We intend to look at three questions:

- ✶ *Our more general aim was to employ technology that was personal and easy to use in a way that pushed the students into collaboration to talk about mathematics, and therefore raise achievement. Our impression is that this occurred. This study was too short to test this formally, which should be the next step.*
- ✶ *Work with personal technology encourages the adoption of an open-ended teaching and learning style. "The students can get on more and find out things for themselves. They retain more by finding out for themselves," said Kirti Patel. What effect does this have on pupils' confidence and attitude to mathematics?*
- ✶ *More work is needed to integrate paper-and-pencil and graphic calculator methods, and to combine visual and symbolic strategies. We would ask if the adoption of a visual or a symbolic strategy to investigate parallel and perpendicular lines leads to better achievement.*

Three teachers from the project ran a workshop at the Association of Teachers of Mathematics (ATM) 1997 Easter conference in Oxford.

Teachers will publish the work in articles for the professional journals *Mathematics Teaching* and *Maths in School*.

We contributed a paper to the British Congress in Mathematics Education weekend conference in July 1997.

We will contribute to a pamphlet series on small-scale classroom research (Anne Watson, Education Department, Oxford University).

The other members of the study team were Christine Atkinson, Bola Abiloye and Kirti Patel at Sarah Bonnell School and Sarita Sidbu and Stuart Llewellyn at John Kelly Girls' School.

Further reading

Hart, Kathleen, "Concepts In Secondary Mathematics Project At King's College", in *Children's Understanding of Mathematics: 11-16*, John Murray, 1979.

Smart, Teresa, "Visualisation, Confidence And Magic" in *Technology in Mathematics Teaching – a Bridge Between Teaching and Learning*, Chartwell-Bratt, 1995.

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Girls, calculators and graphic concepts

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AIM

To help students to improve their understanding of graphs with the use of a graphic calculator.

SUMMARY OF FINDINGS FOR THIS CASE STUDY

- ✶ Secondary school students overcome traditional misconceptions about plotting, interpreting and reading graphs if teachers mix pencil-and-paper work with the use of a graphic calculator.
- ✶ This improved understanding is shown on pencil-and-paper tests.
- ✶ Using the graphic calculator in the classroom increases the confidence of teachers in using new technology.

A research project commissioned by the Teacher Training Agency as part of the Teacher Research Grant Scheme 1996/97

The study

Personal technology such as the graphic calculator has the potential to raise achievement and improve mathematical understanding. To show how this potential might be fulfilled, the researchers selected a well-known area of difficulty – graphs. The researchers then set out to collect and develop teaching materials for use with the graphic calculator, and to determine if understanding was improved.

The research was undertaken in eight classes of girls from Years 9 to 11 (aged 13–15) in Sarah Bonnell School in east London and John Kelly Girls' School in north-west London. Seven teachers participated, including the two heads of department who wrote this paper.

The project was carried out over three weeks in October and November 1996, and involved between eight and 10 classroom hours for each class. In some cases the class worked exclusively in the area of functions and graphs over one period, while in others the teaching was mixed with the teaching of other curriculum areas, such as fractions and equations, to allow the teacher to complete an already designed scheme of work.

Girls in Years 10 and 11 (six of the eight classes) should already have learned the concepts. Pencil-and-paper tests were given before and after, and levels of understanding compared.

Misconceptions to be overcome

Plotting, using and interpreting straight-line graphs have an important role in the National Curriculum at Key Stages 3 and 4. Secondary students learn to plot graphs and answer examination questions. But they often fail to understand the basic concepts and frequently show fundamental misconceptions about plotting, interpreting and reading graphs. This causes problems later when they try to use graphical concepts – for example, to investigate relationships in science.

"The lack of understanding appears to come from the conventional form of pencil-and-paper practice with graphs."

This study tried to overcome four common misunderstandings:

- *most children do not appreciate that a line on a graph is made up of an infinite number of points;*
- *students can draw the graph of a function, but given a graph they cannot find the function;*
- *students can find the gradient of a straight-line graph but often do not believe that the gradient really is constant;*
- *many students do not appreciate that the intersection point of two linear graphs is the solution to the two equations.*

"Using the graphic calculator in the classroom increases the confidence of teachers in using new technology."

If Year 10 students are asked to plot the graph y = 2x, they will typically select three values of x – say, 1, 3 and 5 – find the values of y and simply connect the dots. Asked how many points are on the line, they will say three or perhaps five, mentally including x = 2 and x = 4. Asked if the point (1.5, 3) is on the line, they often say no.

This lack of understanding appears to come from the conventional form of pencil-and-paper practice with graphs, in which students plot graphs by selecting a few integer values. The graphic calculator is a calculator that has a larger than normal screen on which it plots graphs. Teachers have found that using the calculator for rapid plotting of a large number of graphs gives students another way of visualising graphs. This extends and deepens the initial understanding they gained with pencil and paper.

Activities

Classes were introduced to the graphic calculator and worked through teaching sequences in four areas related to straight line graphs.

What is a graph? – Using the calculator to trace along a graph and reading off the values of x and y, introduce children to the concept that the graph represents a relationship and is not simply a finite set of points.

Exploring straight line graphs – This involved investigating the graphs of y = ax + b for different values of a and b, especially looking at both positive and negative values. This allows students to gain a better understanding of the position or placement of the line as a and b vary.

Simultaneous equations – We looked at the intersections of two lines and explored the relationship between them and the pairs of simultaneous equations.

Plotting data – Pupils were given data and attempted graphically to find a linear relationship.

Results

Pupils in Years 10 and 11 (six of the eight classes studied) had already been taught and tested on this material as part of their normal mathematics classes. We set out to assess improvements in understanding because of additional work with the calculator.

Similar tests were given before and after the study period. Three sets of questions demonstrated unambiguous improvement in all eight classes:

- *In all classes and abilities, students showed a better understanding that a graph contained an infinite number of points, and were able to identify points with non-integer values;*
- *Students were better at matching graphs with equations, although many still found difficulties with y = ax + b when a was negative;*
- *In the pre-test most pupils could not solve simultaneous equations graphically, while in the post-test, most could.*

Three teachers involved in the research commented on the response of the students. "The most significant aspect that came across from the use of graphic calculators with my class was the idea of an infinite number of points on a line; using the 'trace' button was ideal for visualising this," said Bola Abiloye.

"The graphic calculators were very important. They enabled the students to see how the shape of the graph changes when the equation changes," said Kirti Patel.

"Before they might have tried only y=2x or 3x, but the calculators gave them confidence to try something like y= 1.9x as a model for data," said Christine Atkinson.

Teachers' confidence in technology

The project was intended to study student improvement. An unexpected result has been that the teachers say they now feel more confident in using technology in their maths lessons. Some teachers privately admit that they are not comfortable with using computers and other new technology as part of the syllabus and that this research gave them experience in that area. "I would use the graphic calculators for other topics, because I have got a lot more confident in using them," said Kirti Patel.

Teachers' involvement and future research

Both schools in the study have a history of under-achievement in mathematics. The seven people involved in the study were all experienced teachers keen to raise girls' achievement in mathematics. Only three of us had previously been part of any formal classroom-based research. The Teacher Training Agency project gave us a deeper insight into the process of doing research on our own students. "I gained in experience by doing the research; I would do some more," said Kirti Patel. "We learned a lot from this project. We allowed too many variations between teachers on this one," admitted another teacher. "I feel we could do a better piece of research next time," she said.

We have produced a set of curriculum materials on the teaching of functions and graphs with a graphic calculator. We will publish this together with a literature review and more detailed findings in a booklet available to interested teachers and researchers.

The research pointed to further questions that require answers, and most of the teachers involved – as well as other teachers in the two schools – wish to continue the project as a way of giving their teaching a stronger research base.

"More work is needed to integrate paper-and-pencil and graphic calculator methods, and to combine visual and symbolic strategies."