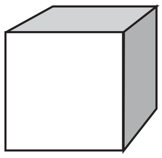
Assessing inquiry learning: How much is a cubic metre?



Kym Fry
University of Queensland
<k.fry1@uq.edu.au >

Kym Fry presents an interesting discussion on the use of an inquiry approach to understand the cubic metre in a year six classroom. Kym uses the PISA assessment framework to understand how her students explored the question "How much is a cubic metre?"

How much is one cubic metre? What are different ways that one cubic metre could be represented, and how could you be sure that this is the actual size? Duckworth (2006) contends that the most wonderful ideas and understandings of children are revealed when adequate time to explore is provided and learning activities are designed to allow conflict and reconsideration of ideas. Textbooks can provide many clever opportunities to build conceptual understanding of one cubic metre. But do we really know what our students understand when they finish these lessons? I thought so, until my Year 6 students completed an inquiry unit on this topic. It was not until they were presented with the inquiry question, "How much is a cubic metre?" that incorrect notions were revealed. It may sound logical to students, after all, to assume that half a cubic metre might look like a space that is half a metre long, half a metre wide and half a metre high. The openness of an inquiry approach to understanding cubic metres presented these students with challenges that conflicted with their own understandings, offering valuable assessment information. This article uses the *Programme for International Student Assessment* (PISA) assessment framework to break down what students learned in this classroom as they explored the inquiry question, "How much is a cubic metre?"

First, an overview of the lessons in the unit is provided. Quality assessment opportunities have been highlighted and where possible, so have links to the PISA assessment framework. Next, the PISA competencies are briefly explained to illustrate a way of thinking about student inquiry learning. Finally, implications for the classroom are discussed.

A mathematical inquiry

Twenty-eight Year 6 students had completed a one week unit of work, supported by a commercial mathematics education series. During this week they had discussed, explored and completed written bookwork on cubic metres as a unit for measuring volume, and how it related to one tonne or 1000 litres. Now students were required to apply their understandings through the inquiry unit. Many examples of classroom units can be found that pose the questions of "How much…?", "How big…?" or "How many…?" which use a mixture of direct teaching and investigative approaches. These lessons were planned using an inquiry approach to teaching mathematics—a teacher-guided approach that uses open-ended and ambiguous questions to challenge students and immerse them in a complex mathematical problem. The approach reflects cycles of exploration and learning between phases of discovery, devising plans, developing plans to solve mathematical problems and defending solutions using mathematical language (Allmond, Wells & Makar, 2010).

Lesson 1: Self-assessment

After reviewing test results from the book unit exploring cubic metres, I asked students to indicate their level of confidence in using and understanding cubic metres (relating to one-thousand litres and one tonne). Traffic light cards are a formative assessment technique described carefully by Wiliam (2011) for students to self-rank their levels of understanding of a particular topic. Each student possessed a named red, orange or green laminated card of which they selected one to hand in at the end of the lesson; a green card indicated a sound or clear understanding and a red card indicated that further assistance was required to understand this topic. I used this information to sort children into groups of three of mixed ability, where there was a 'green' and 'orange' student in each group to support a 'red' student.

Assessment Opportunities

Reviewing test results, offer feedback about strengths and weaknesses to students.

Traffic light cards enable students to give feedback to the teacher about their levels of confidence on a topic.

Lesson 2: Discover

An aim of the Discover phase of learning in inquiry is to attempt to 'hook' the students into the content to be explored. In this lesson the mathematics required to solve the problem was foregrounded and the students' prior knowledge activated. Students were presented with four hinge questions (Wiliam, 2011) about measuring volume to answer individually in their learning journal (Figure 1).

I used this information to quickly confirm who demonstrated correct understandings of the concept of cubic metres. Answers were also kept by the students for comparing to their understandings at the end of the unit of work. Discussion of responses led to the introduction of the inquiry question and students were grouped together to discuss how they might begin to answer the question.

Assessment opportunities

Using hinge questions for 'range-finding' quickly lets the teacher know who already understands the topic, and can be used by students to compare to their understandings at end of the unit of work.

Link to PISA

Responses to hinge questions: opportunity to look for evidence of the use of PISA competencies (Table 1).

Lesson 3: Devise

Next, the task requirements (Figure 2) and expectations were made explicit.

Your task is to answer:

How much is 1 m^3?

You need to show:

- the cubic metre you make,
- how you made the cubic metre,
- how you worked out it is one cubic metre, or how you know it is one cubic metre.

Figure 2. Inquiry task given to students.

Q. What units do you use to measure the volume of solids such as the amount of sand in a sandpit?

Q. Which is heavier: 1 t of feather or 1 t of bricks? Explain your answer.

Q. Write a story problem to match the answer: 1 m^3

Q. Really big things – how much do they weigh?

Figure 1. Hinge questions to gauge the range of understanding about the unit's big ideas.

Link to PISA

Collaborative responses on A3 sheet of paper: opportunity to look for evidence of the PISA competencies (Table 1).

Assessment opportunity

Joint construction of criteria shares and clarifies learning intentions and success criteria (Wiliam, 2011).

Students collaborated by sharing their ideas about the task and recording agreed ideas on a common A3 sheet of paper. These ideas would become ‘Plan A’. Criteria describing the possible complexities of different solutions were agreed upon and it was decided that if the cubic metre made was 1 m × 1 m × 1 m then this would not reflect a Year 6 standard; students were asked to offer more complex examples to demonstrate their depth of knowledge in this area. Students needed to consider where in the real world cubic metres were used or were useful, and to reflect on how they would represent their own cubic metre.

Lessons 4 and 5: Develop

Assessment opportunities

Sharing successes and challenges provides feedback to students about effective pathways to choose.

The teacher is able to capitalise on these teaching moments to guide learning towards the learning goals.

The Develop phase is more than just an implementation phase; students put their plans into action. In these lessons, student thinking was challenged when plans did not work perfectly and satisfying solutions were not reached. Sharing successes and challenges with the whole class was fruitful as previously unthought-of pathways were shared and explored. Student plans could be changed when ideas were challenged. Students were generally moving around the classroom as they accessed models and resources and worked together. I also roamed and conferenced with students to guide thinking where necessary. In these lessons students used a quickwrite (Dodge, 2009) strategy to record their reflections. This involved a timed, two-minute written reflection including their own questions, reflections and ideas about the topic, or predictions for the lesson ahead. Students kept these in their learning journal as a record of their learning. Next, students needed to be ready to defend their solutions.

Assessment opportunity

Quickwrites offer insight into student thinking and do not require intensive marking!

Link to PISA

Quickwrites: opportunity to look for evidence of the PISA competencies. (Table 1)

Lesson 6: Defend

Now in the Defend phase, students justified and communicated their solutions with others in the class. Already established expectations about the use of mathematical language and representations, as well as the complexity of solutions, were reviewed. Decisions made were also defended as students compared and judged the effectiveness of how they and others attacked the problem.

Assessment opportunity

This final phase of learning may offer an opportunity to collect summative information. Consider this part of formative assessment when students use ideas learnt in their next inquiry unit of study.

Link to PISA

Presenting solutions: opportunity to look for evidence of the PISA competencies (Table 1).

The PISA assessment framework

PISA is an international evaluation (more than 70 economies) of the knowledge and skills of 15 year-old students. In mathematics, it acknowledges the importance of application to real-life situations; test questions are embedded in meaningful and authentic contexts that aim to make mathematics relevant. The PISA (OECD, 2009) mathematics assessment framework was provided to describe and illustrate assessment and used by the author in this study. Elements of PISA's definition of mathematics are synonymous with inquiry as emphasis is placed on an understanding of the role of mathematics in the world and how an individual uses mathematics to engage as a "constructive, concerned and reflective citizen" (p. 84). PISA identified eight competencies required by students to engage successfully in mathematisation (Table 1).

Each competency is further able to be possessed at different levels of mastery: at a reproduction level, making connections level, or working at a level involving reflection. The three levels of mastery which organise these competencies reflect conceptual categories of broadly increasing cognitive demand and complexity, summarised below in Figure 3. Described as clusters, they can be used to describe the cognitive activities students undertake when completing mathematical problems.

As a classroom teacher I had become frustrated with how traditional assessment had previously been inadequate in describing the learning of students in inquiry. In combination (Table 1), the competencies and clusters held promise as a design framework for understanding assessable information from inquiry. This provided criteria for identifying whether students were demonstrating basic mathematical competencies (Reproduction cluster) as commonly required on standardised assessments and classroom tests, or reflection and insight (Reflection cluster) to solve complex problems.

Table I. PISA Competencies which are required to engage successfully in mathematisation (OECD, 2009).

Competency	Description	Levels of mastery (Reproduction, Connections, Reflection)
Thinking and reasoning	Posing mathematical questions and knowing the kinds of answers mathematics can offer.	
Argumentation	Using mathematical proofs and reasoning and creating and expressing mathematical arguments.	
Communication	Expressing oneself mathematically, orally and in writing as well as understanding the conceptions of others.	
Modelling	Structuring, interpreting, communicating, analysing, working with, critiquing and validating mathematical models in terms of reality.	
Problem posing and solving	Posing, formulating, defining and solving mathematical problems in a variety of ways.	
Representation	Representation of mathematical objects and situations, according to situation and purpose.	
Using symbolic, formal and technical language and operations	Using mathematical symbols, formal language and operations to solve equations and undertake calculations.	
Use of aids and tools	Knowing about and using mathematical aids and tools, including information technology tools, to assist mathematical ability.	

Mathematical Literacy		
The reproduction cluster	The connections cluster	The reflection cluster
• Standard representations and definitions • Routine computations • Routine procedures • Routine problem solving	• Linking real-world and mathematicalrepresentations and structures • Standard problem solving • Translation and interpretation • Multiple well-defined methods	• Complex problem-solving and posing • Reflection and insight • Original mathematical approach • Multiple complex methods • Generalisation

Figure 3. PISA competency clusters to assess mathematical literacy (OECD, 2009, p. 115).

Implications for the inquiry classroom

Learning through inquiry can be difficult to assess when using assessment methods which track linear progress and emphasise an acquisition of skills, facts and procedural knowledge in isolation. There is potential in inquiry to provide rich insight into student learning yet little is known about how to better understand and describe what or how students learn. I used my knowledge of the PISA assessment framework to analyse student work which provided a more flexible way to articulate and understand the cognitive levels the students were working in, providing some direction in how to push their reasoning beyond those experiences. The framework also allowed opportunities to formatively assess my own teaching and to offer feedback to students that was meaningful, guiding them further in their inquiry. The PISA assessment framework challenged me as a teacher to challenge students to move away from lower-order thinking processes of posing and solving familiar and practiced problems (Reproduction cluster); to instead apply problem-solving processes, knowledge and skills to situations that are not routine (Connections cluster); or with an element of reflection, inventiveness and the challenge (Reflection cluster), to solve complex problems that may be more unfamiliar, such as in inquiry.

This framework may not be as useful in a single unit to provide fast turn-around of feedback as recommended by Furtak and Ruiz-Primo (2008), yet understanding and applying this framework to several inquiries over time may begin to inform a bigger picture of the competencies students develop when learning mathematics through inquiry, as part of a balanced approach to teaching mathematics. Combined with traditional mathematics assessment that may already exist in the classroom, the PISA framework could be useful in offering a broader view into, and a language to describe, the mathematical minds of students. It is wonderful to see how inquiry can support those competencies and higher-order thinking skills considered essential by PISA to being a successful mathematician, which in turn supports the use of the inquiry pedagogy in mathematics.

References

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