Chapter 9
Issues in Teaching for and Assessment of Creativity in Mathematics and Science

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Introduction

Creativity is increasingly highlighted on education agendas. Internationally, mandated curricula explicitly include calls for creativity. For example, Scotland's 'Curriculum for Excellence' talks of 'successful learners' who are able to 'think creatively' (Scotland Curriculum Review Programme Board and Scotland Scottish Executive 2004) and Finland has 'competitiveness, creativity, and social justice' as central curriculum aims (Hargreaves et al. 2007). Even nations known for having traditional curricula, such as Japan, Singapore and Korea, are raising the profile of creativity (Park et al. 2006; Schwartz-Geschka 1994; Tan 2000).

The recently introduced Australian National Curriculum is typical, with one of the stated three overall aims being the development of 'confident and creative individuals' (Australian Curriculum Assessment and Reporting Authority [ACARA] 2011a, b). Drilling down into the curriculum details finds creativity repeatedly emphasised. The list of general capabilities for learners to develop as set out by ACARA reiterates the overall aim through the inclusion of 'critical and creative thinking'. At the detailed level of curriculum content, the specifications both for mathematics and for science each again explicitly stress creativity, calling for 'confident, creative users and communicators of mathematics' (ACARA, 2011a, p. 1), and the science curriculum reiterates science as providing the opportunity for learners to 'develop critical and creative thinking skills' (ACARA, 2011b, p. 1).

Calls for creativity within mathematics and science teaching and learning are not new, but having them enshrined in mandated curricula is relatively recent. Despite, however, such curriculum aims and claims from research for the importance of encouraging creativity in science and mathematics, evidence still points to teachers

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treating the curriculum, particularly for science and mathematics, as a body of fixed knowledge to be delivered and students relying on rote learning and recall (imitative) methods, particularly in mathematics (Hiebert et al. 2003). If creativity is an important learning outcome, then why is the focus in schools still largely on the transmission of facts and the drilling in procedures?

Craft (2000) sums up the tensions in teaching, in being caught between 'soft' skills such as creativity that are seen as necessary for dealing with change and uncertainty and 'hard' skills that are the core of centralised prescription for teaching and assessments:

> If we look at creativity in education, then, we see a need, on the one hand, for teachers to become increasingly experts in fostering creativity and, on the other, an attempt to crush all artistry from the profession and to reduce teaching to a technicist activity. (p. 146)

Jackson (1986) distinguishes between education that is *mimetic*, based on predetermined and measurable content, and the *transformative*, which attends to developing qualities such as values or attitudes. Transformative education means learners are more likely to use maths and science concepts in meaningful ways in their lives outside school (Boaler 1993; Pugh 2004). Despite this, teachers and educational systems are 'more likely to ask questions like, "Do students understand the concepts correctly?" than "Do the concepts make any difference in the students' everyday, out-of-school lives?"' (Pugh and Girod 2007, p. 10).

In this chapter, I examine why calls for creativity in science and mathematics learning and teaching seem so difficult to bring about and the role that assessment may play in promoting creativity. I begin by defining creativity in general and specific aspects of it in mathematics and science. I briefly consider current external assessments and whether or not they suppress or encourage teaching for creativity. I then argue why tests are not appropriate for assessing creativity and how performance tasks are a productive way forward, particularly if supported by holistic assessments and dynamic standards.

While the focus in the main is on looking at the arguments in relation to mathematics, I hope that readers from a science background will be prompted to consider how similar issues hold for science education.

Defining Creativity

Broadfoot (2002) argues that a difficulty in defining standards for attainment arises from 'the failure to locate the search for standards—an assessment challenge—within an appropriate conception of learning itself—a curriculum challenge' (p. 158). The assessment challenge—what assessing creativity might look like—thus cannot be examined until after addressing the curriculum challenge of how to conceive of creativity within mathematics or science classrooms.

One problem is that there are as many definitions of creativity as there are theorists writing about it: in a review of the literature, Treffinger (1996) identifies over

100 different definitions. However, one defines creativity, explicitly or implicitly, will impact upon teaching and learning. There is not the space here to examine the range of definitions and their implications. Instead, I start with this definition:

> Creativity involves intentional imaginative activity producing locally novel and valued outcomes. (Adapted from National Advisory Committee on Creative and Cultural Education [NACCCE] 1999)

I chose this definition because it encapsulates several core ideas. First, although creative activity may involve imagination in considering possibilities, creativity has to go beyond imagination and involve some sort of external output (Robinson 2001). Creative outcomes are usually thought of in terms of some sort of (semi)permanent product but can also include performances, in the broadest sense of that word: learners orally justifying a mathematical conjecture or speculating on a scientific explanation can be thought of as being creative. As Sawyer (2006) points out, the creativity behind performance is even less studied than that behind products.

Second, creativity arises from intentional activity. Without intention, accidental outcomes can come to be seen as creative output. Even outputs that are presented as though they were the result of accident, for example, Jackson Pollock's paintings, turn out to be carefully planned and intentionally executed.

Third, outcomes of this intentional activity need to be novel; otherwise, the activity is reproductive rather than creative. Including 'novel' as a criterion can lead to arguing that school learners cannot be truly creative (in science or mathematics at least) as they are unlikely to advance these disciplines by producing anything novel (Csikszentmihalyi 1996). Others take the position (as I do) that novel can be interpreted as novel to someone, somewhere at sometime. So although the outcomes of creativity in science or mathematics classes may not be novel to experienced scientists or mathematicians, from the perspectives of the learners, they can be judged as novel and hence as creative. This distinction between the creativity that moves a discipline forward and the creativity that produces locally novel outcomes is denoted by some as the difference between Creativity and creativity (Craft 2000). Big C Creativity is associated with 'great works' by experts in contrast to the more everyday small c creativity that might arise when a student creates a solution to a novel problem or connects together two seemingly disparate ideas. Small c creativity moves creativity away from being something that only the few are capable of to being something all learners can engage in (although a substantial amount of the writing on creativity in education is still located within the 'gifted and talented' literature; see, e.g. Treffinger et al. 2002). Herein lies a first difficulty in assessing whether or not learners' outcomes are creative: how to decide whether they have produced things which, although possibly familiar to the teacher, are novel to the learner, or whether learners are reproducing ideas that they have previously encountered. I return to this question of 'novel to whom?' later.

The fourth aspect of creativity is that there has to be some value to the outcome. The value of a solution to a mathematical problem is largely down to whether or not the solution is correct, while considering the difference between two solutions in terms of creativity brings into play such considerations as 'elegance' or 'economy'.

Similarly in science an explanation needs testing out and would also be looked at in terms of the breadth of phenomena for which it can account. The inclusion of value in the definition makes creativity 'fundamentally and unavoidably social' (Sawyer 2006, p. 122). This is important in challenging the view, still popularly held, that creativity is an attribute of individuals. As most of the literature on creativity comes from psychology, the individualist view of creativity still tends to be dominant with sociocultural explanations still in the minority. Vygotsky (1971) acknowledged this many years ago (although sadly only with regard to art!): 'Art is the social within us, even if its action is performed by a single individual, it does not mean that its essence is individual' (p. 249).

One obvious implication of the definition for creativity provided above is that the outcomes of creative activity cannot be fully predicted in advance. This may be one reason why teachers shy away from lessons that involve creative activity as they cannot predict and control the outcomes. And if teachers expect to be able to produce assessment criteria in advance of student activity, then this adds to the view that creativity cannot be assessed. As I shall argue later, this need not be a deterrent to assessing creativity.

Creativity in Science and Mathematics

While the shift from big C Creativity to little c creativity allows teachers to accept that even young children can be creative, a barrier to teaching mathematics or science for creativity and consequently with assessing creativity is the view that these disciplines do not lend themselves to creative endeavour. Robinson's (2001) four-phase model of the creative process provides a framework for thinking about creativity in these disciplines:

- The importance of the medium
- The need to be in control of the medium
- The need to play and take risks
- The need for critical judgment (p. 111)

Importance of the Medium: This draws attention to the fact that creativity is context bound. Psychologists no longer hold to the idea of creative individuals in the sense of possessing a general talent or disposition that they can apply to many contexts. If we want students to be creative in mathematics or science, then the opportunities for that to happen must be made within the mathematics and science lessons. Ways to assess this creative activity must also be developed so that teachers can help learners become more creative within these subjects.

Being in Control of the Medium: This could be taken as support for the argument raised earlier that since young learners cannot be considered to be in control of the medium (be it mathematics or science), then they cannot be capable of creativity activity. One could also argue, however, that the breadth of the disciplines is such that no mathematician or scientist now could ever consider themselves to be in (total) control of the medium and so creative activity cannot be engaged in by anyone. I prefer to think of control here in the sense of control of parts of the medium. In other words, students can demonstrate creativity in the parts of the curriculum of which they have gained control. Young learners have control in this sense: once confident in adding pairs of numbers, they can look for patterns in working with odds and evens and create and test conjectures about patterns they have noticed.

Assessing such creativity requires teachers to disentangle the content that is being played with from the creative processes. Teachers are often most interested in assessing content that they have recently taught, yet research shows that this may not be the content that learners can use creatively. Students in the later years of secondary school, for example, displayed a 2-year gap between being taught some mathematics and being able to apply it (Bell et al. 1983). If we assume that learners are in control of the medium too soon after meeting particular content, then they are unlikely to display creative activity, but this should not be taken as an indication that they cannot be creative.

The Need to Play and Take Risks: Being creative often involves failing or getting things wrong. These are qualities that are often absent from mathematics or science lessons. The measures of success in mathematics that learners pick up on are speed and correctness, neither of which is conducive to playing and taking risks. As Edwards and Mercer (1987) showed in science lessons, students' observations or explanations that did not fit with expected outcomes were often reconstructed to fit with teachers' desired outcomes.

The Need for Critical Judgement: This is linked to the point that creative outputs need to have value. It is often assumed that it is the teacher's role to decide on the value of learners' creative output but opening up the validation to the class could benefit all learners. The work of Cathy Fosnot and colleagues in the 'Young Mathematicians at Work' programme (e.g. Fosnot and Dolk 2001) has many examples of even young learners engaged in dialogue about each other's solutions to problems and going beyond simply judging whether or not these are correct, as they develop their critical judgement. In assessing creativity, self and peer evaluations may be core.

Spaces for Creativity in Science and Mathematics

In science, Newton and Newton (2009) offer suggestions for (at least) four types of creative activity. The first two are encapsulated within the theme of making sense of the world scientifically and in learners constructing either descriptions of or explanations for phenomena. The second two sources of creative activity arise from collecting and evaluating evidence and then constructing either means of gathering descriptive data or ways to test explanations. Newton (2010), drawing on the work of Klahr and Dunbar (1988), further describes generating explanations as working in 'the hypothesis space' and testing these as working in 'the experiment space' (p. 188). As an exemplar of these, Newton offers the task of exploring what happens when dropping a wooden metre rule onto the floor. The question raised, ‘What does the ruler bounce?’ engages learners in creative activity in the hypothesis space, with a move into the experiment space in testing out their hypotheses.

I suggest that parallels to the hypothesis space and experiment space in mathematics education are ‘the conjecturing space’ and ‘the justifying space’. Children exploring number patterns may notice that the sum of two odd numbers is always even and, rather than taking this as a mathematical ‘fact’ established on the basis of only a few examples, be encouraged to frame this as a conjecture: ‘the sum of any two odd numbers will always be even’. Children enter the justifying space in creating convincing arguments for whether or not they consider their conjecture to always hold true. Different levels of ‘justifying’ in this example could include checking the conjecture with several more examples; taking an extreme case of two very large odd numbers and showing their sum is even; proving the conjecture by arguing that any odd number is made up of an even number plus one, so adding two odd numbers involves adding two even numbers plus the two ‘ones’ which must be even.

As pointed out earlier, the content of the learners’ creations in these hypothesis/experiment or conjecture/justify spaces has to be considered independently of whether or not it is correct, but in terms of whether or not it might be judged as locally novel and creative. Boesen (2006) sets out a model elaborating mathematical reasoning, making a distinction between ‘creative reasoning’ and ‘imitative reasoning’. Creative reasoning displays elements of being novel, flexible and plausible (which does not mean that it is necessarily correct) with a mathematical foundation. In contrast imitative reasoning involves either recall of reasons, when a complete answer is remembered, or algorithmic reasoning, when a solution procedure is recalled and applied. Helpful though this distinction is, it does not get us round the insider-outsider issue (Newton 2010). As an outsider to the children’s world, how can a teacher assess whether the learner’s output is new and novel to the (insider) child and not a reproduction of something from elsewhere? Is the learner presenting an argument for why the sum of two odd numbers must be even displaying mathematical creativity or sharing something learnt from elsewhere? In science, Newton (2010) found that pre-service teachers were inclined to rate a student’s answer as more creative when the answer fitted with the correct explanation, even when it was clear that the student was reproducing something they had previously learned rather than constructing an explanation.

Assessment and Creativity

I have argued so far that calls for more creativity in mathematics and science lessons involve being clear what creative activity in lessons in these disciplines might look like so that we can then begin to think about ways of assessing learners’ creative outputs. But can this argument be turned on its head and assessment itself used as a lever for bringing about changes in classroom practices? So before discussing what assessing creativity might look like, I briefly explore whether current assessment practices, particularly external assessments support or inhibit creativity. I look first at the argument that assessments, and in particular, external assessments (i.e. national or local assessments not chosen or devised by teachers themselves) have a narrowing effect on teaching and learning and drive out opportunities for creativity in science and mathematics. I then look at research that raises questions about whether assessments that do value creativity can in and of themselves encourage teaching for creativity.

Assessment as a Barrier to Creativity

Those arguing that assessment has a narrowing effect base this on the claim that current assessment techniques favour certain learning outcomes, in particular those outcomes that are easier to assess and which tend to be based around recall and application of procedures. If this is the case, then teachers in the knowledge of what will be assessed focus their energies on 'teaching to the test', and students' awareness of the sort of assessments they are going to encounter impacts both on what and how they learn (Gipps 1994; Sadler 2002). Recall and procedures come to dominate lessons as these are what are going to be valorised through assessment, effectively sidelining other, possibly more valuable, learning outcomes. Even if the intended curriculum includes statements about the importance of creativity, the implemented curriculum comes to focus on outcomes that are more easily assessed, even if these are less educationally valuable.

Nevertheless, it is important also to ask whether it actually is the case that national assessments have a focus on recall and imitative reasoning. The item in Fig. 9.1 is adapted from England's national mathematics test for 11-year-olds and demonstrates how assessments that may look, on the surface, as assessing recall or procedures can have more to them.

At first glance this assessment item appears to simply assess recognition of fractions, but it is more challenging than that. It is unlikely that children will have met the noncanonical representation of a third in the first diagram. In reasoning out an answer, children have to coordinate the information presented in the diagram with the worded direction as to what the unit is and conclude that, despite two of the 'thirds' represented in the first diagram being recreated in the second, the fraction shaded is still 1/3. Teaching to such test items is not simply a matter of practising old papers in the knowledge that similar questions regularly appear over the years. The national tests in England have a preponderance of such items that are not easily answered by recall or application of memorised procedures. Yet despite this, there is still much talk of teachers 'teaching to the test' and how the national tests prevent teaching focusing on reasoning or inquiry.

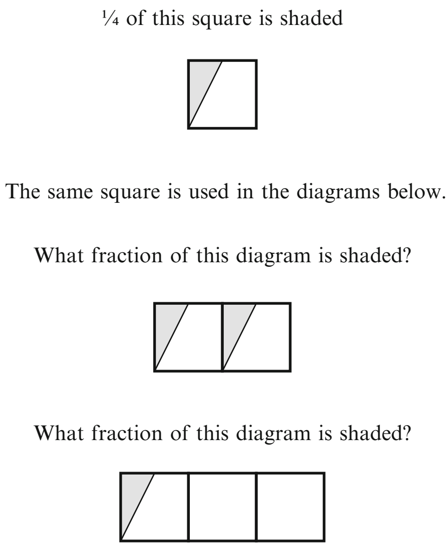

Fig. 9.1 A test item that assesses more than recall or procedures (Adapted from England's national mathematics test for 11-year-olds)

Assessment as a Lever for Change

Is it possible that introducing new forms of external assessment that explicitly attend to the spaces of hypothesis/testing and conjecture/justify could act as a lever to encourage teaching for creativity? While shifting assessments in that direction is no doubt a good idea in and of itself, as Boesen's (2006) research shows the evidence that this will be a strong force for change to teaching is less clear.

Boesen (2006) was one of the team of national assessment developers in Sweden devising assessments with an emphasis on 'reasoning, modelling, generalising, communicating and the ability to critically examine things' (p. ii). In subsequent research he examined teachers' construction of assessments to see if the teachers had included items that might require reasoning. In line with other findings, the majority of teacher assessments focused on tasks that required only 'imitative reasoning'. Teachers' exclusion of tasks requiring higher-order thinking was not, as might be expected, due only to teachers' lack of awareness of the need for such tasks, but was also because of their deliberate intent not to include them. The teachers made this decision to exclude tasks requiring non-imitative, creative reasoning tasks on the grounds that they believed such tasks to be too difficult for most students to deal with. Assessment tasks were chosen to get as many students gaining pass grades as possible and, particularly for lower attaining students, the teachers thought this to be more easily achieved with items requiring recall rather than reasoning. This points to the importance of teachers' beliefs about the nature of learning and learners in mediating whether or not teaching provides space for creative endeavour. It also suggests that teachers' views on creativity fit with the popularly held perception of creative activity being something that only a small group of learners are capable of engaging with.

Boesen (ibid.) suggests that another possible reason for this mismatch between the intent of assessments and teachers' perceptions of the nature of the tests may be a consequence of teachers not being privy to the thinking involved in the test development. Thus, although tests may be designed with the intent of promoting reasoning and creative thinking, without professional development that helps teachers come to appreciate it, the reform intentions may not succeed.

Assessing Creativity

Treffinger and colleagues (2002) suggest four ways to assess creativity: behaviour or performance data, self-report data, rating scales and tests. I think there is a category error in including rating scales in this list, as this is a way of grading the results of assessment not a form of assessment itself. I shall argue that self-report data is best considered within making judgements and therefore look at tests and performance data.

Tests

As indicated in the discussion above, test items can indeed have an element of assessing creativity built into them, but rather like the argument that because dogs can be taught to walk on their hind legs, they should be taught do so, we have to ask whether, however, well-designed tests are the best means of assessing mathematical or scientific creativity. A particular issue from the literature on creativity suggesting a drawback to the use of tests is the time-bounded nature of traditional testing.

The 'eureka' moment of quick and extraordinary insight is a popular view of creativity, but creative outcomes are more likely to arise from deep, flexible knowledge in specific content areas and extended periods of work and reflection (Silver 1997). Reflection time leading to creative outputs may be intentional, but it does not always involve self-conscious activity. Craft addresses the issue of 'insight' in the creative act, which has an element of the nonconscious to it, defining insight as 'the ability to build sense making bridges between different experiences and stimuli, and to be able to reflect on these' (Craft 2000, p. 120). Nonconscious aspects of insight, Craft argues, must not be underestimated and given the emphasis on teaching and learning about how things 'should' be, there is a danger of unwittingly blocking the 'non-conscious creative insights of children, given their relative powerlessness in claims on time, space, knowledge and experience' (p. 121). With regard to most testing practices, learners are powerless over time and space as, generally, tests are mandated to be carried out in particular spaces at particular times.

The growing empirical evidence for the power of 'sleeping on it' to promote insight suggests that assessing the insightful aspects of creativity requires a rethinking of current teaching and 'testing' practices. For example, adults participated in what they thought was a test of memory: they were taught a rule for generating a numerical sequence and asked to return a day later and report on whether they could recall the rule. What the participants were not told was that there was a much simpler rule for generating the sequence than the rule that they had been taught. When asked the following day if they could remember the rule, a significant number of the participants spontaneously reported that there was a simpler rule—an insight that they had reached without being prompted to try and find (Stickgold and Ellenbogen 2008).

Performance Tasks

As Treffinger and colleagues (2002) note, there are two potential sources of performance data: from learning in 'everyday' settings (in other words, occasions when creativity might arise spontaneously) and in tasks specifically set up for their potential to promote creativity. As learners creating within the hypothesis/test or conjecture/justify spaces are most likely to encounter these within specific classroom activities, I restrict the discussion here to this second type of data. While there is no shortage of suggestions for the sort of tasks in mathematics and science that might encourage learners to enter these creative spaces, how the teacher sets these up is a key determinant of whether or not the outcomes are creative. An example from my own research illustrates this.

As part of a 5-year longitudinal study of learning numeracy (defined in this case as the number aspects of the mathematics curriculum) in English primary schools, a team from King's College London devised two forms of assessment. The first was a fairly 'traditional' assessment (although unusual in that the majority of questions were not presented on the student test papers—the teacher had to orally administer the assessment) and the second a performance assessment aimed at exploring learners' extended problem solving and reasoning. We supplied the teachers with details of how to administer each assessment. In the case of the orally administered assessment, the students' papers and subsequent interviews with the teachers both indicated that these assessments had been administered appropriately. But the data returned on the performance tasks was so varied as to be unusable for the research. Responses ranged from students' scripts that showed so little evidence of productive activity as to suggest that the learners had been set off to do the task with virtually no help in becoming engaged with it (despite advice to the teachers on how to do this). At the other extreme, scripts returned showed every child's response was almost identical, suggesting heavy direction from the teacher. These assessments thus revealed much about how the teachers had set the assessment up but little about learners' reasoning.

Besides the difficulties in setting up tasks, the research shows the need to help teachers develop the range of things that they look for when assessing performance tasks. In particular teachers need to set aside expectations of 'correctness' in order to consider creativity. As noted earlier, Newton's (2010) research shows that this is challenging, for pre-service teachers at least. While it may be that serving teachers are more able to bracket out their knowledge of correct answers, research still needs to be done to investigate whether this is the case. If creativity is to be considered in the light of what is creative from the perspective of the learner doing the creating, then practices of normative assessment will make assessing creative performance difficult. The question of what sort of criterion-based assessment might be helpful here is discussed in the next section.

Other commentators have argued that variation in teacher assessment is too broad and that other factors include teacher assessment being unreliable, both between teachers and by the same teacher over time; the impact of the order of assessments—the effect of judgements from other assessments, either at a different time or in the sequencing of items; the 'halo effect'—the impact of general views of a learner; a teacher's overall leaning to harshness or not; and the effect of non-relevant factors such as neat handwriting (from Sadler 2002).

Such limitations would seem to support the case against teacher assessments and the need for externally validated assessments. Such objections, however, seem largely to be grounded in the primary purpose of assessment as summative, for comparing individuals, and assessment done in order to communicate 'standards' to others and the consequent drive for grades. In assessing creativity, the emphasis needs to be more formative and supportive of helping learners to become more creative rather than on assigning a 'creativity grade'.

Judging Creativity

> Assessing creative and cultural development is more difficult than testing factual knowledge … We noted earlier that creative outcomes have to be both original and of value. But there are different types and degrees of originality. Moreover, judging value depends on a sense of clear and relevant criteria. Teachers are often unclear about the criterion to apply to children's creative work and lack confidence in their own judgment. (NACCCE 1999, p. 127)

Although it may not be helpful to 'grade' learners on creativity, making judgements is necessary if teachers are to help learners improve. In doing so the specification 'of clear and relevant criteria' is no simple matter. Two approaches do appear to hold promise: dynamic standards and holistic judgements. Newton (2000) argues that despite the apparent difficulty in assessing creativity, teachers can make holistic assessments of creativity in scientific explanations and this is easy and the assessments are reliable. This builds on Amabile's (1983) pioneering work in holistic judgements. In a review of subsequent research, Hennessey (1994) makes a strong case for such an approach, noting that the bulk of the research draws on experts in the field to make the judgements. As many primary school teachers would not consider themselves to be experts in mathematics or science, this raises the question of how effective holistic judgement might be in the elementary years of schooling. In fact, in research with pre-service teachers, Newton found little agreement in their holistic assessment of learners' work in science (Newton 2010). Further research into this with experienced teachers is needed.

Newton's research demonstrated better agreement when the student teachers assessed learners' outputs against three attributes of creativity: novelty, scientific accuracy and elegance. In mathematics, in judging the work of learners in the conjecture/justify space, arguments could be considered against criteria such as strength of justification or elegance. These could be further refined. For example, Mason et al. (1985) argue for judging whether a justification would convince yourself, convince a friend, or convince an enemy (that is a mathematician!), and Sullivan categorises the language of arguments into 'naïve' (empirical and based on checking specific examples), 'crucial experiment' (considering extreme cases) or 'conceptual' (based on analytic or deductive reasoning).

It may be that teachers coming together and drawing out criteria for assessing creativity on the basis of initially holistic judgements—developing dynamic standards—would be the most productive way forward. Arguing for dynamic over arbitrary (external) standards and, drawing on the work of Moss and Schutz (2001), Broadfoot (2002) advocates the process of generating standards as 'the essential dynamic of educational quality and innovation' (p. 158).

In other words, teachers working together on dynamic standards to assess creative activity in science and mathematics are likely to lead not only to developments in assessing creativity but also to innovation in pedagogy. Engaging teachers in the processes of defining assessments is more important than providing them with an assessment product against which to judge learner outcomes. From this perspective of dynamic standards, the 'difficulties' associated with assessing creative activity become transformed into resources to work with.

> Where the emphasis is on generating, discussing and using 'dynamic standards' in a formative way, assessment is a key tool for system improvement. Where, however, the emphasis is on the imposition of 'arbitrary standards', not only does this represent a misguided belief in the power of numbers and words to contain the wealth of human creativity, the coercion and exclusion, the 'teaching to the test' to which it so often leads represents a tragic loss of opportunity for genuine progress and real learning. (Broadfoot 2002, p. 158)

Conclusion

It seems clear if we are to value and promote creativity in mathematics and science classrooms, then shifts are needed in both classroom cultures and assessment practices.

A shift is needed in the classroom culture, not simply in teachers' practices. For creativity to be encouraged, mathematics and science lessons need to have an element of playfulness and be safe places where learners can take risks. A shift is needed in assessment practices to help teachers adopt 'insiders' perspectives'—both the learner perspective and the discipline perspective—and so enlarge their repertoire for making judgements of creativity. Research is needed into the nature and support of both these types of shifts.

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