied socio-economic background. Students were randomly divided into two batches, each of about 20-25 students. Two teachers from the research group taught (individually, not together) a batch of students through inquiry. (One of these teachers is an author of this report.) Both the teachers (referred to as Teacher IJ and Teacher IK in this paper) had at least a Masters degree in science but were not formally trained teachers.

Two teachers (referred to as Teacher TN and Teacher TP in this paper) from nearby schools, nominated as among their best science teachers by the school authority, taught the other batch. Although they taught in the traditional way, they reported that they could do full justice to their teaching in these classes as they were not constrained by time limits for transacting material as demanded by the school schedules, nor were they limited to the content of prescribed textbooks. They also put in considerable effort to make these classes more interactive than their normal classes. Both these teachers had a Masters degree in science and were formally trained teachers with substantial teaching experience.

Data sources

Two researchers (mostly individually, at times together) observed the classes using an observation protocol developed for the project. The interactions in the classroom were recorded in detail and all the questions raised during class were noted. Utterances with the either the structure or intonation of an interrogation were taken to be questions. Transcripts were made using data from the protocols, referring to video records as necessary. Additionally, discussions with the teachers before and after the class, their written lesson plans and summaries of the classes served as data sources. Additionally, written self reports by teachers on their motivations and purposes for questioning were obtained. The analysis here is based on 12 classes-a random selection of 3 classes of an hour each per teacher. However, observations from all classes conducted throughout the year have informed the analysis in this paper. The topics taught in these particular classes included a unit on the student's immediate environment, plant reproduction and human circulatory system.

Data analysis

A plethora of subtle cues from the classroom may guide a teacher to ask a particular question. The exact motivation the teacher has for asking a question at the moment it is asked is clearly not available to the observer. Therefore, by using these multiple sources of data we attributed a category to the questions in the context in which they were asked i.e., the classroom interactions that preceded and followed the questions. In doing so, we have taken into consideration the three dimensions of teachers' questioning suggested by Carlsen (1991): the context of questions, the content of questions and the responses and reactions to questions.

Each question was examined and coded for its intended purpose as well as its effect in the teaching episode (such as stimulating interest, invoking reasoning, directing attention). When there was more than one possible purpose, all of them were noted; the categories of questions are thus overlapping. Such polythetic classification schemes (which allow an observation to be assigned to multiple categories) are appropriate in handling the complexity of human discourse (Graesser & Person, 1994; Roth, 1996). Questions were also coded as open or close-ended questions to see their proportion in classes of each of the teachers. Further discussions with the teachers on questions and their purposes in particular instances (reported here) helped fine-tune the analysis. The categories of questions that emerged were then sequenced and grouped/ regrouped according to relatedness. Further the sequences of questions were analysed for emerging patterns.

Results

Teachers' questions and their purposes - in inquiry classrooms

Our analysis of teachers' questions led to five broad categories as given below. The sub-categories within these categories and their examples are given in Table 1. For the purpose of clarity in illustrating and explaining these questioning strategies, the purpose most prominent for each question has been noted in the table although one question can and many a times does serve more than one purpose.

Exploring pre-requisites/ setting the stage

These questions basically gave feedback to the teacher about the familiarity and difficulty level of the topic. While this category of questions included close-ended questions, there were also open-ended questions eliciting students' personal experiences, setting the stage for the class. Teachers (more often in the inquiry classes) used these questions as wonderment questions-as starters for discussions. For instance, Teacher IJ asked, "How many milliseconds make one second?" after students were shown a video of falling raindrops in slow motion spanning seconds, to draw attention to how short a millisecond is, inspiring awe.

Generating ideas and explanations

These questions further stimulated interest and provoked thought. They usually preceded or immediately followed activities and helped students to articulate their observations, making further close observations and coming up with explanations. In inquiry classes, asking for an opinion or a stance on the issue at hand also helped to generate ideas for discussion.

Probing further

These questions probed students' initial ideas. In the discussions that followed, often there were questions from students. More often than not, the teacher responded to these questions with a question - a "reflective toss" (Van Zee & Minstrell, 1997b). We found such reflective tosses serving a variety of purposes - asking for clarification, elaboration and justification, pointing out contradictions with what has been observed or discussed in class, providing a hint to guide the student towards the answer and, in the true spirit of inquiry, asking the student if the student can think of a way to find out the answer. Thus, questions in this category begin with eliciting students' ideas and seamlessly lead to the following category; however the emphasis in this category is on students' initial ideas.

Refining conceptions and explanations

There was a rich variety of ways in which the teachers provided scaffolding to extend students thinking and refine their thoughts. We illustrate this with the following episode in a class taught by Teacher IJ.

The context was a unit on the measurement of rain– how odd that it should be measured in units of length! Does the cross sectional area of the rain gauge matter? Does its shape matter? In an earlier class, a homework task was given – place cylindrical containers of different cross sectional diameters at two points under the shower and see if the height of water was the same in both. Prior to this episode, one student had said that identical containers placed close to each other in rain would collect different amounts of water because rain drops may not all be of the same size. The teacher addressed this student's observation in a subsequent class with a new experiment: Artificial "rain" was made by each child by sprinkling water on his/her absorbent brown sheet, resulting in drops of different sizes. These were traced on a transparent sheet and in the end all the sheets stacked together (essentially, averaging over time) – the amount of water in two different quadrants of the total was about the same despite variations in individual sheets. The teacher tried to relate this experiment to the child's observation about varying raindrop sizes affecting measurements.

Episode 1 (S1, S2 etc. refer to students; codes for questions are given as indicated in Table 1)

Teacher: *Why did we do this experiment?* (Rs)

S1: *To see shape of raindrops*

Teacher: *We already know that.* (An experiment to see this had been done earlier)

I want others too to answer... (only 3 students had raised their hands) *What did S11 observe in the shower experiment?* (H, Cor) (S11 had erroneously used identical containers)

S3: *She got different levels of water in containers of same size.*

Teacher: (Repeated answer from S3) *Why?* (Ex)

S4: *Small holes on one side.*

The teacher reminded students of another experiment where rain-gauges were placed in "rain" created using a plant sprayer and the level of water was found to be same in different gauges.

Teacher: *But in the shower... why was it different?* (Ex, Con)

S3: *Because she did not change the place.*

S4: *She kept it in the centre of the shower where there was no hole.*

S5: *Holes in the middle are small.*

Teacher: *There were different-sized drops...but in the rain too we find that. So..?* (Al, Con)

S1: *In rain sometimes small drops fall here, sometimes big drops. In shower small drops always fall in the same place* (the crux of the argument!).

Teacher: *That's what S1 thinks. I want everyone to answer* (Er, S)

Teacher recalled another experiment where actual raindrop sizes were clearly seen on a cloth that was briefly exposed to rain for this purpose.

Teacher: *Now tell me why we did this experiment?* (Rs, I) Take a minute to think about it.

S2: *Raindrops are coming from a height.*

Teacher: *So. . ?* (C, E)

S9: *Rain is slanting.*

Teacher: *Shower is also slanting.*

S1: *Small drops in shower fall in the same place, it will not change.*

Teacher: *So if we keep a transparency, each time it would look the same?* (A, H)

Some students nod. The teacher again stacks the transparencies made by students together.

Teacher: *What happened now?* (A, Ex, Rs)

S3: *Same amount of water (in different quadrants)*

S1: *In rain the same thing happens.*

Teacher: Now *tell me what is different in shower and rain?* (Rs, I, P)

Some students answered.

Teacher: So *tell me why we did this experiment?* (I, P)

S10: *To check if different beakers (gauges) kept at different places get same amount of water.* (Some other students gave similar answers).

Guiding the entire class towards the scientific concept

In an inquiry classroom, where students express their own opinions and come up with their own explanations which could be different from the canonical scientific knowledge, conclusion of the discussion is a very significant phase. Also, unlike in traditional classrooms where the teacher moved on with even one student giving the correct answer, teachers in the inquiry classrooms made attempts throughout to involve the entire class in the discussions (evident in sample episode). At times, specially at turning points of conceptual change, a show of hands was invited - *"How many of you agree/ disagree/ are unsure ....?", "How many think...?"* which not only served to take stock of how prevalent a particular conception was but also nudged students who had not already taken a side to weigh the pros and cons of the options in order to do so. Sometimes such questions also helped to point out patterns (results) during activities. For instance, Teacher JK asked, "How many of you got the heart-rate and pulse rate the same?" to point out that most students had found them to be the same.

There were also some questions for class management like asking if students want more time to think or discuss among themselves before answering.

Kinds of Questions and their codes	Examples
1. Exploring pre-requisites/setting the stage	
Ft - Factual recall (from what was taught)	*How many milliseconds make one second?*
Fw - Factual recall (from child's observation)	*What do water drops look like?*
Exp - Eliciting student experience	*Where do you go on picnics?*
2. Generating ideas and explanations	
A - Directing attention	*Did you see anything different when a drop broke up?*
Ex - Asking for explanation	*How does water enter the wells?*
G - Asking for guesses	*Which, do you think, are the youngest (larvae)?*
O - Drawing on what has been observed	*How many kinds (of larvae) did you see?*
Ob - Calling for further observation	*Do the pupae move in the same way (as larvae)?*
Op - Asking for an opinion or stance	*Suppose we have to rank these places from 1 to 10, what rank would you give the placeyou selected?*
3. Probing further	
C - Clarificatory	*How can that be? What kind of cells?*
E - Asking for elaboration	*So, what would happen? Will there be a difference?*
J - Asking for justification	*Raindrop sizes are different? How do you know?*
Con - Pointing out contradictions	*When they are larvae, they are not (C-shaped), right?*
H - Hinting	*We have to think what we mean by "dirty water".*
T - Asking for a way to test or find out	*How can we find out?*

4. Refining conceptions and explanations	
Rs - Calling for Reasoning	*Will the level in the both containers be the same?*
I - Asking for inference	*Why did we do this experiment?*
Cor - Helping to make connections	*Both pulse and heart rate increase? Are they related?*
Al - Presenting alternative viewpoints	*If we have a cold, we can't smell things; then is it ok to have garbage around?*
Me - Invoking reflective thinking	*What kinds of places you like for picnics? Why?*
Fl - Pointing out flaws in the argument	*Do we select only oxygen while breathing in?*
P - Driving towards the focal point	*So, what was the difference in shower and rain?*
Qt - Quantitative thinking	*More than double or less than double?*
L - Focusing on Language	*Do you know any words starting with 'cent'?*
V - Aiding in visualisation	*What if we cut it, how will the vein look from here?*
5. Guiding the entire class towards the scientific concepts	
Er - Encouraging wider response	*Each of you think of an example of stagnant water.*
V - Urging to consider a variety of viewpoints	*S1 and S7 wrote that stigma is sticky. How do we know? We don't feel that when we touch it.*
S - Encouraging students to take up a side	*Do you agree with S7?*
Ts - Taking stock	*How many of you rated it as 10?*
Re - Rephrasing students' questions	*S1 is asking – do all fruits turn into flowers?*
6. Classroom management	
M	*Do you need a minute to think about it?*

Table 1: Teachers' questions in the inquiry classroom

Teachers' questions - in the traditional science classrooms

Contrary to reports in the literature, and perhaps our expectations, there were almost as many teachers' questions in the traditional science classes as in the inquiry classes (an average of 23 and 17 questions per class for TN and TP compared to 28 and 26 questions for IJ and IK) but with a stark difference: only 15% of the questions in TN's class and 19% in TP's class were open-ended compared to 92 % and 86 % in IJ and IK's class. More than half the questions in these classes were either revision questions or rhetorical or those asking for sentence completion. The answers to these questions were mostly given in chorus. Other questions included those asking for pre-requisites and a smaller proportion of open-ended questions eliciting experiences and asking for elaboration, instances, and rarely, explanations.

Teachers' self-reports

When asked to explicitly deliberate on what purposes questions serve in their classrooms, what was common in all the teachers' responses was the need to know what pre-requisites students had for the topic to be taught. Consistent with the oft reported findings in literature (Chin, 2007), the traditional teachers in this study too said that they "ask questions to test students' knowledge" and "if they (students) have learnt the material".

Both the inquiry teachers reported that their further teaching plan would be dependent on students' responses. They expressed a genuine desire to understand where the students were and whether the level of difficulty of the topic suits them. Both of them reported that they actively tried to stretch students thinking to draw out answers from them whenever it was possible and thought that additionally this would also increase student engagement and curiosity. One of them, Teacher IJ articulated a much more nuanced understanding and awareness of her questioning practices and the many crucial roles they play in inquiry - ranging from directing students' thought to the topic at hand to probing difficulties students have in understanding the topic and tracing the roots of these difficulties. She also pointed out an important purpose of questions-that of involving the entire class in an exercise of genuine inquiry in the classroom: “Questions allow a topic to be thrown into the ‘public’ arena (of the entire classroom) for discussion, and provide opportunities for evaluating their own and others’ answers... This exercise allows for tentative explanations and possible ways to check whether a solution is acceptable...Further, children develop a culture of listening to and respecting others’ views, learn that theirs and others’ views matter to the teacher.” Indeed, this led us to create a new category of questions - ‘Guiding the entire class...’

Discussion

Teachers’ scaffolding of students’ thinking in the various ways discussed in this paper brought the quality of exploratory talk to the inquiry classrooms. Though TN and TP made the class interactive by asking many questions, these mostly asked for what students already knew while in inquiry classes, the questions aided in stimulating students’ thinking and making it explicit to the student as well as to the entire class. Also, the inquiry teachers made active attempts to engage all the students in the discussions and move them towards conceptual understanding. The categories of teachers’ questions reported in this paper depict the progression in an inquiry class from eliciting, diagnosing and probing students’ ideas to refining them and guiding the entire class towards accepted scientific knowledge.

In order to bring about this progression, teachers’ questions in the inquiry classes were contingent on students’ responses; their lesson plans were tentative and changed in response to what the students’ ideas were. At times when students were groping to come up with an explanation, the teachers asked nested questions giving a hint or directing them to the pre-requisites and then repeated the question. This cycle continued till the explanation was constructed wholly. Because students’ responses were treated in a respectful manner and actively solicited they formed a significant part of the classroom talk. Also, the feedback from the teachers to students’ answers and questions came in various ways as reported in Table 1. This resulted in discourse patterns other than the typical IRE or IRF sequence. Note that, the pattern of interaction in the sample episode is a long IRFRF chain which is typical of discourse that supports a dialogic interaction (Mortimer & Scott, 2003).

In the traditional science classes, there was not much difference in the questions asked or their sequence in the class from what had been planned prior to class. Also, though many a times the teachers’ asked, “Clear? Understood?”, students were given little or no time to respond before the teacher moved on, nor were other cues taken into account thus just playing the ‘guess the answer in my head game’ (Amos, 2002).

Through the repertoire of questioning practices reported here, the teachers in these inquiry classes tried to give children a flavour of what inquiry is - note that at the end of the sample episode, the student answered that the experiment was done “to check if...” and not “to show that...” (a phrase appearing commonly in the traditional classes). These questions also brought an added advantage–as reported by the teachers, it made teaching interesting for the teachers and engaged them in an inquiry into what goes on in children’s minds–something they enjoyed thoroughly.

Conclusion

One of the hurdles in adopting inquiry-oriented teaching practices has been that teachers have few operational models to understand what inquiry looks like and what their roles might be in helping students develop scientific understanding through an inquiry process (Asay & Orgill, 2010; Crawford, Zembal-Saul, Munford, & Friedrichsen, 2005). In this study, we have attempted to make explicit the teachers’ tacit strategies employed in inquiry-oriented teaching. We believe that the teachers’ self-reports and the fine grained analysis of everyday instruction in inquiry classrooms would be helpful to teachers to frame questions that make a science lesson into an inquiry one.

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