Mathematics Learning: What Do Pupils’ Questions Suggest About Their Thinking?

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Abstract

The purpose of this study was to firstly explore how pupils’ questions contribute to the knowledge construction process, and secondly relate the nature of pupils’ questions to their approaches to learning. Forty-eight Junior Secondary School II (J S S 2) pupils in the Winneba District Basic Schools in Ghana were observed during mathematics lessons, and interviewed after the lessons about related mathematics concepts. Pupils’ questions included basic information questions, which reflected a surface learning approach, and critical questions that characterized a deep approach. While critical questions stimulated the pupils themselves or their peers to hypothesize, predict and generate explanations, basic information questions elicited little conceptual talk or deep cognitive processing. Although the pupils did not always ask critical questions inherently, they were able to generate such questions when prompted to do so. Some techniques related to pupil questioning that teachers can use to encourage deeper thinking in pupils are suggested.

Questioning is an integral part of mathematical inquiry and the learning process. Pupils’ questions can reveal much about the quality of pupils’ thinking and conceptual understanding (Watts & Alsop, 1995; White & Gunstone, 1992; Woodward, 1992), their alternative frameworks and confusion about various concepts (Maskill & Pedrosa de Jesus, 1997), their reasoning (Donaldson, 1978), and what they want to know (Elstgeest, 1985). Pupil questioning, particularly at the higher cognitive levels, is also an essential aspect of problem-solving (Pizzini & Shepardson, 1991; Zoller, 1987).

Self-questioning is also considered to be a metacognitive activity (Wong, 1995), and is consistent with the view of generative learning (Osborne & Wittrock, 1983, 1985) as learners try to reconcile their prior knowledge and new information in their attempts to make sense of these ideas. Despite the educational values of pupils’ questions, Dillon (1988) found that pupils asked remarkably few questions, and even fewer in search of knowledge. Few pupils spontaneously ask high-quality thinking questions (White & Gunstone, 1992, p. 170), and low levels of questioning and explanation on the part of pupils were found to be correlated with lower achievement (Tisher, 1977).

Watts and Alsop (1995) found that pupils’ questions were diagnostic of the state of pupils’ thinking, revealing their frames of reference and unorthodox understanding of mathematics, and being indicative of the routes through which pupils were seeking understanding. Three categories of pupils’ questions seem to illuminate distinct periods in the process of conceptual change (Watts, Gould, & Alsop, 1977). These include (1) consolidating questions where pupils attempt to confirm explanations and consolidate understanding of new ideas in mathematics; (2) exploration questions where they seek to expand knowledge and test constructs; and (3) elaboration questions where pupils attempt to examine claims and counterclaims, reconcile different understandings, resolve conflicts, test circumstances and track in and around the ideas and their consequences.

Keys (1998) found that when Grade 6 students worked in groups to generate their own questions for open-ended science investigations, they mainly varied the teacher directed activity by essentially repeating the activity but changing one or more of the variables, or invented questions from their own ideas from previous science lessons and personal experiences from everyday life. Pupils’ questions determine the depth and breadth of the concepts to be learned, the scientific processes to be used, and the cognitive difficulty of the investigation of the tasks. Allowing pupils to generate their own investigation questions stimulated curiosity and encouraged profound thinking about relationships among questions, tests, evidence, and conclusions.

In the study by Maskill and Pedrosa de Jesus (1997), the teacher stopped the lessons from time to time and requested the pupils to write down any questions they wished to ask about problems they were having. The questions provided information about pupils’ learning difficulties and served as useful feedback for future teaching. In the study by Dori and Herscovitz (1999), Grade 10 mathematics pupils posed questions while practicing a variety of learning activities. The pupils’ questions-posing capability was then evaluated by giving the pupils a case study and asking them to compose as many questions as they could about the case they had read. There was a significant increase in pupils’ question-posing...
capability after instruction (as indicated by the total number, orientation, and complexity of questions). The findings also showed that question-posing capability could be used as a means of evaluating higher order thinking.

The findings from the above-mentioned studies indicate that there is substantial educational potential in pupil-generated questions in directing pupils’ inquiry and guiding their construction of knowledge. Earlier studies (such as those concerned with text-based questioning) adopted a process-product approach, typically comparing the effects of an intervention with comparison group and focusing on pupil achievement. More recent studies, however, have used a sociolinguistic approach that emphasizes the interactional nature of classroom discourse and social contexts. Carlsen (1991) suggested that three features of questions (viz. context, content, and responses and reactions by speakers can be considered in sociolinguistic research on classroom questioning which can address the dynamics and active construction of meaning that the process-product paradigm is unable to consider.

Previous studies focused primarily on questions produced individually, and in written form. Little research has been done to investigate the role of pupils’ questions in the knowledge construction process, especially in classroom discourse. It is thus with interest to study how questions produced both individually and in a group setting scaffold and interact in pupils’ collaborative inquiry, and help in the construction of conceptual knowledge. Accordingly, the purpose of this study was to (1) explore how pupils’ questions contribute to the knowledge construction process, particularly in educational discourse in small-group collaborative settings, (2) relate the nature of pupils’ questions to their learning approaches, and (3) suggest some ways related to pupil questioning that teachers can use to promote deeper thinking in their pupils.

Methodology

A case study approach (Miles and Huberman, 1994) of forty-eight Junior Secondary School II (J S S 2) target pupils from sixteen basic schools in the Winneba Education District of Ghana was used. Purposive sampling of a few target pupils allowed the tracking of selected individuals over time, as well as the collection of rich, in-depth data from classroom discourse in small-group settings for subsequent analysis. The pupils represented learners of different academic abilities (above average, average and below average). They were identified by their classroom teachers’ evaluation of their schoolwork. To ensure validity in the choice of pupils, it was imperative that the teachers’ evaluation matched the pupils’ scores on class assignments as well as class tests and records from examination performance. Other selection criteria included: good attendance, being verbally expressive and on-task, having at least average success in mathematics, and having the ability to work well with each other.

The mathematics class was observed for seven weeks. The topics covered included the construction of geometric figures, activities on finding areas of plane figures, solution set of inequalities, expansion of algebraic expressions, transformations and making the subject of a formula.

The pupils were both audiotaped and videotaped during the mathematics activities, and were encouraged to think aloud and verbalize their thoughts. Field notes were taken. The pupils were also interviewed individually after instruction of mathematics topics to find out more about their understanding of the mathematics concepts in each topic. The interviews were audiotaped. Stimulated recall was used to obtain further information about how the pupils tackled the tasks and what they were thinking of while engaged in the mathematical activities. This provided information about silent thoughts, which were not always verbalized and captured, on tape.

To find out if pupils had other questions that were not verbalized during the mathematics activities and thus not captured on the tape, the pupils were asked to write down at home any questions they had, as part of learning journal, particularly about things that puzzled them. For the activity pertaining to the finding of areas of plane figures, the teacher set aside time during the lesson for the pupils in class to write down questions. During the post-instructional interviews, the pupils were also asked if they had any questions regarding to the various activities.

Data from multiple sources (field notes, transcripts of classroom discourse from the audiotapes and videotapes, audiotaped interviews with the pupils, and pupils’ written work) were analyzed in relation to each other; this served to triangulate the data and to help enhance the credibility of the findings and assertions made (Lincoln & Guba, 1985; Stake, 1995). The target pupils’ taped interviews and discourse during class activities were transcribed verbatim and subsequently analyzed. Transcribed discourse from the videotapes was also supplemented with descriptive notes obtained by viewing the videotapes to get information about what the pupils did during the mathematics activities.

To identify the type of questions that pupils asked, the transcripts were read through several times. Coding categories (Bogdan & Biklen, 1992) were developed by making annotated descriptive and interpretive comments on the margins of the transcripts each time a question was documented. These
became the tentative coding categories. Subsequent transcript segments containing questions were then annotated with the appropriate code. A constant comparative method (Glaser & Strauss, 1967) was used to cluster the codes into progressively more inclusive categories forming a hierarchical taxonomy or working typologies. Segments of the transcript following the questions were scrutinized to study the evolution and progress of pupils’ thinking and actions during their knowledge construction process. Assertions were made based on patterns observed which were grounded in the data.

Results

The nature of Pupils’ Questions

The types of questions that pupils asked were identified, and details regarding this information are presented. In summary, pupils’ questions could be broadly classified as basic information questions and critical questions. Basic information questions comprised factual and procedural questions. Factual questions were often closed questions, usually requiring only recall of information, and typically relating to information in the textbook or some simple observation made about an event. Procedural questions attempted to clarify a given procedure or asked how a task was to be carried out especially when step-by-step instructions had been given.

Critical questions, which were pitched at a conceptually higher level, included: (1) comprehension questions which typically sought an explanation of something not understood; (2) prediction questions of the “What would happen if...” variety involving some speculation or hypothesis-verification; (3) anomaly detection questions where the pupil expressed scepticism or detected some discrepant information or cognitive conflict, and sought to address this anomalous data; (4) application questions in which the pupil wondered of what use was the information that he or she was dealing with; and (5) planning or strategy questions where the pupil was temporarily stuck and wondered how best to proceed next when no prior procedure had been given.

Most of the questions that the pupils asked during the activities were generally not of conceptually high level that manifested deep thinking. Procedural questions formed majority of all questions asked. Critical questions comprised only very few of all the questions asked, with fewer still of the critical questions being comprehension questions which focused on explanations.

Discussion, Implications, and Conclusions

This study identified some of the types of questions that pupils should be encouraged to ask to bring about deeper learning and meaningful knowledge construction. Such a taxonomy of question types, which classifies pupils’ questions according to different conceptual levels, would be useful in helping teachers plan their activities so as to foster pupil questioning at a higher cognitive level.

One limitation of this study is that the findings were based on only forty-eight pupils from one education district (there are one hundred and ten education districts in Ghana). The findings are thus presented as grounded hypothesis rather than generalizable findings. Another limitation is that some pupils’ questions may not have been verbalized or thought-aloud during the activities, and thus were not documented for subsequent analysis. However, attempts were made to maximize the collection of data on pupils’ questions through stimulated recall during post-instructional interviews.

How Pupils’ Questions Contribute to Knowledge Construction

Basic information questions did little to stimulate deep thinking in pupils, and elicited only short responses, which dealt with factual and procedural information. On the other hand, critical questions facilitated knowledge construction by guiding thinking and promoting conceptual talk that pertained to the core concepts of an activity. It was found that such questions stimulated not only the pupils themselves, but also their group members to hypothesize, predict, seek and generate explanations for things, which puzzled them. These questions triggered the use of deep thinking strategies, which may not be invoked if these questions had not been asked. The questions played an important role in engaging the pupils’ minds more actively, engendering productive discussion, and leading to meaningful construction of knowledge both individually and collaboratively.

Questions are one of the psychological tools for thinking, and when embedded in the discourse of collaborative peer groups, help learners co-construct knowledge inter-psychologically. This knowledge is then appropriated or constructed intra-psychologically by the individual members (Vygotsky, 1978). From a social cognitive perspective, questioning in a group context can also encourage pupils to reconsider their ideas in new ways because they are exposed to different perspectives. Question-generation is a constructive activity and is an essential component of pupil discourse in “talking mathematics” (Hawkins & Pea, 1987; Lemke, 1990) in the social construction of knowledge (Driver, Asoko, Leach, Mortimer, &Scott, 1994).
Link Between Nature of Pupils’ Questions and Their Learning Styles

The types of questions that pupils ask can reveal their depth of thinking. Critical questions are associated with a deep approach to learning whereas basic information questions are related to a more surface approach. Since asking critical questions is reflective of deep learning, teachers should encourage pupils to ask questions and to “enter the depth dynamic” (Chin & Brown, 2000a) so as to increase their depth of thinking in other related areas. According to this “depth dynamic” model, the asking of critical questions can help learners initiate a process of hypothesizing, predicting, thought-experimenting, and explaining, thereby leading to a wave of generative activity. However, asking critical questions is indicative of only one dimension of a deep learning approach, the other possible dimensions being generative thinking, nature of explanations, metacognitive activity, and approach to tasks (Chin & Brown, 2000b).

Pupils mainly asked procedural questions when the assigned tasks required them to follow given instructions and step-by-step procedures, and this did not engage them at high cognitive levels. Such questions elicited only short, simple answers without leading to further conceptual talk, and pupils adopted a surface learning approach. In contrast, an open-ended, problem-solving activity carried out in the spirit of scientific inquiry elicited a richer range of critical questions and talk at higher conceptual levels. This implies that the nature of tasks that teachers set and the cognitive demands required of the pupils influence the types of questions that pupils ask, and thus to some extent, the learning approach and learning strategies that they adopt. Hence, to encourage deep thinking in their pupils, teachers should present their mathematical activities in a way that encourages inquiry and problem-solving rather than following instructions to obtain an expected answer.

Asking critical questions can stimulate either the questioners themselves or other pupils to generate an answer, thereby bringing to the fore other deep learning strategies that have hitherto been latent, and potentially leading to talk at a higher conceptual level. One implication arising from this pertains to the assignment of pupils in groups. A teacher might consider including at least one “inquisitive” pupil in a group to steer other group members in their thinking and co-construction of knowledge.

Although the pupils did not always generate critical questions inherently, they asked more meaningful questions upon subsequent probing and nudging during the post-instructional interviews and when they were requested to write questions in their learning journals. This suggests that many pupils would not ask this kind of questions unless they are stimulated to think about such questions. Consequently, a lot of potential conceptual talk could be untapped if these questions are not asked. Teachers cannot simply rely on pupils’ inherent questioning and must explicitly orient their pupils toward asking questions, for example, by specifically encouraging them to generate questions, either verbally or written, as part of their class activities. Besides prompting pupils to think more deeply about what they are doing and encouraging critical thinking, such questions could also provide feedback to teachers about their pupils’ thinking and puzzlement.

Even the pupils who typically did not inherently ask higher-level critical questions were capable of asking thoughtful questions when time was specifically set aside for them to ask questions about things that puzzled them or which they were curious about. This suggests that teachers could explicitly encourage such pupils to ask questions by providing them extra opportunities to do so.

Techniques to Encourage Pupil Questioning

The findings of this study indicate that pupil-generated questions are an important aspect of learning in mathematics as they can stimulate pupils to engage in thinking processes such as hypothesizing, predicting, and explaining. So how can teachers encourage a “question-based learning” approach (Watts, Gould, & Alsop, 1997) in their classrooms? Teachers could ask pupils to write their questions before performing an activity to help them direct their own inquiry and use these questions as a springboard for investigation and discussion. The pupils could write questions as they are working on their tasks or at the end of the activity, regarding what had puzzled them, or what they want to know more about. Teachers can ask their pupils to record their questions in a learning journal, thus documenting a set of “I wonder” questions (Kulas, 1995). Teachers can also pause at convenient intervals during the lesson and request the pupils to write down questions they wish to ask, and then use these questions as “thought-provokers” for stimulating discussions (Maskill & Pedrosa de Jesus, 1997). Watts, Gould, and Alsop (1997) have also suggested including specific times for questions such as a period of “free question time” during lessons, a question “brainstorm” at the start of a topic, a “question box” on a side table where pupils can put their questions, turn-taking questioning around the class where each pupil or group of pupils must prepare a question to be asked of others, and “question-making” homework. Teachers can also establish a “problem corner” in the classroom and encourage pupils to supply “questions of the week” (Jelly, 1985).

It is common knowledge among educators that to know how to question is essential to knowing how
to teach well. However, given the current emphasis on critical thinking, inquiry, and pupil-centered learning, we should also impress upon our pupils that to know how to question is also to know how to learn well.
References


