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## The use of open-ended question pictures in the mathematics classroom

**Mela Aziza<sup>a\*</sup>**, University of Bristol, Senate House, Tyndall Ave, BS8 1TH Bristol, UK

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### Abstract

Teachers have to ensure to pose open-ended questions that allow multiple solutions in a mathematics classroom regarding problem-solving and mathematical creativity. Teachers can use visual representations or pictures to ask open-ended questions in order to encourage students to be curious about finding possible answers. This research is focused on the use of open-ended question pictures, students' responses and students' mathematical creativity in response to the questions. This study used observation of a lesson that involved a teacher and twenty-seven class-three students (aged 7–8 years old) in a primary school in the UK. During the observation, a whole-class activity between the teacher and students was recorded and notes were also taken. There were three open-ended questions using pictures that the teacher orally posed during a lesson. The findings showed that open-ended question pictures could stimulate students' responses and mathematical creativity.

Keywords: Open-ended question pictures, representations.

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\* ADDRESS FOR CORRESPONDENCE: **Mela Aziza**, University of Bristol, Senate House, Tyndall Ave, BS8 1TH Bristol, UK.  
E-mail address: [ma16922@my.bristol.ac.uk](mailto:ma16922@my.bristol.ac.uk) / Tel.: +44 (0) 117 928 9000

## **1. Introduction**

Although teachers need to ask students all kinds of questions, both closed questions requiring one answer and open-ended questions that have multiple answers (Capraro, Capraro & Cifarelli, 2007), there is a huge potential of using open-ended questions. However, some researchers found that the majority of teachers posed closed questions instead of open-ended questions in the mathematics classroom (Kwon, Park & Park, 2006; Muir, 2009). Teachers are able to ask open-ended questions to foster students' problem-solving skills (Al-Absi, 2012), reasoning and critical thinking skills (Sullivan & Lilburn, 2002), interpretation and communication (Silver, 1997), as well as mathematical creativity (Kwon et al., 2006). It is in line with the standards of the National Council of Teachers of Mathematics (NCTM) that have been focusing on the development of problem-solving, communication, reasoning skills and mathematical creativity since 1989 for the school mathematics curriculum (NCTM, 1989, 2000). However, Silver (1997) recommended teachers to involve mathematical creativity in asking questions because it is usually linked to problem-solving activities. Thus, I will explore how a teacher asked open-ended questions to students and students' responses to the questions in the mathematics classroom related to mathematical creativity.

Despite the fact that teachers can find it challenging to develop open-ended questions using pictures, it will enhance their abilities in seeing mathematics through a new lens (Bragg & Nicol, 2011). Bragg and Nicol (2011) explained that a question using a picture can stimulate students' curiosity in answering the question as well as their engagement during the questioning process. Representations like pictures will also help teachers to explain mathematical ideas and to connect the abstract concept to students' concrete experiences (Harries & Barmby, 2011). It seems that pictures are pivotal in learning mathematics and can be used for many reasons during teaching and learning mathematics in the classroom.

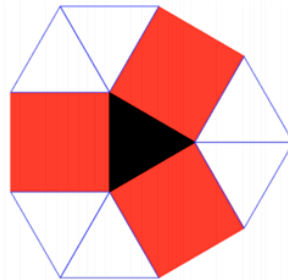
### **1.1. Questioning activity**

Questioning has important roles in a mathematics classroom because most teachers spend their lesson asking questions (Sullivan & Lilburn, 2002). Teachers normally use questions to evaluate students' understanding, challenge students' mathematical thinking, as well as promote students' problem-solving skills (Tofade, Elsner & Haines, 2013). Furthermore, teachers are able to create classroom discussion through questioning in which it will not only build interaction between students but also students and teachers (Hufferd-Ackles, Fuson & Sherin, 2004). During questioning, teachers can ask either oral or written questions to individuals or groups (Cotton, 2001). However, Shahrill (2013) found that teachers can create rich classroom discussion by asking questions orally.

### **1.2. Open-ended question pictures**

Based on the number of possible correct answers, there are two types of questions: closed and open-ended questions (Yee, 2002). Closed questions have only one correct answer, while open-ended questions have multiple answers (Kwon et al., 2006; Nohda, 2000). Even though Mason and Johnston-Wilder (2004) argued that it is unclear whether open-ended questions are more effective than closed questions, there are numerous findings related to the benefits of using open-ended questions (Al-Absi 2012; Kwon et al., 2006; Silver, 1997; Yee, 2002). Teachers ask questions in order to obtain any kind of responses from students (Hufferd-Ackles et al., 2004). One of the ways that teachers can boost students' eagerness in offering possible solutions to an open-ended question is through using pictures (Bragg & Nicol, 2011). In addition, Bragg and Nicol (2011) defined an open-ended question picture, which is a familiar picture or photograph accompanied by one or more open-ended questions. They also pointed out that teachers may use an interactive whiteboard and projector to show a large picture on the screen, or printed papers for written questions. Elia and Philippou (2004) explained four functions of pictures in mathematical problem solving those are decorative (only for additional

decoration that is not related to solution of the question), representational (representing the whole part of questions), organisational (giving direction for supporting the solution procedure), and informational (providing essential information for answering the question).



What could be the next layer around? Now lay the tiles – were you right? What else do you notice?

**Figure 1. The example of an open-ended question picture (Primary Team Maths Resources, 2014, p. 2)**

### **1.3. Students' responses**

After a teacher asks a question, students will respond to the question by giving answers (Graciano, 1998). Muir (2009) classified students' responses into explanation, sharing, justification, challenge and answer/response. The explanation is different to sharing because students are required to explain their answer or strategy. Justification refers to when students elaborate their explanation, usually occurring when responding to a probing question. The challenge category is given by students while they question or challenge the answer. Meanwhile, if students give a brief answer or response, this response would be termed the answer/response category. Explanation and justification closely link to the development of mathematical ideas, communication, problem solving and reasoning skills (Yee, 2002). However, Tanner, Jones, Kennewell and Beauchamp (2005) pointed out that most students answer questions briefly during the questioning activity. Students may respond differently to open-ended and closed questions. They are likely to give a brief answer in response to closed questions, whereas they may criticise and explain their answers when responding to open-ended questions (Cai, 1997). Similarly, Muir (2009) found that open-ended questions can produce students' explanation rather than closed questions. Furthermore, Cai (1997) stated that teachers can encourage students to give a reason behind their answers by asking why and how they get the answer. Through those questions, teachers can also detect students' errors and misconceptions.

### **1.4. Mathematical creativity**

Kwon, Park and Park (2006) found that open-ended questions were effective in fostering students' mathematical creativity because these questions allowed students to apply their own strategy in finding diverse answers that were likely to be novel. Furthermore, Nohda (2000) pointed out that to evaluate students' responses to open-ended questions, teachers can analyse four factors (fluency, flexibility, originality and elegance) which are parts of mathematical creativity. Meanwhile, Silver (1997) only described three parts of mathematical creativity: fluency (the number of different answers), flexibility (the number of strategies to solve the question) and originality (how rare the response is in the set of all responses or the infrequency of the response). Elegance may not be categorised as mathematical creativity, because Nohda (2000) described that elegance is how far a student answers a question clearly and simply. However, clear and simple answers are generally related to common answers that can be produced by the majority of students.

## 2. Methods

This study involved a female teacher who teaches mathematics in a Primary School in the UK to class three that consisted of twenty-seven students (aged 7–8 years old). Data were collected using observation and interviews. The observation was done in one lesson that involved the whole class and aimed to investigate the way the teacher asked questions, the type of questions that the teacher posed and the responses that the students gave. During the observation, a whole-class activity between the teacher and students was audio-recorded and notes were also taken. The audio-recording was transcribed after the lesson.

## 3. Results

### 3.1. The observation of one lesson

During the lesson, the teacher asked questions both orally and in written form. However, she posed the majority of questions orally including three open-ended question pictures. The first question (see Figure 2) was asked for reminding students about the definition of angle. The teacher sketched the picture on the whiteboard and then asked students to connect these three pictures to a definition of angle.

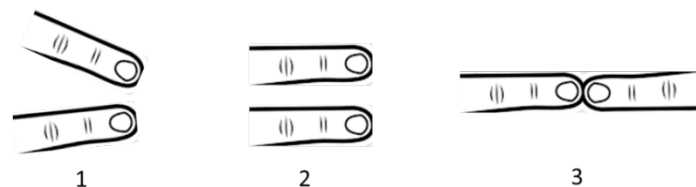


Figure 2. A question about the definition of angle

After some class discussion about the meaning of angle, the teacher posed the next question which she projected onto the interactive whiteboard. She gave a different colour to every shape (see Figure 3) and then asked students some questions related to the picture.

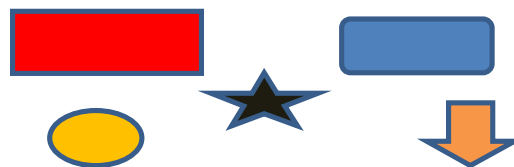


Figure 3. Some different shapes

In the last part of the lesson, the teacher asked students to create a statement based on a given picture on the slide (Figure 4).

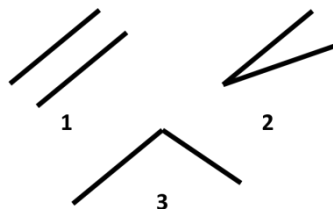


Figure 4. Three different pictures

### 3.2. Teacher’s questioning activity

Based on the observation, the teacher did not use a picture for every question. She only posed three different open-ended question pictures during this lesson on angles. While asking the question, the teacher applied some questioning strategies. She sketched the first question briefly on the whiteboard, while the next two questions were posed orally using projected slides. However, when she used projected slides, the teacher spent less time in asking questions rather than using whiteboard. Furthermore, the teacher tried to involve students in rich classroom discussion by posing those questions orally to the whole classroom so that students could listen to their classmates’ answers and respond to the answer together. She asked the first question (Figure 2) to create a relation among pictures in order to find the definition of angles. After getting multiple answers from students, she asked the entire classroom to conclude the definition together.

T: *So, what’s we are doing yesterday?*

T: *What’s an angle? Think about it, Write an answer on your whiteboard... Can you remember the little sentence we said yesterday?*

T: I have a picture. So you can help me!

T: *Please show your whiteboards!*

S: Different answers [showing their whiteboard]

T: *Let’s say together!*

S: An angle is the amount of turning (1), between two lines (2), that are joined (3)

Furthermore, from one picture, the teacher could produce some questions, both open-ended and closed questions. From the second picture (Figure 3), the teacher could ask 10 questions, while for the third question (Figure 4), she produced nine questions. Some of the questions that she asked can be seen in Table 1.

**Table 1. Some questions produced from the second and third pictures**

| Open-ended questions                       | Closed questions               |
|--------------------------------------------|--------------------------------|
| Can anybody tell me about the sharp point? | What is this (red)?            |
| How about this?                            | What is this (blue)?           |
| How’s about in the middle?                 | What’s rectangle has?          |
| Why is it not an angle?                    | What’s this (black)?           |
| How do they join?                          | Does star have an angle?       |
| Tell me something else about (3)?          | Is there a straight line here? |
| Why is that an obtuse angle?               | Is this has an angle (brown)?  |
| Why is that large?                         | What’s larger? What’s smaller? |
|                                            | What’s picture 2?              |
|                                            | Does it influence angle?       |

Related to questioning strategies, the teacher stimulated students’ thinking by asking follow-up questions to students’ answers. It can be seen from the transcript of students’ answers to the second question from pictures in Figure 3:

T: What is this (blue)?

S: Square

T: It’s not square. *Is it?*

S: A curved rectangle

T: I like the idea, but we don't have a curved rectangle because rectangle has a watch.

*What's rectangle has?*

S: Straight angles, ages!

T: Think about a sharp thing and straight line, *is there a straight line here?*

S: There are two straight lines

T: There are two lines turning and joined. So, *is it an angle?*

S: Yes

This is a transcript of students' answers for the third question using pictures in Figure 4:

T: Please, make a statement based on this picture!

S: *It is not an angle (1)*

T: *Why?*

S: It's not joined

S: Angle because that's joined

T: *How do they join?*

S: Two lines joined together

It appears that the teacher posed additional questions like 'what?', 'how?' and 'why?' in order to get a clearer explanation from students. The teacher also asked students to share and discuss their answers to their partners beside them.

T: Does star have an angle?

S: Yes

S: No

T: *Why? To your partner explain why?* (Discussion for a few minutes)

### **3.3. Students' responses to open-ended question pictures**

Students gave multiple answers to open-ended question pictures. However, it is difficult to see all of the students' answers to the first question because they wrote the definition of angles on their own small whiteboard. In addition, this questioning process was only recorded so that the physical activities cannot be analysed further. During answering closed questions, students seemed only to give a brief answer. Furthermore, they were likely to explain their answers to open-ended questions. It can be seen from the transcript when the teacher asked the second and third questions below:

T: Rectangle has a sharp point. Can anybody tell me about the sharp point?

S: *Doesn't have any corner*

T: Try again?

S: *Angle*

T: Yes

T: Is this has angle (brown)?

S: *Yes*

T: How's about in the middle?

S: *There is no line in the middle*

T: Perfect

T: How do they join?

S: *Two lines joined together*

T: Tell me something else about (3)

S: *3 joined, larger than 2 and 2 smaller than 3*

T: What's larger? What's smaller?

S: *3 larger, 2 smaller*

### **3.4. Open-ended questions produced students' mathematical creativity**

Students' mathematical creativity can be seen from students' answers to open-ended questions. Students produced different answers to every open-ended question so that they had fluency (the number of different answers) in answering the question. However, there were no strategies that students applied when answering the questions because they answered oral questions directly and orally so that they might have limited time to give different ideas. Thus, flexibility (the number of strategies to solve the question) may not be easily found. Meanwhile, for the originality (how rare the response in the set of all responses or the infrequency of the response), the researcher will have to compare the answers among students. Teachers seemed to praise some students' answers, but whether it shows that the idea was rare and original could not be seen clearly.

## **4. Discussion and conclusion**

The teacher asked open-ended question pictures orally and created rich discussion during the learning and teaching of mathematics. She used some questioning techniques when asking the questions like using slide projection that is stated by Bragg and Nicol (2011) as one of the ways of representing pictures to students. The teacher is able to save time when using slides because students can answer the question directly. Furthermore, the teacher uses the pictures not only for presenting the question but also as essential information for answering the question because, without the picture, students will not be able to answer the question. From one picture, the teacher can pose both open-ended and closed questions. When getting an answer from a student, the teacher is seen to ask follow-up questions ('how?' and 'why?') in order to encourage students giving explanations. It seems that the teacher has done three activities during the questioning process, those are asking a question, getting responses, and providing an evaluation or additional questions (Graciano, 1998). However, it may be analysed further the way the teacher develops the question, whether starting with a problem (the teacher decides what problem that she wants to ask, then find the appropriate picture) or starting with a picture in which she finds the picture and then thinks about what the questions are (Bragg & Nicol, 2011). Open-ended questions can be used not only to get longer answers but also to provide an opportunity for students to generate different ideas (Yee, 2002). Despite the fact that open-ended question pictures produce multiple answers from students related to fluency, it may be difficult to look for students' flexibility and originality through a classroom discussion in which the teacher ask oral questions and students also answer orally.

## 5. Recommendations

There are some limitations of this study. During this research, the questioning activity is done orally. Hence, other studies may try to find out the use of open-ended question pictures in written tasks. The way a teacher asks questions is likely to produce different ideas and deeper answers. The researcher should also expand the research methodology in order to collect more data that can be analysed further, especially related to how the teacher develops open-ended picture questions.

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