Evidence for Pupils' Mathematical Achievements

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In 1991 I was Head of the Mathematics Department of a 13-18 comprehensive school Pupils came to us at age 13 from several different schools and brought with them records, constructed by their previous teachers, which purported to show the mathematics they "knew and could do". This was the first year in which these records had to be based on the legal requirements of the relatively new National Curriculum. We would be required to produce our own assessments of the achievements of individual pupils, who would also be assessed using national tests the following summer. At the time the plan was to publish all the results locally and nationally so that schools could be compared There was also the possibility that different classes within schools could be compared.

In addition the records would ensure continuity of teaching and learning when pupils transferred between schools and therefore we ought to be able to use them to decide what each pupil might be able to learn next

The records, therefore, had several purposes: monitoring individual progress, recording achievement summatively, providing information for teacher, parent, school, and government. The added pressure of national testing, with which these records would inevitably be compared, made it urgent that we should understand what they meant and devise ways of using them to enhance learning, or reject them as useless. We had extra difficulties if we did not accept the implication that mathematics was necessarily learnt in a prescribed order.

It was immediately clear, however, that some of the records were about what had been taught rather than what had been understood For instance, all pupils from one teacher's class had exactly the same "record of achievement" Others showed more variety but some were detailed and dense as if every bit of mathematics the pupil had ever done had been fully understood and recorded. Others were only partial and tentative as if the teacher was unwilling to commit herself to any definite statements

In 1983, which was a long time ago in terms of British educational change, Alan Bishop and Marilyn Nickson had said:

> *There appears to exist a great need for a study of teacher judgements of pupils' mathematical potential It would also be of interest to compare the bases for these judgements, and their validity, between primary and secondary teachers.*

Looking at these records, which consisted of quite detailed statements, I felt no wiser about their source or their meaning in terms of achievement or potential.

In order to make sense of these records I felt it was important to know how the judgements about what a pupil could do might have been made I met and talked with about a dozen teachers of 10 to 13 year-olds from a variety of schools and types of school, including our "feeder" schools. The stories they told me about their decisions were enlightening and informative. There was a variety of issues and strategies involved and a sense of several levels of awareness at work, as these quotations from the teachers show:

> *You think someone knows something and then you discover they don't, through errors, or a question they ask. Usually it's something verbal ... no ... sometimes it's what they've written.*

> *How do we all know that we are assessing the same things? The commitment isn't there and we have to find our own time to meet after school*

> *If it's on paper I get really cross with myself if they haven't divided properly and I know that they grasped that at the end of the previous term ...*

> *Parents like to have concrete evidence in the form of a test result*

I was still a full-time teacher at the time and needed to devise a way of working with diverse records very soon. Nevertheless, within the limitations of my time and resources, I soon became aware that the stories I was hearing were worthy of some analysis beyond immediate pragmatism

All the quotations in this article, unless otherwise stated, are from the teachers with whom I talked.

The teachers largely conformed to the model which has been described as "evidence gatherers", who collect evidence of various kinds from normal classroom practices, with occasional bouts of being "systematic planners" for particular aspects of mathematics assessment [see McCallum *et al*, 1993]. Several teachers combined the two approaches by using a published scheme, adopting the intentions and plans of the scheme but recognising other aspects of mathematics which could be incorporated and manifested during work on a particular topic. My main concern here, however, is about the nature of the evidence rather than its collection and manipulation.

Teachers would show me their record sheets or other evidence-recording devices and I would try to encourage them to return to the scene and attempt to reconstruct the moment, the interaction, or the behaviour which led to a particular record being made. Sometimes teachers would remember specific lessons and at other times a more general answer would be given

> *Chantelle had the idea of not only counting squares but also putting half squares together. Helen was working with her but I don't think she was quite at the same stage*

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Rachel knows + and – and can use these in stories. I know that she knows how to present things in a mathematical way.

My aim was to get teachers to talk quite specifically about single incidents with one pupil and describe what had informed their judgements

Types of evidence used by teachers

There was a large measure of agreement about the types of evidence available to the teacher, but the relative weightings given to the types by different teachers varied Some of the types conformed to descriptions of evidence in, for instance, Conner [1991], but others do not seem to be recognised in the literature as evidence, though it is clear from my interviews that teachers use them The methods I identified are:

Oral evidence from the teacher overhearing conversations or commentary by pupils, or through formal and informal pedagogic dialogue;

Written evidence in the form of exercises, tests, rough work, notes, or writing about mathematical explorations;

Actions observed by the teacher while watching the pupil do practical activities or other work;

Voluntary use of mathematics while working on other subjects or in some other context;

Evidence based on *knowledge of the pupil* as a learner or in other respects;

Evidence based on the teacher's own *view of mathematics;*

Observation of *behaviour and body language.*

The first four are widely recognised as clear and legitimate sources of evidence The last three are more problematic, requiring interpretation and prediction based on experience, on the models the teacher has constructed from her experience, and what is variously described as "subjectivity" or "professional judgement", and so on

I shall write briefly about each type, with quotations from the teachers chosen to illustrate from the whole set of conversations.

Oral

Shape is a talky sort of subject anyway.

...he wasn't writing much down and then when I got to talk to him about it he would actually come out with "Well, if I do this one this is going to happen". He was making predictions, but the written work was very slow and not at all methodical.

I would say, "How did you come about that answer?" It's quite fascinating how they come about them in different ways. Some would make adult short cut kinds of approaches, others use very safe strategies and won't make any of their own

I sometimes sit and work with them and listen to what they are saying to each other.

I believe linguistic ability is not far from mathematical ability.

Alongside these statements of relative certainty ran comments about lack of time to manage oral communication effectively with all pupils. Some teachers mentioned that they could not always be there when, for instance, two children were discussing mathematics in a revealing way. They recognised time lags between the pupil being able to do some mathematics practically or on paper, talk about what they had done, and then write about it. For some pupils this was perceived as an inability rather than a time lag. There is usually no permanent record of the oral interaction and the teacher, if she is pressed to provide evidence, can only talk of an unrecorded conversation When and if her judgements are held up to wider scrutiny, or compared to test results, the teacher can feel vulnerable Nevertheless it seems to be the most common way—apart from observed actions—in which pupils reveal their knowledge to teachers in primary schools. It can be problematic in several situations, such as where there are language difficulties, or where the pupil's perceptions of the power of the teacher engender fear, or where elaborate forms of language are not encouraged and supported at home For instance, where else but in school is a child expected to "Tell me how you did that"? Nevertheless the ability to "tell back" the mathematics to the teacher in the pupil's own words is regarded as a powerful indicator of understanding.

The last quotation above is from a teacher who recognises a link between language and the learning of mathematics Mainly, however, the oral evidence teachers referred to was obtained from reporting or explaining some mathematics which had already been "done". The use of language in concept-formation or in the mental processes involved in doing mathematics was not raised as a source of oral evidence

Written work

Although I think that marking a test is useful it's not the be-all and end-all

Her written work is good as well ... she can write down what she's done, which helps. Since September she has been continually surprising me with her comments and her written work and just the way it shows she has gone about tackling things

Damien couldn't pick out which numbers were in the units or tens columns. If you had asked me before the written assessment if would he be able to do that I would have said "Yes"

This was certainly regarded as a safe, reliable, and robust form of evidence because it is permanent and can be held up to scrutiny It seems to take two different forms The first is the traditional list of examples correctly or incorrectly done, perhaps as a test, the second is a more discursive record of explorations into mathematics. The first

often offers no clues about what is understood or misunderstood even when the teacher has encouraged pupils to "show their workings".

> *... for division I asked them how they'd done it and the ones who seemed able to show how they'd got to where they'd got could all explain it. Others looked blank.*
>
> *Often they can't show their workings and say "I just did it".*
>
> *Sometimes I insist that they give an explanation of how they got there but I don't always follow what they put, and some of them don't put anything.*

The second often makes language demands in excess of the pupil's current linguistic power and hence may not truly reflect the maths that was done. The classroom norms of written work can affect the pupil's pre-editing of what is written. If the desired finished product (that it should be neatly written in columns, for instance, or decorated for later wall-display) does not easily relate to how the pupil actually worked on the mathematics, much can be lost in the attempt to conform. Olwen Macnamara has written about the inevitable selection and reduction involved in writing accounts of mathematics and explores the reasons [1993]. There is also the fairly common phenomenon of pupils putting up some kind of barrier to writing, possibly based on a fear of exposing error in a way which has not been helpfully dealt with in the past.

Observed actions

> *She was having problems with the basics of measuring, getting one metre and parts of a metre ... she could manage halves but was having problems with fifths and tenths ... when I asked her with the metre stick to calculate how many centimetres she could give to each of five children she could do it.*
>
> *Clair was unpicking cubes made with joined squares to find different cube nets. She began to be systematic by detaching one square and moving it along the sides of the others without going to the trouble of re-attaching it each time.*
>
> *Some of the practical skills ... you've got to be there with them.*

This provides no permanent record, unless an artifact is produced, and may depend on the teacher's interpretation of what is going on inside the head of the learner. A timid pupil who prefers to sit and watch, or one who prefers to work in the abstract or with mental imagery rather than with materials, might not be assessed this way. A running commentary may help, but only if the teacher is near enough to hear it. Unless there is a commentary it is possible to assume one thing is being thought when in fact it is another.

> *I really thought Mel understood multiplication until I asked her to explain all the little marks in the margin of her work. They turned out to be tally marks and she wasn't even adding, she was counting.*
>
> *When he was counting he was touching all the counters but telling me the wrong answer. When he said the number words out loud I could tell, to my horror, that he did not know it had to be one number word per counter! He was survived until now by learning addition facts without knowing what they mean.*

Conner [1991, p.47] comments that:

> *The process of observation is going to be one of the major ways in which teachers will gather together the evidence upon which to base their judgements about children's progress ...*

and yet most of the teachers I talked with commented that they did not have enough time to assess through observation in general. In mathematics they were not happy to rely on observation alone, particularly on isolated incidents. The looked for repetition in similar circumstances, repetition in different circumstances, and some kind of language-based supplementary evidence.

Voluntary use of mathematics

> *I asked them to work out some ages, and some of them used their heads, others wrote out sums, others used calculators or counters.*
>
> *When teaching them for every subject I could see much more how they used what they learnt in other situations.*
>
> *It's always a relief when shown they can apply it in practical situations but I wouldn't use those to say they couldn't do it ... hadn't internalised it ... if they hadn't applied it*

Apparently this gives teachers a very sound way to tell if a pupil has understood, has internalised, and can manipulate and draw on the concept in unexpected situations. The disadvantage is that waiting for voluntary use to "happen" for every bit of mathematics is unrealistic, and there is usually a time lag between knowing about and being able to use a concept. Teachers can plan as many openings for this to happen as possible. I was left with the impression that sometimes teachers deliberately offered an open-ended activity and were prepared for anything to happen, but at other times they hoped one particular aspect of mathematics would be used, without prompting, by the pupils. Some of those who talked about time-lags during which pupils might not be able to apply knowledge, and after which they might have forgotten it, offered anything from "two or three weeks" to "about six months" as realistic time-scales for planning purposes. Others talked about pupils forgetting what they knew during the holidays, however long the holidays were.

Knowledge of the child

> *Parents are concerned about her, she's a day-dreamer. She sucks her thumb and this prevents her holding her book in place so she doesn't record her work.*
>
> *My opinion of him has changed this term due to his own confidence and the relationship we've built up ... the talks have built my confidence in his ability.*

She always thinks she can't do things, she needs a lot of help and encouragement to get going. Maybe she can't go further with algebra on her own but working with some others she could.

The importance of knowing the pupil was referred to many times. It seems to be about seeing him do so many things that the teacher can construct a model of how that pupil learns from which predictions can be made with confidence. The predictions also depend on some idea of how mathematics is put together, so that the teacher's view of mathematics (whether it is linear, hierarchical, a network, and what order, if any, it has) and the model of how the pupil learns (particular ways of working and reasoning) link to tell an overall story which the teacher can use to fill in the gaps in her own observed knowledge. This relates to what we mean in everyday life by saying we "know" people: we can predict how they might act and what they might think about something and what we can safely say to and about them. However, the extensive literature on the effects of a teacher's expectations on a learner's achievements suggests that we should be wary of being too comfortable with this approach. At the very least it is limited by the teacher's own model of mathematics (which is often a deficit model in the case of primary teachers) and her knowledge of the pupil in the classroom situation. Nevertheless when I asked teachers to tell me about the mathematics a particular child knew and could do, they invariably started with a description of the child's general emotional state, ways of working, and behaviour.

If you see what they do in a variety of situations it is sometimes easier to stand back and see them a bit more

Views of mathematics

I use stories to see if they understand or not, and it helps me unravel errors. I try to ask them a question with a slightly different slant

Learning is not a straight line that everybody does.

There's so many avenues and so many things they say, which are all valid, or if they're not then they're ambiguous. You've got to listen to what they say.

Most of the work looks like consolidation and practice because the steps forward are so small that children accept them easily. For instance, the step from using 1cm to be one unit on an axis to it being 2 units. I have to be aware of the step they're making

I think it always has to be logical. For instance I teach subtraction by decomposition because it is logical, but I always do it the other way myself, particularly if I am in a hurry.

There was a variety of views and levels of confidence about mathematics among the teachers I worked with. Some saw mathematics as a prescribed linear hierarchy of small steps. Some saw it as a mystery in which they did not feel initiated and hence relied on the ordering of a published scheme. Some saw it as a totally practical subject and likely to crop up anywhere and everywhere. Others saw calculation as a "basic" which had to be learnt in a "right order", but everything else could be flexible.

One teacher engaged her pupils in conversations about the inverse of a concept in order to test their understanding. It was an integrated part of her practice and I saw her using it several times. She called it "turning the question round" when I described it to her. For instance, she had wanted to check whether a pupil had understood 54/6 = 9 by asking about 6×9 and 54/9 and expecting an explanation using apparatus or a story rather than just an answer. She would sometimes ask questions like, "What if we wanted the answer to be so-and-so?" or "Will it always work out exactly?" to get oral evidence of understanding.

This is not the place to go into the full effects of these differences but there was not, from this small sample, any observable relationship between beliefs about mathematics and choice of assessment styles. All teachers used all the kinds of evidence I am writing about, although the weight they gave them and the confidence with which they used them differed.

Behaviour and body language

The way they sit, the way they look at you, they nod, eyes are bright, they seem as if they're with you.

I can see her face there just smiling like she always is

He says he can't do it and he has regressed in terms of attention seeking and avoidance tactics

You can tell whether they're concentrating and quite often, if they're not, it's because they don't understand. You look for contentment.

What sounds like a very human-based approach to identifying confidence in a child, and watching for signs about how far you could or could not go, is sharply thrown into focus by the following comment from a very highly-regarded teacher whose class is about 50% Asian Muslim children from largely uneducated backgrounds. The rest of the class are predominantly white middle-class children from educated backgrounds.

I don't feel the same pressure to get it right with white children because I know more about their cultural backgrounds. The Asian children may think differently, their constructions might be different, their experiences have been different. I am always trying to examine my attitude. I've just realised that the white children look at me but the Asian children don't. I have assumed that because they're not looking they haven't taken it in.

The "it" that the teacher wanted to get right was her assessment of what they had learnt and could learn. She was sensitive to much of the research about underachievement by particular ethnic groups in this country and eager not to limit her own expectations. All the materials she used had been examined for bias and she ran her classroom in a way that offered as much equality of opportunity as she could, given some language difficulties. By examining what she looked for in her pupils she was able to recognise that the

actions she expected from pupils, and her interpretations of them, were based in her own culture. She therefore became aware that if she reacted intuitively to body language and facial expressions of pupils as part of her assessment of them there was a built-in bias against her Asian pupils.

She went on to say:

> *I find it easier with white children to say what they know, because they are more likely to voice their understanding I asked Shamila "Do you understand?" and she said "Yes" but later I could see her struggling alone and she hadn't understood at all.*

Although body language, facial expression and behaviour were mentioned by all the teachers I talked to as indicators of understanding, particularly when I asked them about specific individuals, I remain unaware how much this affects the judgements they are prepared to pass on to other teachers or otherwise "go public" about The question of how these casual judgements affect the pupil's day-to-day experiences in school and learning in general is an important and well-researched one and it needs to be asked in the context of teachers' assessments of pupils' achievements too However these ephemeral indicators are what teachers appear to use as part of assessing pupil progress in the classroom when oral, written, or observed actions are not available as evidence or do not appear to give the full picture of understanding

Although many teachers mentioned that written tests made them more confident about what pupils could do, there was also a general willingness to draw on memory and impression if the rest of the evidence seemed to fall short of their own judgement

> *I think about the child and the sort of conversations we have had and the sort of things they have volunteered to do.*
>
> *At the end of each term I have to write a review of each child in each subject, it takes me half-an-hour per child and I do it from my head.*
>
> *An answer on a test sheet doesn't mean proficiency to me, it's more a gut reaction when they say something . . when they go into detail.*

This tension was elaborated on by one of the mathematics coordinators:

> *Teachers want to feel that children are making progress You want to be positive and encouraging and you transfer that to actual record-keeping . . it's wishful thinking sometimes. You can be coloured by your previous experience of that child. We are human.*

When I asked teachers explicitly about possible bias they generally talked in terms of this kind of judgement only being additional to other evidence, or that they would take account of positive reactions but would not regard lack of positive reaction to mean lack of understanding

Conclusion

Each of the approaches I describe could lead to differences of opinion and interpretation Some may serve to perpetuate class and racial differences in achievement, particularly if they are used to assume potential. Teachers' own preconceptions and expectations run through them It is hardly surprising that we ended up regarding the information sent to us by feeder schools as at worst partial and at best enriching rather than hard, true and incontrovertible

We also had to face up to the fact that our own assessments of pupils could, and probably did, involve the same kinds of evidence and range of judgements, including bias and omission.

Our conclusion, as a department, was that we should accept the records as the authentic attempts of fellow-professionals to record what pupils knew and could do. We would try not to use them as statements about potential or as definitions of some sort of innate ability. We could add to them as pupils worked with us on mathematics but decided we would not remove anything from the records, no matter how sceptical we might feel. In fact, we banned scepticism and talked of "having regard for the judgement of professional colleagues" instead. In cases where the pupil had been assessed as achieving more than we believed to be true then it was up to us to construct activities involving reinforcement, review, or revision alongside progress to new knowledge. The records which appeared to be based on what had been taught rather than what had been achieved were more credible and hence more immediately useful but, of course, could not be used then as evidence of achievement or potential.

We had, as a school, been involved in a pilot project using 100% moderated teacher assessment for public examinations and had found this to be hugely motivating for pupils and teachers What I find disturbing is that, although I still advocate teacher assessment and welcome the current moves towards it in the UK, in Southern Australia, in Portugal and elsewhere, I now have to question afresh the fairness and bias inherent in the process

> *Problems stem from a system which arranges for evaluation on behalf of others to be made.* [Wheeler, 1968]

In 1968, when this warning was published, the teacher was identified as evaluating on behalf of the pupil Since then the audience for teacher evaluations has grown to include parents, government, employers, the next teacher and, still, the pupil. Only one of the teachers talked about any form of self assessment

> *Sometimes we do a pre-topic assessment where they tell me what they think they already know.*

If teacher assessment of mathematics is the way, as I believe it is, to provide holistic stories of pupils' achievements, then there should be awareness of its complexities and potential for bias. These are the same sources of bias which have been so well documented as disadvantaging girls, poor children, and those from racial minorities in our education systems in the past.

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"objectively" about such "contexts". "Context problems"—that is the point. And yet, there are similarities between realism and RC. Children's ideas can be used in order to create education. They can indicate a path towards a curriculum. The bright ones can lead the class. These similarities are based on great communal respect for the individual with his or her own ideas, both in RC and realism.

4. Notes

[1] This function, by the way, is not only applicable to mathematical theories; a curriculum, too, is capable of justifying the placement of a topic. Only in the unit entitled "Mecca", for instance, do great circles appear in the new mathematics program for Dutch schools [see: Team W12-16: *Background to the new mathematics curriculum* 12-16, 1992]. And yet they do belong in the program as a whole. They constitute a topic within spatial geometry, and they belong with "cross-sections", "sight lines", "place determination" and "calculating in geometry", that is, with the other units that make up the curriculum. For this reason, great circles and other topics in spherical geometry can be expected to receive more attention in the future.

[2] Freudenthal [1971a]: "Definitions are not preconceived to derive something from them, but more often they are just the last element of analysis, the finishing touch of organizing a subject. Children should be granted the same opportunities as the grown-up mathematician claims for himself." (424) But he warns: "Geometrical axiomatics cannot be meaningful as a teaching subject unless the student is allowed to perform these activities himself." (426)

[3] For instance, by going in search of the shortest distance between two points on the earth (following a great circle) without needing to change course (following a "loxodrome"). Some of the students' suggestions were: "Following a meridian?", "Following the equator?", "Following an almucantar?"

[4] We observed the students' tendency to weigh up their "definitions" of great circles (which is the best?, which is the most comprehensive?) as is the case when formalizing a mathematical system. Johan formulated two separate definitions, "The circle that goes straight around the earth" and "Where the earth is the thickest", but he did not choose a "best one". Peter formulated spontaneously, "A great circle is a circle straight through the middle of the earth that comes back at the same spot". He formulated a complex definition of an intersecting circle through the "three-dimensional" sphere and the line straight across the two-dimensional "sphere's surface".

[5] A helmsman once told me: "First I draw a straight line on the cylindrical projection map. That's a great circle. I then transfer the intersections with straight lines, which are loxodromes on the mercator projection. So I navigate loxodromically towards the points of a great circle. We call this a composed track."

[6] Mathematics is an empirical science—whether one is researching axiomatics or developing a model of the world using great circles and suchlike.

[7] In the United States, radical constructivism is the focus of a great deal of controversy; many criticisms are being raised, and certain aspects are consequently being emphasized and expanded upon (socio-constructivism, social constructivism, didactic constructivism, etc.).

[8] In physics, too, the world (reality) is viewed from various perspectives, resulting in a diversity of theories (Newton's world view, theory of relativity, quantum mechanics).

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