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Question Generating: Creative Formative Assessment for Metacognition

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Abstract

Here we describe an unusual and versatile formative assessment procedure that provides a wealth of insight into thinking. It has been trialled with secondary students of science in the UK, and with STEM teacher educators in Uruguay.We design a part of a teacher answer, within a specific context, and require participants to create as many questions that could have been asked. As a second stage, we collect the questions, and challenge the participants to rank them in order of content knowledge and/or process knowledge demonstrated. One example of a part answer was: because stars give out their own light. Responses included: a) why is the sun a star? b) how can we count stars? c) what is a star made of? The range of responses to well-developed part answers provides deep insight into participant understanding.Generally, we have discovered that teacher participants provide only a few questions, whereas younger participants provide many. The paper provides many validated answers in STEM for secondary participants, and for teachers. We will also describe a session with Uruguayan STEM teacher trainers learning to use this unusual method in their teacher training programmes. It has also been used with schoolchildren aged from 9 years old upwards.

1. Introduction

This innovative method is open ended and values learners being at different levels. It is a development from White & Gunstone [1]. It goes like this:

'I was in a class when I heard the teacher give part of an answer to a question. From this, construct as many questions as you can that might have been asked. When you have finished, place the questions in a list that reflects the level of knowledge the learner might already have.

With young learners, especially, many potential questions are generated by this open-ended kind of assessment task.. The evidence, in the form of the types of questions generated, can be used to assess depth of understanding and develop metacognition. Peer discussion of the evidence demonstrates different levels of understanding and can provide formative evidence of how the participants are thinking about the topic and their depth of understanding. It could be a disadvantage that it is not targeted at one specific aspect of understanding, but this is offset by the creativity it unlocks as it is used.

This activity can be extended to develop metacognition:

1. After generating the questions ask the students to put them in order of difficulty – such as which is the hardest question to answer?
2. In groups, they discuss the order, does everyone agree on the order?
    - This process activates metacognition – builds understanding of what we know and what we do not.
    - Ordering the questions helps them understand the level of difficulty
    - Collaboration helps build understanding of how different people think as well as thinking critically about the different levels of understanding.

This makes this assessment firmly in the formative fold, rather than summative. There are those who claim they would not use this method because it does not mirror examination questions. We see this as a positive point, since the metacognition produced is rarely assessed by summative assessment, yet we regard it as an important outcome of the formative process. It is too valuable to let slip simply because it may not fit summative assessment criteria. We found that creating part answers that are

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sufficiently broad enough to encourage a variety of questions, yet focused enough to keep responders on topic was a hard part of this method.

2. Examples

Younger learners find this method of working easier than older learners. They generate a larger variety of question types and look at process as well as content. Older learners however tend to look for the one correct answer when in fact multiple reponses are appropriate. However the teacher eduactors found te process very engaging and illuminating helping them see different viewpoints and to think about the content knowledge in different ways.

A full range of examples can be found below. In the Maths context one part answer used was an equation - two experienced teacher educators came up with very different types of questions based on an assumption about the methods for problem solving. They made different assumptions about what type of question that would lead to a particular answer. The illuminating aspect for them was that they had not considered the alternative problem solving method. This led to an insight into why pupils made mistakes within this topic.

3. Findings

STEM teacher trainers in Uruguay (February 2016) consistently noted the challenging nature of the activity, especially in creating multiple questions. They put this down to their normal activity of only creating a single, correct response in class. Their part answers were set at a relatively high level, requiring knowledge at High School or university level. They were easily distracted by attempting to pin down a definition, such as what is amplification, rather than seeing some ambiguity as a valuable asset of a part question. They also tended to focus on just one aspect of a topic, often the most complex aspect rather than seeing the variety of questions that could lead to a single answer. Peer discussion helped reveal the multiple ways of approaching the topic and what teachers themselves viewed as difficult or interesting.

4. Conclusion

We have found that younger learners find this method of working more successful than older learners, and especially teachers, who find it difficult to create multiple suggestions. This could be due a ‘fear of failure’ and concern about producing one best answer, echoing the focus on answering exam questions.Even in Uruguay, where there seems to be much more flexibility than in the UK, the same problem exists, that is teachers search for a unique response, where multiple responses are appropriate. This could be due a ‘fear of failure’ and concern about producing one best answer, echoing the focus on answering exam questions. Nevertheless, the creation of part answers requires teachers to think at different levels at the same time, and to value responses at different levels, not just looking for the right answer. This approach could therefore be valuable in Professional Development courses for developing pedagogic content knowledge and insight into how learners develop under standing and maybe more refreshing than using more traditional approaches. A common problem for teachers especially pre service is undertstanding the progression of ideas within a topic and understanding what others find easy or difficult, there is a tendancy for teachers to assume that everyone thinks as they do. Peer discussion can help broaden understanding in this area.

We propose this method of Question generating as a useful method for formative assessment. It provides insights into the way in which participants are thinking about a content area, giving information about the depth and security of understanding and potentially revealing misconceptions. The emphasis on discussion within the activity helps to build metacognition and encourage creative thinking. Together these are an effective method for developing teachers’ pedagogic content knowledge.

Part of answer	Pedagogy	Some possible questions
Climate change		
1. … because humans are burning fossil fuel.	Promotes the idea of human involvement in climate change.	Why does human activity increase carbon dioxide in the atmosphere? Why are fossil fuels running out?
2. … because we make less carbon dioxide that way.	Promotes thinking about action	Why does using public transport reduce carbon dioxide emissions? Why does using nuclear reactors affect carbon dioxide content of the atmosphere?
3. … because extreme weather events are dangerous.	Promotes thinking about impact of extreme weather events	Why does it matter that we have warmer and wetter summers?
Biology		
4. … because a flower is not usually green	Explores the role of flowers in the attraction of pollinators. Also, points up the need for a plant to have some green parts to make and store energy via photosynthesis.	How does a plant attract insects? Why does a plant need some parts that are green?
5. … because it is a plant	Explores the role of classification of part of living things. Also, could be used to look at plant features, and their roles in ecosystems.	Why is there more grass than cows? What advantage is there for some living things to be green?
6. … because they are different species	Apart from mating and reproduction, this answer looks at issues of classification.	Why cannot cows successfully mate with sheep? Why must pollen for fertilising an apple come from a related apple tree flower?
Education for sustainability		
7. … because humans are causing environmental change	The impact of humans on the environment is at the centre of this answer.	What makes a remote wilderness so different from a farm environment? Why are some fish becoming extinct or in short supply? Why is the earth warming?
8. … because electricity is not readily available everywhere	As well as mechanical questions, this can also relate to accessibility to electrical supply and social justice.	Why are some human groups so reliant on hand machines and methods of agriculture?
Chemistry		
9. … because burning involves both a fuel and oxygen	This emphasises that both parts are essential for burning.	Why does the gas in a burner pipe not burn? Why does oxygen not burn?
10. … because a solution is a homogenous mixture (the same all through)	This distinguishes between such things as solutions and suspensions.	Why are mixtures of gases also solutions? Why is salt solution not a suspension?
11. … because both solute and solvent particles mingle (intermix) during dissolving	This makes the point that both the solute and the solvent are active in the solution process.	How do the particles interact in the dissolving process?
12. … because some solutes	Few solutes dissolve in any	Why is there a limit to

are only partially soluble in the solvent	proportions with a solvent.	solubility?
13. … because reusing is better than recycling	It takes energy to recycle but not to reuse.	How does it cost energy to make a bag from old discarded pieces of plastic?
Physics		
14. … because sound can travel through solids, liquids and gases, but not a vacuum	This answer points to importance of a medium for sound.	Why could we not hear a spacecraft exploding in space?
15. … because power = work/time	At first sight, this could be a simple calculation issue. However, even more complex questions can be generated.	Why is power an intrinsic rather than extrinsic property?
16. … because light can travel through a vacuum but sound cannot	This focuses on a distinction between sound and light.	Why can we see a spaceship explode in space but not hear it?
17. … because it can be reflected	Reflection is itself an interesting property of both light and sound.	Why can a person see themselves in a mirror? How do echoes form?
Earth Science		
18. … because a fossil is evidence of life from pre-human history	In this answer, we could dispel the myth that a fossil has be petrified.	Why is a mammoth footprint a fossil?
19. … because rock can be deformed by an extreme pressure and heat	Is rock a perfect solid?	How are mountains pushed upwards?
20. … because the earth's surface is continually being regenerated	The idea of the earth's surface being a dynamic system is at the heart of this answer.	Why are there fossils of sea creatures at the top of mountains?
Mathematics		
21. … because it simplifies to 2a + b	This is a reverse form of the usual question that requires a learner to simplify.	What is the simplest form of a + a +b? What is the simplest for of 2(a+b) – b?
22. … because it is an integer	This explores the features of an integer?	Why can we count whole numbers?

References

[1] White RT & Gunstone R "Probing Understanding Chapter 10 Question Production" Routledge 1992 Abingdon, Oxford, UK pp158-176