Editors note: Unfortunately we were unable to obtain the full paper for this lecture. However, the editors thought it maybe useful to include the OHP slides for Richard Browne's keynote lecture.

The role of calculators and computers in national assessment of mathematical attainment:

where we are now and where we may be going

QCA

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Overview

QCA's role and responsibilities

My own interest in computer algebra systems (CAS)

What are the issues?

What have QCA and predecessors done about these issues?

What does the future hold?

Issues

Should CAS be used in teaching mathematics and in mathematics examinations?

If so, when and how should they be used?

Should aspects of current teaching and assessment be adjusted as a result?

The analogy with four function calculators

The Secretary of State's 'ban' following the Numeracy Task Force report

'There is no place in primary school mathematics lessons for using calculators as a prop for simple arithmetic, since children are still learning the mental calculation skills and written methods that they will need throughout their lives. Used well, however, calculators can be an effective tool for learning about numbers and the number system...'(NTF report p 52)

The *Framework for teaching mathematics* identifies two roles for calculators:

- to enable pupils to use real data to work out a percentage or compare totals or proportions;
- to help learn about numbers and the number system, place value, properties of numbers and fractions and decimals

The analogy with four function calculators (continued)

The *Framework for teaching mathematics* goes on to say that pupils should be able to:

- decide whether to use mental, written or calculator methods;
- to draw on sound estimation skills;
- to check whether their answer is correct

'By the end of Key Stage 2, pupils should have the knowledge and competence to use a calculator to work out $(56+97)\div(133-85)$ and round the answer to one decimal place. They should also recognise that an approximate answer is $150\div50$, or 3, and use this to check their calculation.' (*Framework*, p8)

QCA's guidance document '*Teaching mental calculation strategies*' takes a similar line:
'The calculator does not do the strategic thinking for the user. It is important … to decide what operation is appropriate..[and]..to ask whether the result makes sense.' (p55)

Three types of calculations

Those that I always do mentally

Those that I only do with a calculator

Those I could do mentally, but frequently resort to a calculator to resolve

Implications for using CAS

First, we need to think about the implications of information about what calculations we each do mentally for national policy

We need to be clear whether the analogy with four function calculators holds good

And, for the purpose of this talk, I need to consider the implications for examinations and assessment.

Using CAS for teaching and learning

In principle, CAS should be useful to:

- support an investigative approach to learning, ensuring many examples may be considered and calculations are correct;

- give immediate reinforcement through rapid, accurate feedback, for example regarding the shape of a graph;

- ensure that calculations from a pedagogically earlier stage are always correct, thus permitting pupils to concentrate on the present learning objectives;

$$3x = 21$$
$$3x - 3 = 18$$

- avoid miscalculations that are likely to arise if pupils know what their strategy is supposed to achieve, for example when working with simultaneous equations.

The Austrian CAS projects

In Austria, CAS have been given extended trials in a number of projects. What can we learn from these?

Students must recognise the structure of expressions before entering commands

Students must recognise the structure of and interpret results they themselves did not produce

The variety of routes to solutions increases dramatically

A shift from calculating skills to conceptual understanding occurs

There was improved enjoyment of the subject

A need for an agreed notation for recording solutions emerged, especially in examinations

The Austrian CAS projects (contd.)

In an evaluation of the Austrian projects, the following points were made:

In classes using CAS pupils showed fewer skills in manual calculation

In classes using CAS pupils showed better competence in reasoning and interpreting

Even carefully planned use of CAS did not lead to improved competence in applying formulae or finding errors when working without CAS

Many pupils could find and detect mistakes they had made manually by using CAS

Indispensable manual calculation skills

I list below a number of problems that have been described as unsuitable for an examination without CAS support

They follow the rule that an elementary calculation is an indispensable skill, while an iteration of two or more such calculations may be delegated to a calculator

I have listed only some of the items, and only ones that I regard as indispensable manual skills

Find the factors of 30
Simplify $\sqrt{80}$

I should like to propose an alternative rule, at least for me personally. I should only delegate work to my CAS if I cannot (or will not, knowing that I can) do it mentally or in a few seconds with pencil and paper
Simplify $7\times\frac{2}{5}\div\frac{4}{6}$

Simplify $\frac{100x^3y^2}{10xy^5}$

Indispensable manual calculation skills (continued)

Eliminate the brackets $(2a+t)^2$

Factorise x^2-x-6

Completing the square

Product rule for differentiation

Chain rule for differentiation

Differentiate $x\sin x$

Differentiate $\sin^2 x$

Should we permit CAS in examinations?

Graphic calculators are now permitted in English National Curriculum tests at age 14, in GCSE Mathematics examinations (one of two papers) and expected in A/AS examinations (in papers worth up to 80% of the credit)

We now have non-calculator papers in NC tests and in GCSE and will permit only scientific calculators to be used in A/AS papers worth 20% from next September

CAS may still not be used. Why not?

Purposes of non-calculator papers

To ‘ensure’ candidates can handle basic calculations using mental and pencil and paper methods

To ensure basic graphical work can be done without technological support

To ensure basic algebraic work can be tested, since permitted graphic calculators now offer solutions to several kinds of problems

Purposes of scientific calculator papers

Not numeracy, but otherwise the points from the previous slide remain valid

To encourage examiners to use some straightforward questions to test candidates' basic knowledge; these may or may not involve calculation

To ensure candidates really do have to know a set of formulae, at least in some papers

How did QCA arrive in this position?

SCAA began to consider the significance of Derive and other CAS

We looked at the kinds of examination questions that might be needed if candidates were permitted to use CAS

We considered how we might advise principal examiners

We considered how the curriculum might need to be adjusted

We rewrote one set of A level papers with a view to a future in which CAS could be used

Maintaining standards and comparability

QCA's main assessment task is to maintain standards, comparability and fairness to candidates

For GCSE and A/AS examinations we have introduced non-calculator or weak-calculator requirements which guarantee basic numerical/algebraic competence

We do not need any further assurance. From the perspective of standards and comparability CAS could be used

Cost and fairness

However, fairness to candidates means not permitting expensive support equipment that is likely to give advantage

Our view is that the current cost of CAS is too high to permit its widespread use in public examinations

Those who can afford CAS would be advantaged because we cannot write examination papers that are equally challenging with or without CAS

Preparing for the future

Altering the cost of CAS is beyond QCA's control. However, we do need to work with examiners towards a time when CAS are permitted.

We need to increase expertise in considering how best to use CAS capabilities in examinations, without making the papers harder, and without making the papers less accessible to weaker candidates

We need to encourage the use of CAS in other subjects, eg Physics, where it should be less significant whether students can do the algebra without the calculator.

We need to aim towards a future moment when CAS are widely used and when there is much more general agreement about the competence that is needed as a basis for effective CAS use.

Above all, we need clear evidence from those who have trialled the use of CAS about the advantages of using them, especially about unexpected new ways of learning mathematics that emerge.