
**ASSESSING LEARNING FROM MATHEMATICAL INQUIRY: CHALLENGES FOR STUDENTS, TEACHERS AND RESEARCHERS**

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Inquiry approaches (e.g. open-ended questions, investigations, thought experiments) are advocated in mathematics because they engage students and suit a range of student capabilities. They also provide authentic opportunities for teamwork and co-construction of knowledge. Hence, although mathematical knowledge is essential in an inquiry approach it is not sufficient. Through practical examples, this paper will explore various types of inquiry tasks and the implications for assessment.

Inquiry approaches are strongly advocated in mathematics education to provide opportunities for a diversity of learners to engage in interesting and challenging tasks (Henningsen, & Stein, 1997; Stein, Grover, & Henningsen, 1996; Sullivan, 2001). However, inquiry approaches require substantial changes to teaching and assessment (Baroody & Coslick, 1998). The purpose of this paper is to explore assessment that has been used with various types of inquiry-based tasks and to explore the assessment challenges that inquiry tasks provide for students, teachers and researchers.
Inquiry-Oriented Tasks and Assessment

Inquiry tasks are designed to challenge students and engage them in “doing” mathematics. The appropriate level of challenge is important to provide adequate opportunities for learning and high level thinking and reasoning (Henningsen & Stein, 1997; Stein, Grover, & Henningsen, 1996). Challenge and inquiry are interrelated because the cognitive value of a task resides in the opportunity that it provides for students to explore and solve a problem (Hiebert et al., 1996). The opportunity for exploration and problem solving emulates the work of mathematicians and is evident in various forms of inquiry tasks including open-ended tasks (e.g., Sullivan, 2001), mathematical investigations (e.g., Brahier, Kelly, & Swihart, 1999), and thought experiments (e.g., Simon, 1996). Examples of these types of inquiry-oriented tasks and the associated assessment. Assessment can be used to determine a student’s preparedness to engage in an inquiry task, to monitor performance on relevant aspects of engagement during the task (e.g., communication), and to benchmark and establish mathematical performance. Teacher assessment can be formal or informal. Additionally, students can engage in self-assessment.

Open-ended tasks and Formal Assessment

Open-ended questions should challenge students, support concept and skill development, encourage creativity and cater for students with varying mathematical competencies (Sullivan, 2001). An example of an open-ended question is: How would you measure a puddle? (Whestley, 1994). Open-ended tasks, such as this, can be assessed using a rubric because it provides a judgement of the mathematical power of the student (Cai, Lane, & Jakabcsin, 1996; Taylor & Bidlingmaier, 1998). The essential features of rubrics are evaluative criteria, which are used to distinguish between acceptable and unacceptable responses on particular criteria; quality definitions, which describe performance at various levels; and a scoring strategy (Popham, 1997). For example, the rubric that a group of teachers used to assess their students’ performances on the “Puddle Problem” comprised descriptions of various levels of performance and exemplars of students’ work (Whestley, 1994, p. 12) (See Table 1). The students’ work was scored as one of four levels ranging from “low” to an “exceptional” level of performance. Student 1’s answer was categorised as a “low response” because he demonstrated limited understanding of the concept of measurement (See Figure 1, LHS). In contrast, Student 2’s response was rated as an “exceptional response” because she indicated a range of possible measurements, including a novel way to measure the mass of the puddle (See Figure 1, RHS). The teachers discussed responses that could not be easily rated at one performance level until a consensus was reached. However, despite this difficulty, teachers appreciated the utility of rubrics for assessing open-ended tasks.

<table>
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<th>Performance Levels</th>
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<tr>
<td><strong>Low Response</strong></td>
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<tr>
<td>Measurement methods proposed are extremely simple or are unclear or unworkable. Explanation is limited and may reveal basic misconceptions about measurement.</td>
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<tr>
<td><strong>Medium Response</strong></td>
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<td>Measurement methods are fairly clearly presented; they tend to be the most obvious choices. Explanations are adequate, with limited details.</td>
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<tr>
<td><strong>High Response</strong></td>
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<td>The measurements and tools are clearly presented and may include some original ideas. The response shows a good understanding of the problem. Explanations are clear and include some detail.</td>
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<tr>
<td><strong>Exceptional Response</strong></td>
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<tr>
<td>The methods for measuring go beyond the most obvious to include some strategies that show original thought or sophisticated thinking for the grade level. The response reveals an ability to think through a complex problem. Explanations are clear and effective and include relevant details.</td>
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Investigations and Informal Assessment

An investigation is an extended mathematical exploration that is often embedded in a focus question and draws on multi-dimensional mathematics content (Baroody & Coslick, 1998; Brahier et al., 1999; Greens, 1996; Lappan & Briars, 1995). An example of a mathematical investigation undertaken by young children was their explorations of the numerical contents of small, white, translucent, sealed (film) cans filled with Smarties. After predicting the numerical contents of the can, the students opened it and labelled it with the number of Smarties. The cans contained between 19 and 24 Smarties. All the cans were then arranged in a number line and the students were asked to predict how many Smarties were in a similar sealed can. Students were asked to indicate whether they predicted there w ould be less than 19 Smarties, more than 24 Smarties or between 19 and 24. Eddie predicted the number was 13 but was unable to explain why. Eddie’s inability to explain his prediction alerted the teacher to his possible lack of reasoning about quantity. She encouraged Eddie to articulate his answers and continued to monitor his thinking. Additionally, she provided opportunities to challenge Eddie’s mathematical thinking about quantity.

Thought Experiments and Self-Assessment

Thought experiments involve students exploring a particular line of thinking without the use of physical resources (Simon, 1996). Such experiments underpin the design of a plan to be implemented, the articulation of the chain of thinking that leads to a particular conclusion, and the capacity to envision and critique another’s plan. For example, prior to the commencement of a 10-week inquiry program, the students made a plan for the following Piggy Bank task (Brahier et al., 1999).

Make a plan of how you could work out the amount of money in the piggy bank if you are not allowed to open it.
The students were encouraged to use written and pictorial representations to depict their plans. At the conclusion of an inquiry program, the students were re-presented with their initial plans of the Piggy Bank task, which had been typed up and presented without pictures in order to disguise the authorship. Students were given their own disguised plan and asked to explain whether this plan would work and justify their response. The students were not provided with any physical resources, and hence, had to run a thought experiment and mentally test their initial solution plans (Simon, 1996). Many students were able to identify flaws in their initial plans. For example, one student was able to identify specific flaws in her initial plan related to the size of the slot in the piggy bank and the type of coins that were likely to be in the piggy bank. Self-assessment provides for the demonstration of critical thinking and has metacognitive value in the planning stage of an experiment.

Conclusion

Inquiry-oriented tasks present assessment challenges for students, teachers, and researchers. In an inquiry approach, students need to take responsibility for monitoring and critiquing their thinking and the thinking of peers. They also need to be able to explain their ideas and justify their critiques. Thus, even from an early age students need to be challenged and supported to assume some responsibility for their role in assessment. Teachers also face challenges in identifying and using appropriate assessment tools and techniques that are consistent with an inquiry approach. Ideally, assessment should inform teachers how to design and plan instruction to suit the needs and strengths of their class. The final challenge is for researchers. Without an adequate theory base that focuses on teaching and assessment, it is unrealistic to expect that teachers will be able to identify how students’ performance is enhanced through an inquiry approach.

References

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