SELF-EFFICACY IN MATHEMATICS AND STUDENTS' USE OF SELF-REGULATED LEARNING STRATEGIES DURING ASSESSMENT EVENTS

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High stakes summative assessment has been a significant element of educational policy in England and Wales for more than a decade. However, research evidence indicates that formative assessment is more likely to raise student achievement. Although some students are able to use summative assessment formatively, devising their own self-regulated learning strategies, which will support them in lifelong learning, many students fail to do so and for them an emphasis on summative assessment often leads to a reduction in self-efficacy and motivation. This paper reports on an investigation into students' beliefs about themselves as learners of mathematics and the strategies they use before and after assessment. Although most students believe in the value of revision, they often fail to employ effective revision strategies and many fail to use assessment results formatively.

FORMATIVE OR SUMMATIVE ASSESSMENT?

Educational policy intended to raise student achievement in England and Wales, has included high stakes summative assessment as a significant aspect. Over the last decade, the use of summative assessment over and above that required by the National Curriculum has grown rapidly (Harlen & Deakin Crick, 2002) and target setting for both teachers and pupils is often based on such data. However, there is evidence to suggest that it is the process of analysing one's own strengths and weaknesses before and after assessment, rather than the act of target setting, which leads to improved learning (Tanner and Jones, 2000). Proponents of regular, summative assessments claim that they motivate students to learn. However, this is not true for all students. In fact, a recent systematic review of the impact of summative assessment suggested that target setting based on summative assessment often results in students (and teachers) emphasising extrinsic motivation at the expense of intrinsic, and a focus on test performance rather than understanding. This often leads to shallow rather than deep learning, and damaged self-esteem for failing students, thereby resulting in a reduction in self-efficacy and effort for a significant proportion of students (Harlen & Deakin Crick, 2002).

On the other hand, a review of research by Black and Wiliam (1998) demonstrated very clear evidence that formative assessment, which is designed to be integral to the learning and teaching process, can lead to significantly improved performance. Moreover, our aims for education and lifelong learning must demand more than simply improving student performance in standard tests. Our aim should be to develop autonomous, self-regulating learners who are inclined to choose to learn and improve their knowledge and skills throughout their lives. Formative assessment, and particularly self-assessment, clearly has a part to play here.

The terms formative and summative are not used consistently in the literature (Black and Wiliam, 1998). The terms are often used to describe types of assessment with some writers using the term formative to describe classroom assessment and summative to describe externally imposed assessment or examination. However, we use the terms here to describe the *functions* rather than the *types* of assessment (Brookhart, 2001) and recognise that any assessment event, either classroom based or externally imposed, could be used to satisfy formative and/or summative ends. We define an "assessment event" to include: the preparation for the assessment by both the teacher and the student, the feedback from the assessment offered by the teacher, and the impact of the assessment on the subsequent learning behaviours of the student (cf Brookhart, 2001). The ultimate end user of assessment information should be the student and to be considered formative, assessment should be used to improve student performance (Black and Wiliam, 1998).

The literature often refers to the need for clear, shared, learning goals so that students are able to compare actual with desired performance and then try to close the gap. Formative assessment is thus intended to provide feedback information about performance to assist the student in identifying the gap and may suggest strategies to facilitate development (Gipps, 1994; Black and Wiliam, 1998). Unfortunately, many students fail to understand how to interpret or respond to the feedback which teachers offer (Sadler, 1998); indeed, when feedback emphasises marks or grades, formative comments are often ignored (Butler, 1987). However, there is some evidence to suggest that successful students are able to use even summative assessment information in a formative manner, formulating their own goals and monitoring their development towards them (Brookhart, 2001).

Developing self-regulated learning

Much of the literature about formative assessment, naturally emphasises the role of the teacher because teachers are responsible for planning and administering assessment, but in fact, the demand for improved performance should move the focus to the behaviours of the learner. Ideally students should share the teacher's learning goals and plan to close any gaps, monitor their own progress, and evaluate the success of their learning. The ultimate goal of feedback should be to teach students to regulate their own learning (Sadler, 1998; Gipps, 1994; Black and Wiliam, 1998). Successful students have usually learned to do this and are often able to use intermittent assessment events which have been designed to provide summative information for their own formative purposes. They review work and engage in self-assessment as a regular ongoing process and use feedback information in both summative and formative ways simultaneously (Brookhart, 2001). On the other hand, weaker pupils often believe that the purpose of such assessments is to make them work harder rather than differently. In fact when such students repeatedly gain low marks, it may generate "a shared belief between them and their teacher that they are just not clever enough". In such circumstances, the self-regulation which occurs may be to "retire hurt" to protect their self-esteem (Black, 1998: 43-44). Low self-efficacy is often an unintended outcome of summative assessment.

Students' self-efficacy for mathematics may be defined as their judgements about their potential to learn the subject successfully. Students with higher levels of self-efficacy set higher goals, apply more effort, persist longer in the face of difficulty and are more likely to use self-regulated learning strategies (Bandura, 1977; Wolters & Rosenthal, 2000).

Research also highlights the importance of metacognition if students are to regulate their own learning effectively. Metacognition includes three components: a) the awareness that individuals have of their own knowledge, their strengths and weaknesses; b) their beliefs about themselves as learners and the nature of mathematics; and c) their ability to regulate their own actions in the application of that knowledge (Flavell, 1976; Tanner and Jones, 1994; 1995; 1999; 2000).

The development of autonomous, self-regulated, lifelong learners of mathematics depends on the interaction of three linked psychological domains of functioning: the affective, the cognitive and the conative (Bandura, 1977). The affective domain includes students' beliefs about themselves and their capacity to learn mathematics; their self-esteem and their perceived status as learners; their beliefs about the nature of mathematical understanding; and their potential to succeed in the subject.

The cognitive domain includes students' awareness of their own mathematical knowledge: their strengths and weaknesses; their abstraction and reification of processes; and their development of links between aspects of the subject (Tanner & Jones, 2000).

The conative domain links the affective and cognitive domains to pro-active (as opposed to re-active or habitual) behaviour. It includes students' dispositions to strive to learn and the strategies that they employ in support of their learning. It includes their inclination to plan, monitor and evaluate their work and their inclination to mindfulness and reflection. In particular it includes the strategies, which they are inclined to use when reviewing or revising their work (Snow, 1996).

Using summative assessment events to improve learning

The political pressures on schools to use intermittent summative assessments of students' learning are unlikely to reduce in the near future. As we indicated above, several negative impacts on learning may result from on over-emphasis on summative assessment. However, some students have learned to overcome these negative aspects and are able to use intermittent summative assessment to support their own self-regulated learning. Research suggests that the following conditions are necessary for this to occur.

Firstly, the students' self-efficacy must be high. They must believe that their mathematical ability is not fixed. They must attribute their success or failure in mathematics to controllable factors such as effort or revision, rather than uncontrollable factors such as bad luck or lack of ability (Bandura, 1977; Black, 1998; Wolters and Rosenthal, 2000).

Second, they must have metacognitive knowledge of their own mathematical abilities. For example: they must be aware of their strengths and weaknesses, how their knowledge compares with the potential demands of the assessment, what they understand and do not understand, and the errors they are most likely to make (Tanner & Jones, 2000).

Third, they must be aware of, and be inclined to use effective strategies for reviewing and revising their work and analysing their successes and failures. For example, they need to have strategies for planning and engaging in revision, identifying key features of their work and anticipating potential difficulties in questions in advance of assessment. After assessment they require strategies for analysing and evaluating their performance. And finally, they must be inclined to implement these strategies in the belief that their performance will improve (Gipps, 1994; Tanner & Jones, 1994; Brookhart, 2001).

METHODOLOGY

The research reported here was funded by the General Teaching Council for Wales. The aim of the research was to investigate year nine (aged 13-14) students' self-efficacy in mathematics and their use of self-regulated learning strategies during assessment events.

A questionnaire was designed based on the three domains of functioning outlined above to ensure face and construct validity. The aim was to allow the collection of a large data set with minimal disruption to normal teaching or potential for researcher bias or interference. The questionnaire was trialled on a one-to-one basis with a small number of similar students prior to administration to all the students in the study. The final instrument consisted of 47 statements, to be answered using a five-point Likert-type scale, running from "strongly disagree" to "strongly agree". The questionnaire was divided into three sections: self-efficacy, metacognition and learning strategies.

The self-efficacy scale was divided into two sub-sections. The first included nine statements and addressed students' beliefs about themselves as learners of mathematics. In particular it focused on their beliefs about the fixed or changeable nature of mathematical ability. Typical statements included:

Some people just can't do maths

Working hard leads to success in maths

You can't change your maths ability

The second self-efficacy sub-section included 12 statements and addressed students' attributions of success and failure in mathematics examinations. Typical statements were:

If I do well in a maths exam it's because:

I was lucky with the questions

I worked hard

A parallel set of questions was phrased negatively and included statements such as:

If I do badly in a maths exam it's because

The questions were too hard

I have no natural ability in maths

The next section of the instrument focussed on students' metacognitive knowledge. There were ten statements such as:

I know which parts of maths I don't understand

I know in advance if I am going to get a question right

I know which mistakes I am most likely to make in maths

The final section included 16 statements and identified strategies which students might use for learning mathematics. Students were asked how often they used each strategy and the five-point scale offered the options: "Never", "Almost never", Sometimes", "Almost always", "Always". It included statements such as:

If I make a mistake I try to find out where I went wrong

I always revise for maths tests

Before a maths exam:

I find a quiet place to revise

I read through my maths book

I try to predict what the questions will ask

When I get my exam paper back:

I work out where I went wrong

I only look at my mark

I make sure that I understand my mistakes

The sample consisted of two year nine classes in each of six comprehensive schools. The schools were necessarily an opportunity sample of those teachers and schools willing to participate in the research, but comprised a reasonably representative stratified sample of comprehensive schools in South Wales, including examples of affluent suburban, inner city, rural, and industrial locations. The 303 students involved spanned the ability range.

THE RESULTS

Students' responses to the statements were coded from1 to 5 for analysis with 5 representing a strongly positive attitude or an effective strategy which was always used. The total scale proved to be reliable (Chronbach's alpha = 0.89). The sub-scales also had adequate reliability (self-efficacy, 0.76; metacognition, 0.53; strategies, 0.89).

On average students were positive in their beliefs about themselves and their potential to learn mathematics (self-efficacy), their metacognitive knowledge and their use of self-regulated learning strategies (see Table 1). However, the higher standard deviation in the strategies sub-section reveals a greater variability in their use of learning strategies.

	N	Mean	Standard deviation
Self-efficacy	303	3.59	0.41
Metacognition	302	3.40	0.41
Strategies	299	3.45	0.70

Table 1: Means and standard deviations of the sub-scales

The vast majority of students thought it was worthwhile to try hard in mathematics (93%) and thought it was worthwhile to revise for examinations (90%). Most disagreed that only intelligent people could do mathematics (84%) and that mathematics ability was unchangeable (75%). However, although 50% of the sample disagreed with "Some people just can't do maths" worryingly, a hard core of 28% agreed with this statement. Similarly, 21% agreed with "You can either do maths or you can't"

Success in mathematics examinations was generally attributed to hard work (84%) or doing lots of revision (71%). However, other attributions of success included uncontrollable factors such as "luck with the questions" (61%), "easy questions" (46%) or "a good memory" (46%). Failure in examinations was attributed to not doing enough revision (74%) or not doing enough work (56%). However, a hard core blamed their failure on uncontrollable factors such as poor memory (24%), being unlucky with the questions (20%) or having no natural ability in mathematics (14%).

The self-efficacy results indicate that a significant minority of students have beliefs about themselves as learners of mathematics which would impact negatively on their future performance. However, most students have positive beliefs about their potential to succeed in the subject if they work hard and revise. However, the results of the next two sub-scales indicate that many students do not know how to apply their efforts efficiently and unfortunately only 51% of students claim to know a variety of ways to revise.

Students' claims for metacognitive knowledge were generally positive, with 86% claiming to understand some parts of mathematics completely and 75% claiming to know which parts of mathematics they don't understand. Yet only 57% claim to know which mistakes they are most likely to make. Similarly, 47% report that they often get a question wrong but don't understand why. Only 40% have the confidence to claim that they know when they have got a question right and just 23% claim to know in advance that they are going to get a question right. This suggests that their metacognitive knowledge is not as good as their initial claims might suggest and accounts for the relatively low reliability of this sub-scale compared with the others.

The strategy sub-scale reveals that, in line with their beliefs about the value of hard work and revision, most students claim to revise before mathematics tests (66%) and try to find out where they went wrong if they make a mistake (59%). However, most of the learning strategies they employ are of limited value. Only 25% make a note of the main points learned in every lesson and just 23% “like finding bits of maths which link together”.

The efficiency of their revision strategies is dubious. For example, the most popular strategy (73%) is to “read through my maths book” which is unlikely to be of great value for learning. 71% claim to try to work out what they don't know, but given the evidence in the metacognitive sub-section, the extent to which this is successful must be doubted. Only 53% control their environment by finding a quiet place to revise.

More effective revision strategies were used by only a minority of students: making revision notes (44%) doing lots of questions (41%) writing some questions to test myself (39%) highlighting the most important parts of my work (34%) or trying to predict what the questions will ask (20%). All these strategies require some degree of metacognitive knowledge and it is perhaps not surprising that they were used more infrequently.

After assessment had taken place most students claimed to make sure that they understood their mistakes (69%); worked out how to do better next time (65%); and worked out where they were going wrong (61%). However, given that 55% claimed to only look at their mark when getting their examination paper back, the validity of their claims must be dubious.

DISCUSSION OF RESULTS

Although most students have beliefs about themselves as learners of mathematics, which would support future self-regulated lifelong learning, a substantial minority holds beliefs, which are likely to have a negative impact on future learning. Students who attribute their success or failure in mathematics to uncontrollable factors are unlikely to apply effective learning strategies. However, even though the majority of students express positive beliefs and attitudes towards revision, the results of the metacognitive and strategic scales suggest that they are unlikely to apply their efforts to best effect.

The failure of most students to claim appropriate metacognitive knowledge is of concern, as it suggests that their revision is likely to be inefficient. A very substantial minority of students lacks the detailed knowledge of their strengths and weaknesses, which would be necessary for them to regulate their learning effectively. Furthermore, only half the students have knowledge of a range of effective revision strategies to apply.

The majority of students appear to believe in the value of hard work and revision, but either do not know, or are not inclined to apply, effective revision strategies. The most commonly used strategies are passive or reactive in character rather than pro-active. Reading through their books does not require active processing and is unlikely to impact significantly on their learning. Similarly, although most students realise that they should learn from their assessments, the majority "only look at their mark" (cf: Butler, 1987). In such circumstances their desire to "work out how to do better next time" is likely to be restricted to unfocussed targets like "try harder" or "be more careful".

Clearly self-efficacy, metacognition and the use of self-regulated learning strategies are closely associated. There was a strong correlation (0.51, $p<0.01$) between students' self-efficacy scores and their "Strategies" scores. There was a moderate correlation (0.42, $p<0.01$) between students' self-efficacy scores and their claims to metacognitive knowledge. Similarly, a moderate correlation (0.41, $p<0.01$) was found between "Strategies" and "Metacognition". Causality is probably complex, but students who believe that their mathematical ability is not fixed and that their performance is due to controllable factors are more likely to employ learning strategies than those who attribute success or failure to luck or lack of ability. The more effective learning strategies such as "working out what I don't know" and "highlighting the important parts of my work" contribute to the development of metacognitive knowledge. Students with good metacognitive knowledge are likely to revise more effectively. Successful application of learning strategies is likely to encourage the development of self-efficacy. A virtuous circle may become self-perpetuating.

Unfortunately, for many students a vicious circle may develop, with lack of self-efficacy leading to a failure to apply effective learning strategies, or develop metacognitive knowledge. Repeated failure in assessments may then reinforce "a shared belief between them and their teacher that they are just not clever enough" (Black, 1998). Breaking into this vicious circle is difficult, but we would suggest that attempts be made to teach all students the self-regulated learning strategies, which are currently only known by the successful minority of mindful and metacognitively skilled students.

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