What educational research can offer to the enhancement of technology use in mathematics teaching and learning

John Monaghan
University of Leeds

I will describe what mathematics education researchers do, what methods and theories apply in their work and how research could be used by mathematics teachers/lecturers

I will look at two examples of research

I will end by looking at why research is often neglected and look towards how education researchers and mathematics teachers/lecturers can work together

The structure of my talk:

I What mathematics education researchers do

what methods and theories apply in their work

II Examples of research

teachers and ICT

tasks using paper and using computers

III why research is often neglected

how we can work together

What mathematics education researchers do?

Let’s reduce the class of mathematics education researchers to those with full-time university jobs, then, like you they …

teach, do admin and do research

As for research, in common to most university departments

you generally work in a team

you may be lead or support in a team

at any time several projects will be ongoing/in prep

There are lots of different types of research.

Three broad categories:

1. action research (problem solving)
2. ‘jobbing’ research (getting a government contract)
3. own interest research

1 & 3 tend to have *research questions* – RQ

(or hypotheses; aims objectives)

2 tends to have require ‘outputs’

The RQs in 1 often change/develop (in 3 too, but less so)

2 can be frustrating – someone else decides the focus

Getting the RQs right can take a lot of effort

- Setting them in practice and in the literature (usually ‘unseen’)
- Getting the ‘logic’ right
- Ensuring feasibility

⇩

An example of ‘getting the logic right’ children and young people (CYP)

RQ1) How can researchers access the self-knowledge of CYP with regard to their use of technology and the learning that results from this use?

RQ2) What learning results from the use of technology by CYP and what constraints and affordances does technology place on this learning

RQ3) How does technology use in the lives of CYP change and develop over time.

RQ 1‘) RQ1

RQ 2‘) How do digital technologies feature in the lives of CYP?

RQ 3‘) RQ 2

RQ 4‘) RQ 3

RQ 1'') RQ 1'

RQ 2'') RQ 2'

RQ 3'') RQ4'

RQ 4'') RQ3'

Methods and theories

Data collection – analysis – interpretation

Methods for data collection

tests / questionnaires / interviews / observations

Methods for data analysis

qualitative / quantitative (descriptive/inferential)

No method for data interpretation

Theories

implicit

explicit

constructs, e.g. 'procepts'

wide general, e.g. activity theory

education, e.g. pedagogic codes

narrow maths education, e.g. TDS

Theories in maths education have nothing to do with theories in maths/logic. Think ‘framework’ or ‘paradigm’ or ‘world view’.

Implicit theories   We must have a ‘world view’ to make statements, e.g. what ‘world view’ in: *High ability students are more attentive in class*?

On data collection-analysis-interpretation

Two controversial claims

1) Types of maths education researchers

2) Theories for data analysis and theories for data interpretation need not be identical. I will illustrate this in my two examples.

	Collection	Analysis	interpretation
Armchair			✓
Amateur	✓		
Jobbing	✓	✓	
Teacher	✓		✓
Professional	✓	✓	✓

Monaghan, J. (2004) Teachers' activities in technology-based mathematics lessons. *International Journal of Computers for Mathematical Learning*. 9, 327-357.

Threlfall, J., Pool, P., Homer, M. and Swinnerton, B. (2007) Implicit aspects of pencil and paper mathematics assessment that came to light through the use of the computer. *Educational Studies in Mathematics*. 66(3), 335-348.

INVESTIGATING THE MOVE FROM OCCASIONAL TO REGULAR USE OF ICT IN MATHEMATICS CLASSES

Working closely with 13 teachers over a one year period

Aims

1. **To describe continuity and change in patterns of teaching and learning**
2. **To model teachers' preparation for and use of resources in ICT-based lessons**
3. **To examine the interactions between teachers and students' attitudes and beliefs, to mathematics and to ICT, and their activities in the ICT-based lessons**

Re Aim 1

A lot of observations – video recordings of 51 complete lessons were analysed using SCAN

SCAN, three time scales – ‘activity’, ‘episode’ and ‘event’.

Lessons viewed as a series of activities, e.g. teacher exposition, students working, teacher-student dialogue.

Each activity is viewed as a series of episodes, e.g. coaching, explaining.

Events sub-divide the episodes into social and linguistic categories, e.g. managerial, confirmation.

Coding, 30 second blocks. <u>T</u>eacher, <u>Ep</u>isode, <u>St</u>udent

T										
Ep										
St										

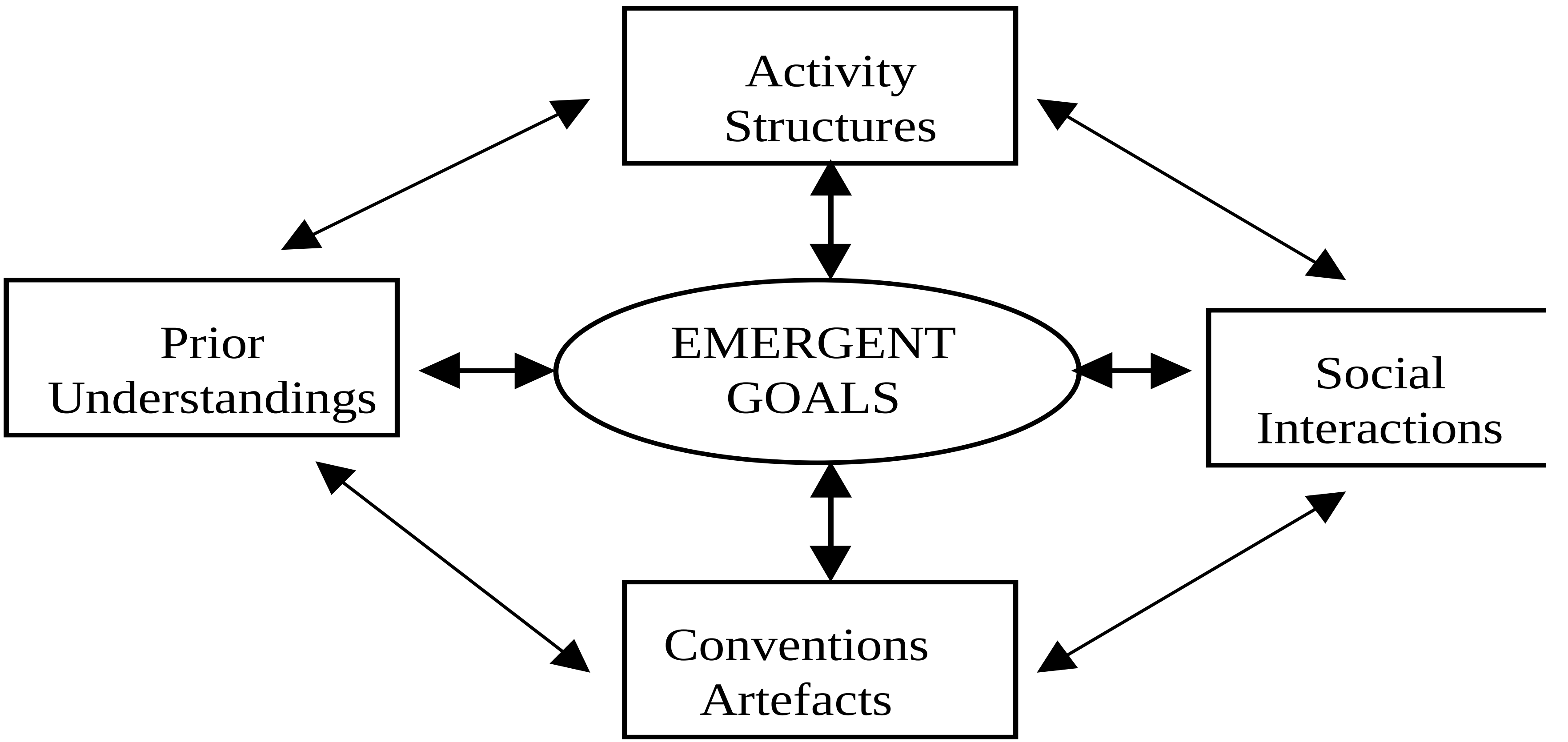
	C	D1	D2/3	Co	EFi	EFt	a	i	cf	qi	qt	α1	α2	α3	β1	β2	β3	γ1	γ2	γ3	time
1	47	39		28	37		15	9	4	15		4				11					29
2	55	28	13	6	8	64			2	6	3	7				2					34
3	26	50	21		72	17	25	42	35	34	4	19			1	16	2				36
4	35	58	3		23	55	44	45	27	18	22	20			2	13				5	35
1	68	21		39	27		5	2	3	51		36	3			12					70
2	41	34		4	17	37	1	18	1	4	3	4				3					70
3	19	74		8	77		61	33	7	33		24	3		1	4			1		59
4	41	44	10		63	25	65	46	8	37	18	44	1			8				2	64
1	61	11		46	7		11	34		38		31				7					70
2	62	25		27	6	39	42	88	2	1	9	5				5					72
3	61	21			35	38	48	80	21	14	19	22	2			11					71
4	38	21			31	20	32	61	12	16	2	13				5					59

SCAN statistics which show a marked difference over all 13 teachers

	non-ICT	ICT
(1) the percentage of time spent in teacher-whole class exposition (C)	48%	19%
(2) the percentage of time teachers spent talking to two or more students (D2/3)	28%	45%
(3) the percentage of time teachers spent coaching or eliciting ideas from students (Co)	19%	4%
(4) the percentage of time teachers spent explaining or facilitating mathematical ideas (EFi)	44%	29%
(5) the percentage of time teachers spent explaining or facilitating technological features (EFt)	0%	24%
(6) the number of assertions teachers made during lessons (a)	9	35
(7) the number of instructions (or initiating remarks) teachers made during lessons (i)	15	50

Interesting but … so what?
Analysis but limited interpretation on why what was happening was happening.

Interpretation: Saxe's model



Extract from Monaghan (2004) :

"Digital technology is only one tool a teacher may use and, when used, it does not act in isolation ... Textbooks and worksheets are tools which emerged as having significant interrelations with technology use … Awareness of changes in practice from different tools is important ... This 'tool shift', textbooks to technology, interrelates with the **activity structure** (tasks and cycles) of lessons and may conflict with teachers' **prior understandings** of 'a good mathematics lesson', e.g. the teacher .. who was uncomfortable with the focus on cell arithmetic … she voluntarily planned this task and wrote a worksheet which resulted in a focus on cell arithmetic and this discomfort only emerged in practice because her emergent goals in the lesson were shaped by the need to get the spreadsheet cells right.

I prefaced this example with

"Theories for data analysis and theories for data interpretation need not be identical"

There was a theory (implicit in SCAN) in data analysis but I used a different theory (Saxe's model) for interpretation.

Second case study and data collection-analysis-interpretation. Conducted by colleagues in the Mathematics Education Research Group, University of Leeds.

Implicit aspects of pencil and paper mathematics assessment that came to light through the use of the computer

John Threlfall, Peter Pool, Matt Homer, Bronwen Swinnerton

- This was ‘jobbing’ research for the QCA
- QCA wanted
  - to offer ICT alternatives to P&P exams
  - to know whether ‘equivalent’ ICT and P&P were actually equivalent
  - a report (including statistics)
- QCA determined that KS2 (11 years) and KS3 (14 years) tests would be used
- The 2004 research was conducted using 2003 national tests

24 questions selected at each KS (aimed at middle attaining students)

‘equivalent’ ICT tests were designed

Each student did 12 P&P and 12 ICT questions

800 students (400/KS) took P&P and ICT tests

Group	P&P	ICT
1	ABCDEF GHIJKL	MNOPQR STUVWX
2	MNOPQR STUVWX	ABCDEF GHIJKL
3	ABCDEF MNOPQR	GHIJKL STUVWX
4	GHIJKL STUVWX	ABCDEF MNOPQR

NB an unavoidable aspect of the research but a cool means of control

Data collection

Representative sample of school, whole classes

Sample observations of classes doing tests

Each question was marked (right and wrong; additional data collected) – not 'ideal' but the intended format

ICT answers based on final screen shot

Data analysis

Facility (% correct) for each question/format calculated

(actually a little more complicated – see the paper for details)

Results

Overall the performance was comparable in each medium: at KS2 students scored 3% better overall on computer than on paper; at KS3 the pupils scored 5% better overall on paper than on computer.

Questions showing a large difference

	Question	P&P facility (%)	ICT facility (%)
KS2 Higher facility on ICT	Length	39.5	52.7
	Circles	64.5	88.1
	Sum	77.1	94.9
	Diagonals	35.9	67.3
KS2 Higher on P&P	Blocks	69.0	56.8
KS3 Higher on ICT	Calculation	21.2	32.9
KS3 Higher on P&P	Shapes	49.0	14.6

Circles & Shapes

Circles states

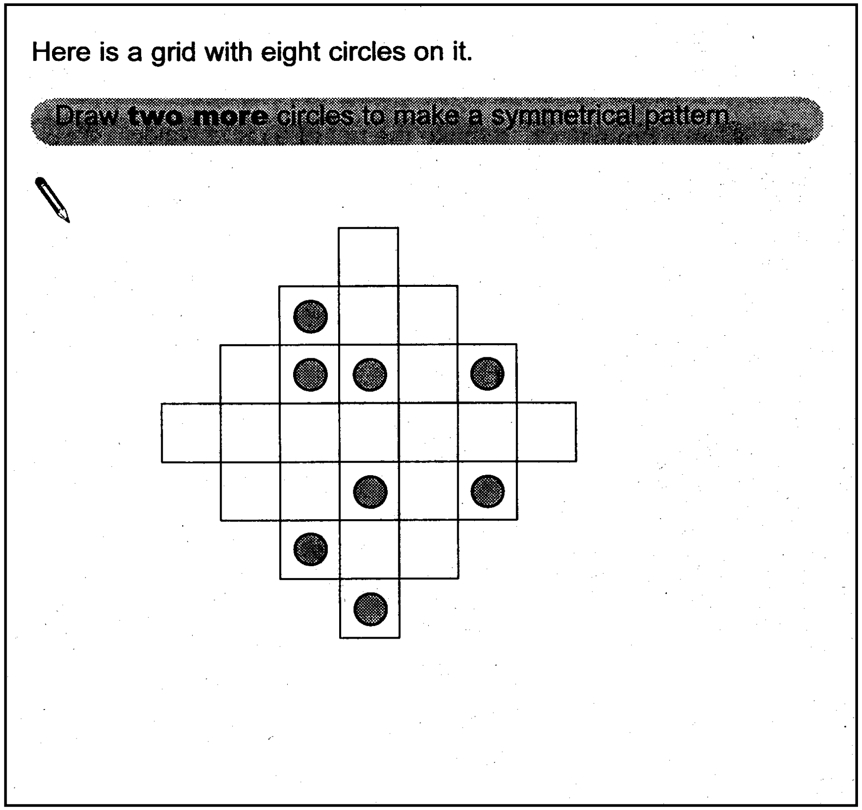
"Here is a grid with eight circles on it"

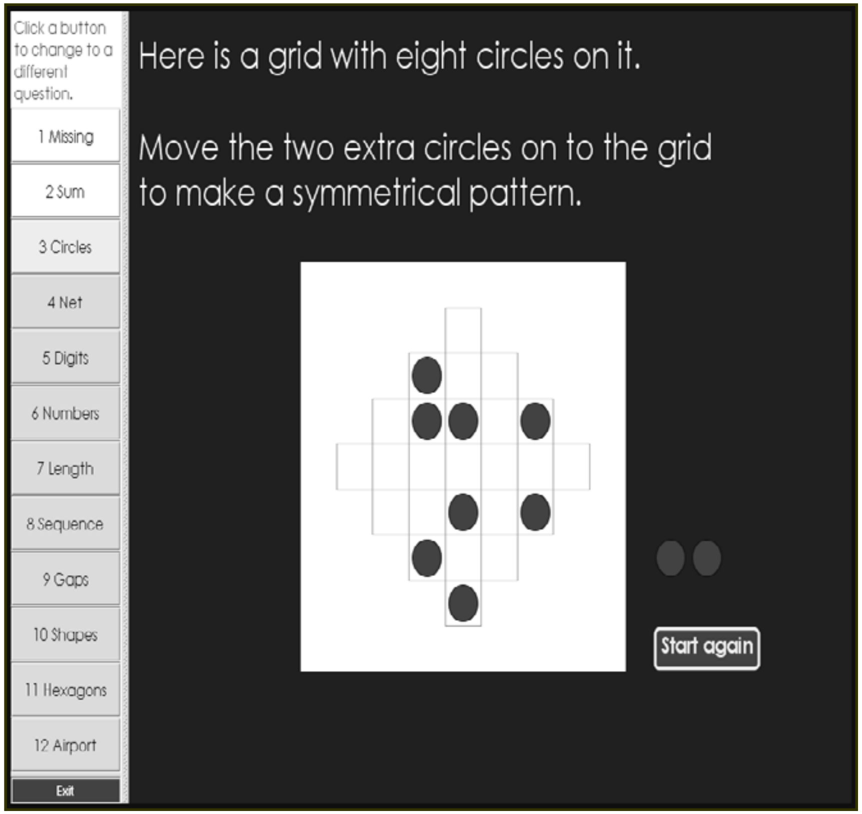
The paper-based item states

"Draw two more circles to make a symmetrical pattern"

The computer-based item states

"Move the two extra circles on to the grid to make a symmetrical pattern"





Facility on paper: 64.5%

Facility on computer 88.1%

The paper and computer versions of *Circles*

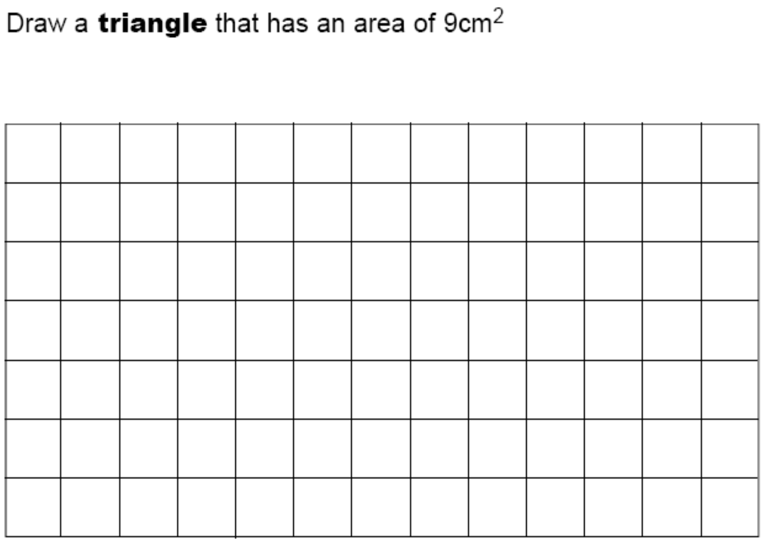
Shapes

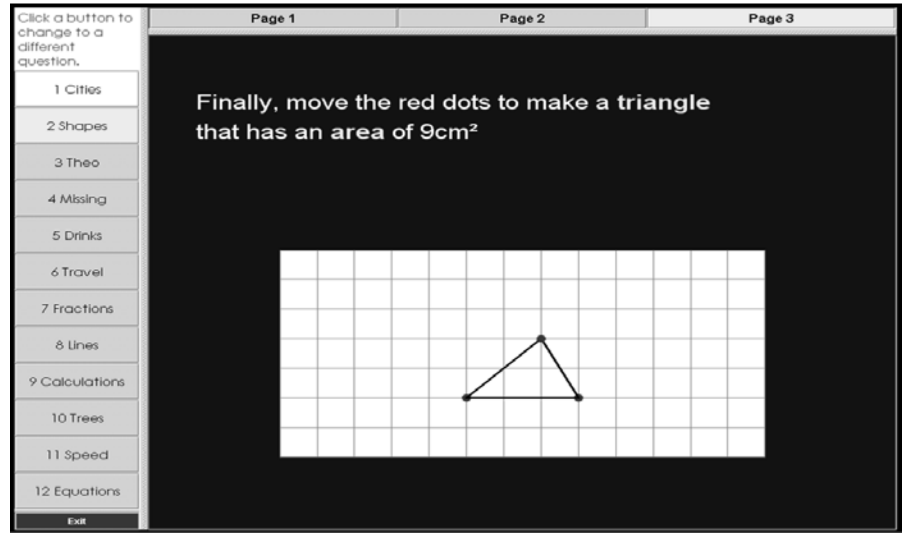
The paper-based item states

"Draw a triangle that has an area of 9cm^2"

The computer-based item states

"Move the red dots to make a triangle that has an area of 9cm^2"





Facility on paper 49%

Facility on computer 14.6%

The paper and computer versions of *Shapes* (third part)

For the Report to QCA the results were presented and possible reasons suggested (in a practical manner). For an academic paper **interpretation** of the results were sought. The construct ‘affordances’ (of ICT in this instance, of tools in general) and ‘attunements’ (patterns of using artefacts for practices) was their means to do this.

Circles

... two circles have to be located so as to make the overall design symmetrical. On paper, the circles cannot actually be drawn until after a decision has been made about where they should go … The pupil needs to decide that it will look right without being able to try it … On computer, the pupil can put the two circles on and make a judgement by recognition – does this arrangement look symmetrical? … Here the affordance of the computer medium enables easier success – by recognition of symmetry … The implicit aspect of the paper assessment is that a desirable understanding of symmetry is more than just the ability to recognise it when one sees it, but also should incorporate elements of visualisation and / or analysis … then the activity afforded by the computer is not legitimate for the assessment, and the computer question is an inferior assessment item.

Shapes:

… it might be thought that the computer version would be easier for pupils … affordance of exploratory action – pupils can try out different shapes ‘for size’ … on a trial and error basis …It seems that the computer affordance to enable exploratory action was not as useful as might be supposed. ... On the paper and pencil question … most pupils began by drawing a horizontal line, and then building a triangle up from it … and many pupils evaluated size by counting squares. ... The computer version of Shapes seems to require a more analytic and strategic approach to the problem than the paper version does. On paper … the affordances of the medium, starting with a plausible line, then seeing what it leads to. In the absence of a similar attunement to the computer affordances … pupils probably had to consider the problem in terms of the formula for the area of a triangle, …

How research could be used by mathematics teachers/lecturers?

Why education research is often neglected?

First an observation

Research is just research, it is not a cure for problems but can be used in the solutions of problems. Dangers arise if too little – and especially if too much – is expected of research.

How might Monaghan (2004) help?

"Saxe's model provides one way of viewing teachers' technology practice 'as a whole'. It allows us to consider the interrelations between tools, conventions, social interactions, prior understandings and activity structures in activities where unexpected emergent goals come into being and pass away. The model accounts for diversity in practice. It does not provide expected outcomes. In particular it does not provide pre- and in-service teacher trainers with models for teacher development. If training, however, includes reflection on practice and/or case studies, then an appreciation of the dialectics of emergent goals may help teachers to appreciate the dynamics of practice."

In a similar manner Threlfall et al. conclude:

"In some cases the methods that are used in the paper questions are legitimate means to answer the question in terms of the mathematics that is being assessed, and the computer question is less appropriate as a means to assess that mathematics. In other cases, the paper version allows pupils to answer successfully using means that are not legitimate for the assessment, and the computer version is more valid."

As to my questions:

I think research could (should!) be used by mathematics teachers/lecturers to help them understand and work towards solving problems. And I think it is often neglected because research seeks an understanding of issues.

This leads to how mathematicians and maths education researchers can work together:

(i) understanding an issue

(ii) practical work towards a perceived positive resolution of the issue.

Both should be involved in (i) and (ii):

mathematicians in (i) because involvement in an activity increases understanding;

maths education researchers in (ii) to keep their research focused on practical needs.

As Threlfall et al. conclude, with regard to their 'framework of analysis':

"improvement to assessment is not determined by the framework of analysis, but has to be addressed on a case by case basis by mathematics practitioners and the mathematics community. It requires clarity in what is wanted from assessment – What behaviours are valued? Which approaches are legitimate? With these questions clarified, the analysis can proceed to suggest whether a computer-based assessment item is more or less likely to assess the mathematics fairly compared to its paper-based equivalent."