The impact of a thinking skills approach (CAME) on students' mathematical ability

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Publisher:
Educational Studies in Mathematics (2007) Vol. 64, pp. 265-291

[Original title:
Fostering cognitive development through the context of mathematics: Results of the CAME project]

Introduction

The Cognitive Acceleration in Mathematics (CAME) project was developed in response to concerns among practitioners about the mismatch between students' ability to solve mathematics problems and what the secondary curriculum demanded of them. Based on research and theory about students' thinking, CAME aims to boost the capacity for mathematical thinking of students aged 11 to 14 years and consequently raise their attainment in standard tests.

This study reports the findings from 12 schools in which students were taught CAME lessons during Years 7 and 8. Over half the 78 classes involved showed larger than expected gains in mathematics tests at the end of Year 8. After a further three years in the same schools, GCSE pass rates in mathematics were significantly higher than those in control schools. Pass rates in English and science also showed improvements.

Keywords:
England; Key Stage 3; mathematics; Science; accelerated learning; attainment; achievement; thinking skills; collaboration; learning strategy

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What effect has CAME had on students' achievement?

Researchers found that students who had participated in CAME lessons in the first two years of secondary school:

- made a range of gains against control classes – out of 78 classes 11 showed large improvements, 37 showed moderate improvements while 30 showed zero effect;
- later gained, on average, 0.80 of a GCSE grade in mathematics compared with other students whose teachers had not used the approach. Higher ability students, in particular, made substantial gains – in some classes, the proportion of students gaining a C-grade or above doubled; and
- achieved value-added gains of 0.30 of a grade in science GCSE and 0.32 of a grade in English.

The findings also highlighted a potential problem with setting in mathematics. Students in the lowest ability sets gained little from CAME lessons despite being taught by experienced CAME teachers whose students in other classes had achieved significant gains. The researchers suggested that such groups lacked higher-ability students who could provide the greater range of insights pupils needed to help them extend their own thinking. They also referred to evidence from a CAME school, which had adopted a mixed ability approach, that there were gains for students of all abilities.

The researchers also suggest that value-added gains for science and English GCSE supports their belief that the ability to handle more complex aspects of reality in mathematics can also enable students to handle complexity in other subjects too. (transfer)

What is the CAME project?

What theory underpins CAME?

The CAME project, like its predecessor CASE (Cognitive Acceleration through Science Education), is underpinned by social psychological ideas about cognitive development. From Piaget the designers of CASE and CAME took descriptors of children's intelligence, particularly the following:

- Concrete operational thinking – this characterises the thinking of 5-10/11 year-olds. They can describe with increasing sophistication the real world around them. They may be able to see patterns in observations e.g. the longer a pendulum the slower it swings but cannot 'get beneath the surface' to understand the problem further

- Formal operational thinking – some 12 to 16 year-olds can engage in reflective thinking. They propose explanations and methods for testing them. They can use mathematical symbols to express relationships. In the pendulum example they probe whether it is only the length that matters or is it the mass or angle of swing too. In their thinking they use ways of organising knowledge (Piaget called them *schemata*) including controlling variables, using proportions, correlation, for example.

What problem did CAME aim to address?

Shayer and co-workers applied these age-related descriptions to a large population of children in the 1960's and 1970's (See **Where can I find out more?**) They found that the actual profile of children's thinking abilities in a large sample of students is different from Piaget's model. The main difference was that by the age of 14 years half the population were not yet competent concrete operational thinkers. Only about 24% of the population were ready for formal operational thinking. This matters because secondary school science and mathematics curricula require formal operational thinking for the majority of students, not just the top 24%. The question then became how to improve this situation.

Why intervene?

Shayer and co-workers believed all adolescents had the genetic potential to achieve in mathematics, it just hadn't emerged for 70-80% of 14 year-olds. They believed that a school-based intervention could boost children's thinking from concrete to formal and so improve their attainment. Findings from the CASE project had shown significant improvements in students' attainment and this made the CAME researchers more confident in their approach.

How might collaboration help children's thinking?

The researchers took the view that children's thinking was not, as Piaget's work suggested, rigorously fixed by age. They drew on the ideas of the social developmental psychologist Vygotsky in order to design an intervention process for use in mathematics lessons. The two key elements of Vygotsky's work were:

- the Zone of Proximal Development (ZPD); and
- a social collaborative model of developing thinking

Vygotsky described the ZPD as the distance between the actual development level of a learner as determined by independent problem solving and the level of l development s/he could achieve under adult guidance or in collaboration with more capable peers. This suggests that testing does not tell us all that is in a child's mind at the time. There may be partially formed ideas and understandings in different degrees of completion which will surface in completed form at some stage (hence proximal).

Vygotsky believed that social activity was a key factor in developing thinking. In his view when children collaborate on a task they work in a common ZPD. Vygotsky believed that through interaction, children who are further on in their understanding of a problem (further into their ZPD), can help move other students forward too. He described this as 'mediation'.

The CAME team regarded the role of the teacher as helping in the mediation process, for which they would need to display specific skills. Their approach to designing CAME mathematical activities therefore involved creating tasks that provide maximum opportunities for stimulating thinking in a context of collaboration and dialogue. The project also built in a requirement for teachers to be trained to be effective mediators of children's thinking.

What is a CAME Thinking Maths lesson like?

CAME activities (known as 'Thinking Maths' lessons) contain enough material for 30 lessons, taught over two years. One task called 'Twigs and leaves' asks students to firstly describe the pattern relating to the numbers of leaves on some twigs then to express it in a word equation such as:

Number of leaves = number of twigs times 3 plus 2 leaves at the trunk

By this point students have moved to the high concrete generalisation stage. If they go on to replace the words by letter symbols they have begun formal thinking.

All Thinking Maths lessons have the same three stage format:

Concrete preparation

This begins as a whole class activity and is managed by the teacher who asks students to explain to each other what they think the task is about. (5-10 minutes).The aim of this part of the lesson is helping students to create a shared understanding of the task. (The authors refer to this as beginning to establish a shared ZPD.)

Collaborative learning

The students work for 10-15 minutes in pairs or small groups on one of a small number of tasks knowing they will be expected to explain their ideas to the rest of the class later. The tasks frequently lead pupils to contradictions that challenge their existing ideas. The teacher goes around the class to listen, see and note where each group has got to. Depending how far each group has got the teacher plans the order in which each group will contribute to the whole-class discussion which will follow. During this stage the teacher does not 'help' the groups but might ask a prompting question if a group seems stuck.

Whole-class discussion

This second whole-class discussion begins once the teacher judges that a sufficient variety of ideas has emerged in at least some of the groups. (Not all groups need to have completed their tasks.) Groups report ideas in the order directed by the teacher. This may involve focusing on a specific idea requested by the teacher. The teacher's role is to manage the students' interactions with each other and s/he encourages other students to ask questions. The teacher may intervene at various points to encourage students to reflect on their reasoning using probing questions and to draw pupils' attention to key ideas and vocabulary. During this phase, each pupil has the chance to extend their understanding using ideas from all the groups. (The authors suggest the discussion enables students to complete the movement through their ZPD.)

How was the research carried out?

The study is based on two sets of test data from 12 project schools:

- administration of pre- and post-tests of mathematics understanding; and
- GCSE results

The general mathematical ability of students in the 12 project schools were assessed using the *Thessaloniki Maths* test (See '**Where Can I Find Out More?**') as pre-test in the Autumn term 1995 (when they were in Year 7), and as post-test at the end of June 1997 (at the end of Year 8). The test is in three sections: the four operations, algebra and proportion, all with questions ranging from concrete to formal.

In 2000 the researchers collected GCSE data in mathematics, science and English from the project schools in order to see if there were any long-term impacts.

Data were collected on a similar number of control schools whose average levels of intakes covered the same range as the CAME schools, but who had not received either CAME or CASE interventions.

What are the implications of this research?

Teachers seeking to improve behaviour and motivation in their schools and classrooms may wish to consider the following implications of the findings of the study:

- would you find it helpful to use some of the strategies discussed in the study even if adopting the whole programme is too big a step? (This could include, using a greater range of questioning techniques or displaying key questions and vocabulary to focus students' thinking)
- do your students work effectively in pairs or small groups? Do they work more co-operatively and listen to each other's ideas more effectively? Can they reach a decision together? Would it be useful for you to model effective dialogue for them, perhaps using a group of students to help?
- thinking skills approaches can be used in different parts of the mathematics curriculum. Would it be helpful for you to work with colleagues to identify where you might use the approaches most effectively?

School leaders may find the following implications of the findings of the study:

- the study findings support the idea that learning together can be very effective in enhancing students' learning. Would it be helpful to explore your own and your colleagues' beliefs about the benefits of students working collaboratively by looking at evidence from your own school showing students learning in different contexts – whole class, in groups, individually?
- would it make sense to implement a whole school approach to cognitive intervention to develop the teaching and learning strategies the research found to be successful in raising achievement?
- it takes time for teachers to learn and embed new approaches in their teaching. The study suggests that teachers' learning of Thinking Maths closely models students doing Thinking Maths. Could you create more opportunities for supporting teachers' own learning to use the learning strategies you and they hope to make available to their students?

Where can I find out more?

Related research

Effective talk in the primary classroom – GTC Research of the Month summary:
http://www.gtce.org.uk/research/romtopics/rom_teachingandlearning/effective_talk_sep06/

Effective teachers of numeracy – GTC Research of the Month summary:
http://www.gtce.org.uk/research/romtopics/rom_curriculum/numeracy_apr03/

'Improving learning through cognitive intervention' presents a summary of the CASE project.
http://www.gtce.org.uk/research/romtopics/rom_teachingandlearning/case_jun01

'Social interaction as a means of constructing learning: the impact of Lev Vygotsky's ideas on teaching and learning' – this GTC Research of the Month summary is available at: http://www.gtce.org.uk/research/romtopics/rom_teachingandlearning/vygotsky_dec03/

Other digests about Thinking Skills:

Effects of a Cognitive Acceleration Programme on Year 1 students (Updated)
http://www.standards.dfes.gov.uk/research/themes/thinkingskills/6553/

Helping students classify and tackle mathematics problems
http://www.standards.dfes.gov.uk/research/themes/Mathematics/studentsclassify/

Understanding graphs – does metacognitive questioning help students develop and refine their mathematical ideas?
http://www.standards.dfes.gov.uk/research/themes/thinkingskills/understandinggraphs/

Other digests about classroom dialogue

Reasoning as a scientist: ways of helping children to use language to learn science
http://www.standards.dfes.gov.uk/research/themes/science/language_science/

Widening access to educational opportunities through teaching children how to reason together
http://www.standards.dfes.gov.uk/research/themes/speakandlisten/wegerif_access/

Other references

More details about CAME are available at: http://www.caaweb.co.uk/came.php

Robert Fisher site contains a number of helpful articles about teaching thinking: www.teachingthinking.net

The original CASE programme is described, explained and analysed in Adey, P. and Shayer, M. (1994): *Really Raising Standards: cognitive intervention and academic achievement*. London: Routledge.

The Thessaloniki Maths test was derived from original research by:

Demetriou A, Platsidou M, Metallidou Y, Shayer, M (1991) The development of quantitative-relational abilities from childhood to adolescence: Structure, scaling, and individual differences *Learning and Instruction,* Vol. 1, No. 1, pp. 19-43

Thinking Through Geography shares a range of features with CASE and CAME. Edited by David Leat of the Centre for British Teachers (CfBT), Reading, it is published by Chris Kington Publishing, Cambridge. The second volume, *More Thinking Through Geography*, is published by the same company