

## Concept Cartoons: What Have We Learnt?\*

Stuart NAYLOR<sup>1</sup> , Brenda KEOGH<sup>1</sup>

<sup>1</sup> Co-Director, Millgate House Education, Cheshire-UK

**Received:** 27.11.2011

**Revised:** 30.12.2011

**Accepted:** 15.01.2012

*The original language of article is English (v.10, n.1, March 2013, pp.3-11)*

### ABSTRACT

Concept Cartoons were created approximately 20 years ago. Since then research and feedback from teachers and students has led to a variety of improvements in the format and presentation of Concept Cartoons. Sets of Concept Cartoons have been developed for classroom use. For several years Keogh and Naylor's ground-breaking research provided the only evidence for how Concept Cartoons can be implemented in the classroom and what the impact of Concept Cartoons can be. More recently a wide range of researchers have added to that research base.

This article sets out the major developments in the nature and format of Concept Cartoons. It identifies some of the major implications for teaching and learning, including using them to promote cognitive conflict and argumentation, using them for formative assessment, challenging misconceptions and enhancing motivation and engagement. It also identifies some aspects of teacher professional learning, including implementing constructivist approaches, developing pedagogic subject knowledge, and promoting change in professional practice. Some future developments in Concept Cartoons are suggested.

**Key Words:** Concept Cartoons; Engagement; Learning; Misconceptions.

### INTRODUCTION

The first Concept Cartoons were created by Brenda Keogh and Stuart Naylor in 1991. A brief outline of the Concept Cartoon strategy was first published in 1993 (Keogh & Naylor, 1993). The purpose for creating them was as a strategy to elicit learners' ideas, challenge their thinking and support learners in developing their understanding. The response of learners to these Concept Cartoons was encouraging. Primary school students, secondary school students, teachers and student teachers all responded very positively.

During the next few years Keogh and Naylor developed a wide range of Concept

\* Paper presented at the Fibonacci Project European Conference, Inquiry-based science and mathematics education: bridging the gap between education research and practice. Leicester, UK, April 2012.



Cartoons (Naylor & Keogh, 2000), drawing inspiration from their own teaching experience and published research such as Driver, Guesne and Tiberghien (1985) and Driver, Squires, Rushworth and Wood-Robinson (1994). Feedback from learners led to further developments in the nature of the Concept Cartoons. These included a shift from a single statement to multiple statements; a shift from characters making negative comments to positive comments; and ensuring that the scientifically acceptable viewpoint(s) is always included in the alternatives provided. Publications during this period capture some of this development, as well as how thinking was evolving in relation to the potential value of Concept Cartoons (Keogh & Naylor, 1997a; Keogh & Naylor, 1997b; Keogh & Naylor, 1998).

Three significant papers were published during 1999. These publications provided extensive background on the nature and important features of Concept Cartoons; on their potential value and the pedagogic implications of using them in science classrooms; and on how they might be used successfully in informal learning situations (Keogh & Naylor, 1999; Naylor & Keogh, 1999a; Naylor & Keogh, 1999b). Further research and development resulted in some additional changes to the format, which are evident in more recent publications of Concept Cartoons for classroom use (Dabell, Keogh & Naylor, 2008; Naylor & Keogh, 2010).

Significant features of Concept Cartoons and how they are presented now include the following:

- They are based on everyday situations that don't appear to be scientific, so students lacking in confidence are less likely to be intimidated by the science and more likely to engage with them. These everyday situations appear to be effective across geographical and cultural boundaries, enabling Concept Cartoons to be used successfully in a wide range of countries.
- They present alternative viewpoints on the situation, including the scientifically acceptable viewpoint(s). Most of the Concept Cartoons embed scientific ideas in everyday contexts, and the contextual features can influence how the problem is interpreted, so that in many cases there can be more than one scientifically acceptable alternative. This presents an additional level of challenge to learners, especially to high achieving students.
- They have a blank speech bubble, to give a clear statement that there may be more ideas that are not yet included in the dialogue so that learners are encouraged to explore alternative ideas.
- The background text is written in students' language, so they can be used independently by learners if the teacher feels that this is appropriate. This extends the range of ways that teachers can choose to use Concept Cartoons in their classrooms.
- All the alternative viewpoints have equal status. When the teacher presents a set of alternative viewpoints in a Concept Cartoon, all of these viewpoints are seen as legitimate. This gives less confident students support in voicing what they think, because someone else has already articulated their ideas. If their ideas are incorrect then they can put the blame on the Concept Cartoon character. Keogh and Naylor's early research indicated the need to minimize any contextual clues, such as those given by facial expressions or wording of statements, so that students cannot use these to attempt to work out their answer.
- The speech bubbles include common misconceptions, so these can be recognised and addressed directly in the lesson. Some teachers are concerned that raising misconceptions may make students more likely to believe these, but research indicates that this does not happen in practice and that Concept Cartoons can be a very effective way to challenge misconceptions.
- They present plausible alternatives that are based on research evidence about students' ideas at different ages.

Keogh and Naylor's more recent research into using Concept Cartoons has focused on

how Concept Cartoons can stimulate argumentation and promote change in professional practice. Other researchers have also begun to add to the research base available. This article attempts to set out a summary of what has been learnt through research about how Concept Cartoons operate and how they relate to broader themes in science education.

## **Concept Cartoons and Research into Aspects of Student Learning**

### **a) Adjudication**

When learners use Concept Cartoons they find themselves in the role of adjudicator – that is, they make judgments about the ideas that other people hold. This is an unusual role for learners, and a reversal of the more typical situation where the teacher acts as adjudicator for their ideas. One of the consequences of teachers making judgments about learners' ideas is that learners tend to avoid taking the risk of being wrong (Dweck, 2000). Less confident and low achieving learners are often unwilling to put forward their own ideas in case they are wrong. Taking on the role of adjudicator can be empowering for learners, since they are doing the judging rather than having their ideas judged by the teacher. This enables less confident learners to engage in argumentation and put forward their ideas more readily (Solomon, 1999).

### **b) Argumentation**

Concept Cartoons act as an effective stimulus for argumentation, including enabling students to co-construct arguments. They enable argumentation to take place without the need for any formal structure, specific vocabulary, or teacher intervention in managing the process of argumentation. Concept Cartoons focus on scientific issues, in contrast with much of the research on argumentation where the focus is on socio-scientific issues. Research into argumentation using Concept Cartoons raises questions about the value and applicability of the commonly-used Toulmin model for analysing argumentation (Naylor, Downing & Keogh, 2001; Naylor, Keogh & Downing, 2007). The complexity of the model and the language used appear to make it unsuitable for use with younger learners in primary schools or students with a restricted language register. More significantly, when *nearly all researchers have found the application of the Toulmin schema problematic* (Simon, Erduran & Osborne, 2002: 16), it is clear that that the language and behaviours inherent in the Toulmin model may not be consistent with the types of language and behaviours typically found in students in school.

### **c) Auditing subject knowledge**

In England there is a requirement for student teachers' subject knowledge to be audited, in order to ensure that they have sufficient relevant subject knowledge for entering the profession. Concept Cartoons have been used as an effective means of auditing student teachers' subject knowledge, so enabling them to identify where they need to develop their ideas further. In some cases the use of Concept Cartoons acts as an effective stimulus for student teachers to engage in further research to develop their own understanding, coupling together assessment and continued learning in an integrated process (Naylor, Keogh, de Boo & Feasey, 2000).

### **d) Cognitive conflict**

Concept Cartoons draw on the published research into common student misconceptions (such as Driver, Squires, Rushworth & Wood-Robinson, 1994) and build examples of these

common misconceptions into the statements in the Concept Cartoons. In this way the Concept Cartoon characters articulate what appear to be plausible alternative viewpoints. Learners find themselves in a position of having to give serious consideration to these plausible alternatives, many of which they may never have thought of before, and this makes them effective at generating cognitive conflict. For more confident, higher achieving learners this can be an important step in getting them to think more deeply about scientific concepts (Keogh & Naylor, 1999). Not having an obvious right answer, or not having a single right answer, makes cognitive conflict more likely.

#### **e) Formative assessment**

It has been evident since Concept Cartoons were first developed that they can integrate formative assessment and learning in a single activity (Keogh & Naylor, 1999). Even when they are used for summative assessment they can help to integrate assessment and learning (Naylor, Keogh, de Boo & Feasey, 2000). More extensive evidence of how this can be managed in the classroom and how teachers perceive the impact of strategies like Concept Cartoons is now available (Naylor & Keogh, 2007; Naylor, Keogh & Turner, 2011) and a wider range of strategies for classroom use has been made available (Naylor, Keogh & Goldsworthy, 2004). Millar and Murdoch (2002) suggest that Concept Cartoons compare favourably with other formative assessment strategies in their impact on learners. Chin and Teou (2009, 2010) found that Concept Cartoons can be used for both self and peer assessment as part of formative assessment, and that they provide valuable diagnostic feedback to teachers about students' misconceptions, so enabling the teacher to be more effective in promoting conceptual change. Ekici, Ekici and Aydin (2007) noted the value of Concept Cartoons in identifying student misconceptions so that teachers are better able to take these misconceptions into account in their teaching. Kabapinar (2005) found that Concept Cartoons are effective for finding out students' ideas without them being affected by the ideas of their peers, and that the reasoning behind student misconceptions can be uncovered.

#### **f) Informal learning settings**

The nature of Concept Cartoons means that they are not identified exclusively with formal learning settings. They can bridge the gap between formal and informal learning settings because they are based around everyday situations that appear to involve ordinary characters doing ordinary things. They have been used successfully in a range of informal learning settings, such as corridor displays in school, thinking homework that involve family members in thinking about scientific problems, parents' open evenings at school and exhibits at science exploration centres. They have also been used in the UK at professional football matches in matchday magazines. On a larger scale they have been used on transport systems in the UK and other countries, such as Sweden and Russia, for engaging members of the public in thinking about scientific problems in everyday settings (Naylor & Keogh, 1999b).

#### **g) Language skills**

The pictorial representation of ideas, coupled with the minimal text, makes it relatively easy for learners to engage with Concept Cartoons in a language that is not their home language. It is widely recognized that language can be an important barrier to learning in science. With their relatively simple representation of concepts that learners are likely to recognize, Concept Cartoons can provide an accessible entry point for language learning and can help learners to develop their language skills (de Lange, 2009). In some countries (e.g.

Norway), the English versions of Concept Cartoons have been used for many years as a way of consolidating English language learning in addition to learning about science.

### **h) Misconceptions**

Some time ago Gunstone noted that *the methods used to probe students' ideas/beliefs are also, almost by definition, excellent teaching/learning strategies* (Gunstone, 1988: 90). Several of these methods are explored in some detail in White and Gunstone (1992). Concept Cartoons fit into this pattern. As well as eliciting learners' ideas, Concept Cartoons can also be a valuable tool for developing learners' ideas. Generally learners readily engage in discussion when Concept Cartoons are used, and as they attempt to justify their ideas, this exposes their views to the possibility of challenge by their peers. In looking for evidence and constructing suitable arguments to justify their ideas, learners often come to recognize for themselves that their understanding is limited and that there are more productive ways of understanding the situation. Since Keogh and Naylor first noted this (1999), several studies have confirmed how Concept Cartoons help to not only challenge students' misconceptions but can also go on to help remedy these misconceptions (Chin and Teou, 2010; Dolasir, 2007; Ekici, Ekici & Aydin, 2007; Kabapinar, 2005; Rahmat, 2009; Stephenson & Warwick, 2002).

### **i) Motivation and engagement**

Concept Cartoons have been found to be highly motivating for groups of learners of all ages and backgrounds and in a variety of circumstances, including those students who have emotional and behavioral difficulties. Learners tend to spend longer on task, to sustain their levels of interest and to interact confidently with their peers. It is suggested that for less confident students, having voices speaking for them gives them the confidence to discuss their ideas (Keogh & Naylor, 1999). Repeated use of the Concept Cartoon strategy does not appear to reduce the level of engagement of learners (Keogh & Naylor, 1999). Birisci, Metin and Karakas (2010) carried out a study with student teachers and found a similar impact on their motivation to use Concept Cartoons, quoting one student teacher as saying that Concept Cartoons *rescue students from boring traditional teaching*.

### **j) Problem-solving**

In mathematics, how students go about solving a problem can be at least as important as the answer that they arrive at. However it is often the case that students do not articulate the strategies that they use to solve problems. Sexton, Gervasoni and Brandenburg (2009) showed that Concept Cartoons can provide insight into the strategies that students use when solving problems in mathematics. Further research by Sexton indicates that Concept Cartoons can be used successfully to gain access to students' beliefs about learning environments and their preferred approaches to mathematics teaching and learning (Sexton, 2010).

## **Concept Cartoons and Research into Aspects of Teacher Professional Learning**

### **a) Constructivist teaching approaches**

During the 1980's and 90s a constructivist model of learning appeared to be the dominant theme in science education. Research into students' alternative conceptions was very extensive. However Millar (1989) and others recognised that a model of learning was not the same as a model for teaching, and that how constructivist models of learning might be translated into specific teaching approaches was far from clear. Concept Cartoons help to

clarify the relationship between constructivist models of learning, scientific epistemology and classroom practice.

One of the difficulties that teachers experience in attempting to use constructivist teaching approaches is the separation of elicitation of students' ideas from attempting to restructure the students' ideas. These phases are often described as separate and distinct in the literature, but separating them in the classroom can be extremely difficult to manage. Concept Cartoons enable teachers to see how these phases can be integrated. They also help teachers to make sense of how to work with a whole class, even though much of the literature gives the impression that they should respond to students' individual ideas. Concept Cartoons enable teachers to experience taking students' ideas into account in manageable ways, without having to find out or assess individual students' ideas. Students also feel that their learning experiences are personalised without the teacher having to deal with classroom situations that are impossible to manage (Keogh & Naylor, 1997a; Keogh & Naylor, 1997b; Keogh & Naylor, 1999; Naylor & Keogh, 1999a).

### **b) Pedagogic subject knowledge**

Concept Cartoons have played a valuable role in teacher professional learning as well as that of their students. As well as helping them to experience how to take their students' ideas into account in manageable and meaningful ways (Keogh & Naylor, 1996; Keogh & Naylor 1997a; Keogh & Naylor 1997b), they also enable teachers to see the value of dialogic teaching with their own class and help teachers to develop their pedagogic subject knowledge through rethinking and reconceptualising their own scientific ideas (Keogh & Naylor, 1999). Concept Cartoons can often ask questions that teachers or student teachers have never thought about before (such as whether a light reflector is also a good sound reflector, or whether the combined shadow from two separate objects is any darker than a single shadow) and push them into extending their own subject boundaries. If research references are made explicit then they can also enable teachers to see the value of research evidence into students' ideas.

### **c) Teacher professional practice**

Some teachers are willing in principle to make changes in their professional practice, but unsure about how to do this. Because Concept Cartoons are consistently successful when they are used, they can help teachers to see the potential value of changing their professional practice. And because Concept Cartoons are so simple to use in the classroom, they can help these teachers to see how to implement change in their teaching.

When teachers do use Concept Cartoons they often find that students respond well to the pedagogy that is embedded in Concept Cartoons. If a teacher is typically a didactic teacher, then using Concept Cartoons can offer students an opportunity to engage in dialogue and argument, which is clearly motivating for them. When this happens on more than one occasion, teachers can become convinced of the value of this new pedagogy by the evidence from their own classroom, and begin to embed this change in their professional practice. In this way professional change is evolutionary, with change in professional values and beliefs being a consequence of change in practice, rather than a prerequisite for change in practice. Concept Cartoons are based around cognitive conflict, metacognition and social construction of ideas, and can therefore be a stepping stone on the way to more fundamental changes in professional practice. This view of professional change as evolutionary has been explored in some detail in our Active Assessment project, into which Concept Cartoons are integrated (Naylor & Keogh, 2007; Naylor, Keogh & Turner, 2011).

### **Further developments in Concept Cartoons**

Concept Cartoons are popular with teachers in a wide range of countries. Their simplicity ('deceptively simple', as one colleague described them) makes them very attractive to busy teachers, and although some training is helpful, it is possible to use them with no training. Concept Cartoons for classroom use are already available in science and mathematics (Naylor & Keogh, 2010; Dabell, Keogh & Naylor, 2008). Concept Cartoons with a focus on English language teaching will be available during 2013 (Turner, Smith, Keogh & Naylor, in press) and there is a strong possibility that sets of Concept Cartoons will be produced in other subject areas. In principle it is possible to create them in any subject where there is a possibility of alternative conceptions and conflicting viewpoints.

It was noted earlier that the minimal text involved makes Concept Cartoons very suitable for use outside a student's home language. In the UK they are used frequently with students who are learning English as an additional language. In some countries they are used in science lessons, with the English text being used to complement English language learning elsewhere in the curriculum. Translated versions are also valuable, and translations of science Concept Cartoons are already available in Welsh and Norwegian. A Swedish version was released during 2012 and other translations into Danish and Dutch are planned. Further translations are of course possible.

This extensive use outside the UK raises the question of the suitability of the characters for diverse teaching situations. Currently the Concept Cartoons available for classroom use include some non-western characters, with the majority being western in appearance. It will therefore be valuable to rework the classroom materials to make the majority of the characters non-western in appearance, so that it is easier for students in a wide range of settings to identify with the characters and there will be more immediate appeal to a global audience.

The pedagogy that underpins Concept Cartoons is clear. Dialogic teaching styles, formative assessment and an interactive learning environment are central to the effective use of Concept Cartoons. Around the world many education ministries recognise the research evidence which indicates that this type of pedagogy is more effective than the alternatives. Requests from outside the UK for teacher professional development in the use of Concept Cartoons have become more frequent. One possible way of meeting this demand is to prepare an online training package, including video clips of Concept Cartoons being used in the classroom, to support teacher development at a distance.

## REFERENCES

- Birisci, P., Metin, M. & Karakas, M. (2010). Pre-service elementary teachers' views on concept cartoons: a sample from Turkey. *Middle East Journal of Scientific Research*, 5(2), 91-97. Available at [http://www.idosi.org/mejsr/mejsr5\(2\)/7.pdf](http://www.idosi.org/mejsr/mejsr5(2)/7.pdf)
- Chin, C. & Teou, L.Y. (2009). Using concept cartoons in formative assessment: scaffolding students' argumentation. *International Journal of Science Education*, 31(10), 1307-1332.
- Chin, C. & Teou, L.Y. (2010). Formative assessment: using concept cartoons, pupils' drawings and group discussions to tackle children's ideas about biological inheritance. *Journal of Biological Education*, 44(3), 108-115.
- Dabell, J., Keogh, B & Naylor, S. (2008). *Concept Cartoons in mathematics education*. Sandbach: Millgate House.
- De Lange, J. (2009). *Design based research: the use of Concept Cartoons in Flemish science education – improvement of the tools and effectiveness in learners' language skills*. Paper presented at the ESERA Conference, Istanbul, Turkey. Available at <http://www.esera2009.org/fulltextpaper.asp>
- Dolasir, S (2007). *The effect of Concept Cartoons on the conceptual errors of students in elementary science teaching*. Unpublished PhD thesis, Ankara University, Turkey.
- Driver R., Guesne, E., and Tiberghien, A. (Eds). (1985).. *Children's Ideas in Science*. Milton Keynes, Open University.
- Driver, R., Squires, A., Rushworth, P. & Wood-Robinson, V. (1994). *Making Sense of Secondary Science: Research into Children's Ideas*. London: Routledge.
- Dweck, C. (2000). *Self theories: their role in motivation, personality and development*. London: Taylor & Francis.
- Ekici, F., Ekici, E. & Aydin, F. (2007). Utility of Concept Cartoons in diagnosing and overcoming misconceptions related to photosynthesis. *International Journal of Environmental & Science Education*, 2, 4,111-124. Available at [http://www.ijese.com/V2\\_N4\\_Ekicietal.pdf](http://www.ijese.com/V2_N4_Ekicietal.pdf)
- Gunstone, R. (1988). Learners in science education. In P. Fensham (Ed). *Development and dilemmas in science education* (Lewes: Falmer)., 73-95.
- Kabapinar, F. (2005). Effectiveness of teaching via concept cartoons from the point of view of constructivist approach. *Educational Sciences: Theory and Practice*, 5,1,135-146. Available at <http://cimm.ucr.ac.cr/ojs/index.php/eudoxus/article/view/136/137>
- Keogh, B. & Naylor, S. (1993). Learning in science: another way in. *Primary Science Review*, 26, 22-23.
- Keogh, B. & Naylor, S. (1996). *Teaching and learning in science: a new perspective*. Paper presented at the BERA Conference, Lancaster, UK. Available at <http://www.leeds.ac.uk/educol/documents/000000115.htm>
- Keogh, B. & Naylor, S. (1997a). *Developing children's ideas: putting constructivism into practice*. Paper presented at the ESERA Conference, Rome, Italy.
- Keogh, B. & Naylor, S. (1997b). Making sense of constructivism in the classroom. *Science Teacher Education*, 20,12-14.
- Keogh, B. & Naylor, S. (1998). Teaching and learning in science using Concept Cartoons. *Primary Science Review*, 51,14-16.
- Keogh, B. & Naylor, S. (1999). Concept cartoons, teaching and learning in science: an evaluation. *International Journal of Science Education*, 21(4).,431-446.
- Millar, L. & Murdoch, J. (2002). A penny for your thoughts. *Primary Science Review*, 72, 26-29.
- Millar, R. (1989). Constructive criticisms. *International Journal of Science Education*, 11, 587-596.
- Naylor, S. & Keogh, B. (1999a)., Constructivism in the Classroom: Theory into Practice. *Journal of Science Teacher Education*, 10, 2, 93-106.
- Naylor, S. & Keogh, B. (1999b). Science on the Underground: an initial evaluation. *Public Understanding of Science*, 8,1-18.



- Naylor, S. and Keogh, B. (2000). *Concept Cartoons in Science Education*. Sandbach: Millgate House.
- Naylor, S. & Keogh, B. (2007). Active Assessment: thinking, learning and assessment in science. *School Science Review*, 88,325,73-79. Available at <http://www.millgatehouse.co.uk/research/active-assessment-research-ongoing>
- Naylor, S. & Keogh, B. (2010). *Concept Cartoons in Science Education, 2<sup>nd</sup> Edition*. Sandbach: Millgate House.
- Naylor, S., Keogh, B., de Boo, M. & Feasey, R. (2000). Researching formative assessment: concept cartoons as an auditing strategy. In R. Duit (Ed.). *Research in Science Education: Past, Present and Future* p137-142. Dordrecht: Kluwer. Available at [http://books.google.co.uk/books?id=wjF0gYoRhn8C&pg=PA137&lpg=PA137&dq=Keogh,+B.,+Naylor,+S.,+de+Boo,+M.+and+Feasey,+R.+\(1999\).++The+use+of+concept+cartoon+s+as+an+auditing+tool+in+initial+teacher+training&source=bl&ots=Ukut4YE\\_6y&sig=g\\_sBFonmiNGcpPp0roIexTvgA38&hl=en&ei=WOgyTZj1B5a6jAe3q6XDCg&sa=X&oi=book\\_result&ct=result&resnum=4&ved=0CCwQ6AEwAw#v=onepage&q&f=false](http://books.google.co.uk/books?id=wjF0gYoRhn8C&pg=PA137&lpg=PA137&dq=Keogh,+B.,+Naylor,+S.,+de+Boo,+M.+and+Feasey,+R.+(1999).++The+use+of+concept+cartoon+s+as+an+auditing+tool+in+initial+teacher+training&source=bl&ots=Ukut4YE_6y&sig=g_sBFonmiNGcpPp0roIexTvgA38&hl=en&ei=WOgyTZj1B5a6jAe3q6XDCg&sa=X&oi=book_result&ct=result&resnum=4&ved=0CCwQ6AEwAw#v=onepage&q&f=false)
- Naylor, S., Downing, B. & Keogh, B. (2001). *An empirical study of argumentation in primary science, using concept cartoons as the stimulus*. Paper presented at the ESERA Conference, Thessaloniki, Greece.
- Naylor, S., Keogh, B. & Downing, B. (2007). Argumentation and primary science. *Research in Science Education*, 37, 17-39.
- Naylor, S. & Keogh, B. with Goldsworthy, A. (2004). *Active assessment: thinking, learning and assessment in science*. David Fulton/Millgate House.
- Naylor, S., Keogh, B. & Turner, J. (2011). *Changing teacher practice through professional development in formative assessment*. Paper presented at the ESERA Conference, Lyon, France. Available at <http://www.millgatehouse.co.uk/research/active-assessment-research-ongoing>
- Rahmat, F. A. (2009). Use of concept cartoons as a strategy to address pupils' misconceptions in primary four science topic on matter. In A. L. Tan, H. M. Wong, & S., Tan (Eds.), *Action research: Empowering my practice in teaching science* p11-37. Singapore: National Institute of Education and Science Exploria, East Zone Centre of Excellence for Primary Science.
- Sexton, M. (2010). *Using concept cartoons to access student beliefs about preferred approaches to mathematics learning and teaching*. Paper presented at the MERGA conference, Freemantle, Australia. Available at [http://www.merga.net.au/documents/MERGA33\\_Sexton.pdf](http://www.merga.net.au/documents/MERGA33_Sexton.pdf)
- Sexton, M., Gervasoni, A. & Brandenburg, R. (2009). Using a Concept Cartoon to gain access to children's calculation strategies. *Australian Primary Mathematics Classroom*, 14, 4, 24-28. Available at <http://www.thefreelibrary.com/Sexton,+Matthew%3B+Gervasoni,+Ann%3B+Brandenburg,+Robyn-a1827>
- Simon, S., Erduran, S. & Osborne, J. (2002). *Enhancing the quality of argumentation in school science*. Paper presented at the NARST Conference, New Orleans, USA.
- Solomon J. (1999). Personal communication.
- Stephenson, P. & Warwick, P. (2002). Using concept cartoons to support progression in students' understanding of light. *Physics Education*, 37, 2, 135-141.
- Turner, J., Smith, C., Keogh, B. & Naylor, S. (2013, in press). *Concept Cartoons in English education*. Sandbach: Millgate House.
- White, R. & Gunstone, R. (1992). *Probing understanding*. London: Falmer.