Goodchild, S. (Ed.) Proceedings of the British Society for Research into Learning Mathematics 22(1&2) Feb/May 2002

DO TEACHERS UNDERSTAND THE THEORY BEHIND CAME?

Maria Goulding

Department of Educational Studies, University of York.

The Cognitive Acceleration in Mathematics Education (CAME) project aims to improve children's thinking in mathematics and to enhance their achievement. The learning theory underpinning it is described as 'Piaget and Vygotsky in tandem', together with a theory of professional development involving networks of teachers and direct modelling of lessons by trainers. Twenty-one teachers involved in the project were interviewed to investigate their understanding of the theory and their explanations for learning gains. They stressed some aspects of the learning theory much more than others and identified dispositional changes as the most likely explanation for performance gains.

INTRODUCTION

This research was prompted by informal conversations with teachers in the North East of England where all secondary schools in one Local Education Authority (LEA) are involved in the CAME project. Some of the teachers were members of the Durham branch of the Association of Teachers of Mathematics (ATM) and were also involved in school mentoring of students preparing to be secondary mathematics teachers on the Post Graduate Certificate of Education (PGCE) course at the School of Education, University of Durham. As ATM Branch secretary and tutor responsible for the mathematics element of the PGCE course, I became very aware of the interest and enthusiasm which was generated by local involvement in CAME. There was a hint of scepticism in my reaction, since similar interest in past interventions seemed to have been dissipated as new initiatives replaced them. I wanted to find out if these teachers had a good grasp of the aims and principles of this project and if they could articulate these in a considered way.

The CAME project is a younger sister to the Cognitive Acceleration in Science Education (CASE) project, which started at King's College, University of London, in the 1980s. Pupils involved in CASE between the ages of 11 and 13 performed better in public examinations at ages 14 and 16 not only in science but also in mathematics and English (Shayer, 1999). Interestingly, in the Key Stage 3 tests for 14-year-olds, the effects on mathematical achievement in CAME schools were large enough to be statistically significant but those in Science and English were even larger (Shayer, Johnson, Adhami, 1999). At a time when educational discourse in England and Wales is dominated by performance and standards in the core subjects of the National Curriculum, these effects are of great interest nationally. As a cautionary note, despite generally positive effects in CAME schools, there were variations between schools and between classes within them; the project director attributes this to teachers delivering lessons in isolation, rather than as part of an in-school professional development programme, with pooling of experience and use of outside expertise

(Johnson, 2001).

THEORETICAL BACKGROUND

Unlike general thinking skills (GTS) programmes (McGuinness, 1999) CASE and CAME are both rooted within subject disciplines but share elements of learning theory. The move from concrete to formal operational thinking is derived from Piagetian psychology, but the idea that this transition should be made possible for more pupils by appropriate mediation in a social context draws on Vygotsky. The timing and duration of the intervention is also seen to be critical. The authors identify a 'window of opportunity' between the ages of 11 and 13 when a growth spurt results in an increase in the number of synapses in the brain (Adey and Shayer, 1994). The programmes were designed as an addition to the 'normal' Science and Mathematics diet but followed over two years, since Feuerstein's research indicated that unless such a programme covered two whole years it was unlikely to have a permanent effect on pupils' development (Shayer and Beasley, 1987).

It could be argued that putting Piagetian and Vygotskian theory together in this way ignores some key differences in their perspectives, notably epistemological questions about the nature and status of knowledge. Whereas Piaget stresses individual cognition and sees logic and reasoning as the pinnacle of human thought, Vygotsky's sociocultural perspective prioritises language and social process, with community growth and verification of knowledge. These differences tend to be glossed over with the key elements of CAME simply outlined by Shayer (1999) as

	Piaget	Vygotsky/Fueurstein
Schemata of formal operations	√	
Concrete Preparation	√	√
Cognitive conflict	√	
Metacognition		√
Bridging		√
Construction	√	√

It is beyond the scope of this paper to produce a thorough critique of the theoretical background to CAME. In the following section I simply intend to clarify the meanings of the above constructs as set out in the commercially produced CAME teaching materials, 'Thinking Maths' (TM) (Adhami, Johnson, Shayer, 1998).

1. Formal operational schemata are described as "the reasoning patterns" involved with

- control of variables, and exclusion of irrelevant variables;
- ratio and proportionality;
- probability and correlation;
- the use of abstract models to explain and predict. (Adhami, et al. 1998, p. ix).

2. Concrete preparation is taken to be the phase when the teacher introduces the pupils to a problem embedded in their own experiences, draws out links with previous ideas and clarifies expectations for the next phase.

3. Cognitive conflict: In some of the TM activities pupils may be led to experience contradiction which do not fit their previous experiences, and may have to restructure their thinking to accommodate new evidence

4. Metacognition is taken to mean 'reflection on thinking', a process which will usually take place towards the end of the whole class discussion when pupils will share strategies and conclusions, with teacher intervention.

5. Construction may take place in the whole class concrete preparation phase, or when pupils are working in groups on task or in the whole class discussion following small group work. In TM it is described as "the process by which more powerful strategies or concepts are generated to solve a problem".

6. In CAME, the aim of transfer across and within subjects for pupils and teachers is behind the construct of bridging, linking the underlying concepts to situations in other subjects or in later CAME lessons (pupil transfer), and bringing it all together, integrating the strategies in TM lessons with "normal good practice" (transfer for teachers) (Adhami et al., 1998, p. xiii).

All these elements are to be incorporated in highly interactive and collaborative lessons, where the teacher needs to manage pupil talk – challenging and developing their thinking by appropriate prompts, introducing technical language and stimulating the summary and review session. She needs to mediate opportunities for pupils to "internalise in a flash some better understanding" (Adhami et al. 1998, p. xii.) and by sharing such insights, for peers to witness the performance of someone who is "just beyond them".

THE RESEARCH

All the regular teaching practice schools in the region using CAME were invited to take part in the research and all accepted. This amounted to six schools, 3 from the local authority already mentioned. Heads of Department distributed questionnaires eliciting background information and inviting teachers to take part in interviews. In the end, 17 teachers, 3 students teachers and 1 teacher not in a partnership school were interviewed. They represented a cross section of age, experience and training, and the schools represented ranged from those in difficult circumstances striving to raise attainment to those in affluent catchment areas with examination results well above the national average.

A structured set of open questions were used. The questions first elicited contextual information, then moved to enquire about particular CAME lessons and particular preferences and comparisons, before moving on to ask about the principles on which CAME is based and the teachers' explanations for improved performance.

FINDINGS

The teachers were not expected to use the language of the project developers in their responses, rather to articulate elements of the theoretical background in their own words and using specific examples. Three main categories emerged in the analysis: mathematical thinking, constructing understanding and classroom processes. The fourth category brings together teachers' explanations for performance gains. In the following transcripts / represents a short pause.

Mathematical thinking

The strongest theme to emerge was the teachers' preference for algebraic activities and the striking way in which the project seemed to be developing 'algebra'.13 teachers made specific reference to algebra, usually in terms of pupils' ability to produce general expressions in words and symbols or in representing functions graphically:

> They think using letters/ formulas P=2L + 2W or however they get it P=L times 2 plus W times 2/ I can't believe how quickly that comes out

> They connect formulae to the line, the gradient, the y intercept

Only two teachers described algebraic ideas such as hypothesising and predicting

> There was a big argument about how the P would relate to the area/ the long skinny one/ does it have a bigger area than the one with the smallest perimeter

Reasoning patterns associated with rates, ration and proportion were referred to by 7 teachers, but with more caution than the algebraic ideas:

> This doesn't do it for me/ going from $C/d = \pi$ to $C = \pi \times d$

This tentativeness may show that the teachers regard these as difficult ideas, perhaps as examples of higher order thinking but that they are not sure if the pupils are capable of making these leaps.

Constructing understanding

It was very difficult to find teachers identifying the restructuring of previous ideas in the face of contradictory evidence, but one teacher did refer to conflict when explaining how she had first heard about the CASE project at her school and in her own subsequent use of CAME:

> Manufacturing conflict/ you set up a row and try to referee it

The nearest the other teachers came to this were the three who talked in general about challenge

> Challenging them/ stretching their thinking

Comments about metacognition could be found in 8 responses, when teachers talked about the opportunities to compare and evaluate methods in the review stage

> The advantages and disadvantages of different methods

Seven teachers gave specific examples of bridging:

> Some remembered this in their coursework from 2 years ago

Similarly, seven teachers gave specific examples of teachers bringing it all together by talking of similar approaches in their other lessons or expressing the desirability of this.

Classroom processes

It was very common for teachers to talk about classroom processes distinctive to their CAME lessons. Virtually everyone mentioned the role of discussion between pupils as a means of involving pupils in co-operative activity, listening to each other, and talking through their own ideas.

> They are a lot more able to talk about their work/ they're not so shy/ they explain their thinking, don't mind if it's wrong

Hand in hand with this emphasis on discussion were comments from 11 teachers about the unimportance of recording, which was seen as both a relief and a source of tension:

> Like/ and I do it in other lessons/ what you've written down is not important/ what is the state of your mind/ what you've learned and understood I really emphasise/ you don't need your pens, deep thinking

> I feel guilty/ the work comes in and I throw it out

Four teachers went beyond the idea of co-operation to talk about peer learning and teaching:

> pulling up/ some kids will understand, through what they say will pull up the others/ I do use pulling up, I say things like 'you need to speak to him'

Six teachers talked about the teachers' role in managing discussion and 5 mentioned formative assessment:

> not having to get your point across forces you to think carefully about what you do say feeding them their lines is hard/ throwing it back on them

> number 3 was very interesting, finding out what they did, that was a real eye opener

Explanations for performance gains

Although 3 of the teachers doubted if performance gains could be attributed solely to the CASE/CAME interventions, the most common explanation (10 teachers) was best categorised as dispositional rather than cognitive

> Makes them tackle things confidently/ have a go/ the SATs and GCSEs are never what they expect

DISCUSSION

These teachers seemed to prioritise and attach weight to different elements of the underlying theory. There was some identification of the stages of constructing understanding, although cognitive conflict was rarely mentioned and metacognition tended to refer to sharing ideas in the review session. About a third identified transfer for pupils and for teachers. In terms of mathematical understandings, over half were impressed with pupils' ability to construct algebraic expressions but a third were more cautious when talking about ideas of rates, ratio and proportion. The most consistent response was the enthusiasm expressed for the increased use of discussion and argument. Knowing that CAME has produced performance gains in high stakes assessments may be giving these teachers legitimacy to teach in this way, rather than seeing it as a risky approach. If we link this to the common identification of dispositional factors as explanations for performance gains, then these teachers seem to be identifying changes in the culture of their classrooms which are not only preferable to them as teachers but are also associated with better examination performance. It could be said then that these teachers tend to lend more weight to the Vygotskian, rather than the Piagetian elements of the underlying theory.

POSTSCRIPT

When contacted after the introduction of the National Numeracy Strategy (NNS) in Key Stage 3, five schools responded. Of these, four were using CAME less, one because of staffing difficulties and the other three in order to accommodate the NNS.

REFERENCES

Adey, P. and Shayer, M.: 1994, *Really Raising Standards,* London: Routledge.

Adhami, M., Johnson, D., and Shayer, M.: 1998, *Thinking Maths.* Oxford: Heinemann.

Johnson, D.: 2001, *Cognitive Acceleration in Mathematics in Education,* http://www.kcl.ac.uk//depsta/education/research/CAME.html

McGuinness, C.: 1999, *From Thinking Skills to Thinking Classrooms,* Research Brief No 115, Department for Education and Employment.

Shayer, M.: 1999, 'Cognitive acceleration through science education II: its effects and scope,' *International Journal of Science Education,* 21 (8), 883-902.

Shayer, M. and Beesley, F.: 1987, 'Does Instrumental Enrichment work?' *British Educational Research Journal,* 13(2), 101-119.

Shayer, M., Johnson, D.C., and Adhami, M.: 1999, 'Does 'Came' work? (2) Report on the Key Stage 3 results following the use of the cognitive acceleration in mathematics education, CAME, project in year 7 and 8.' in Bills, E (ed.) *Proceedings of the day conference of The British Society for Research into Learning Mathematics,* held on Sat. 5th June 1999 at St Martin's College, Lancaster, England. pp. 26-31.