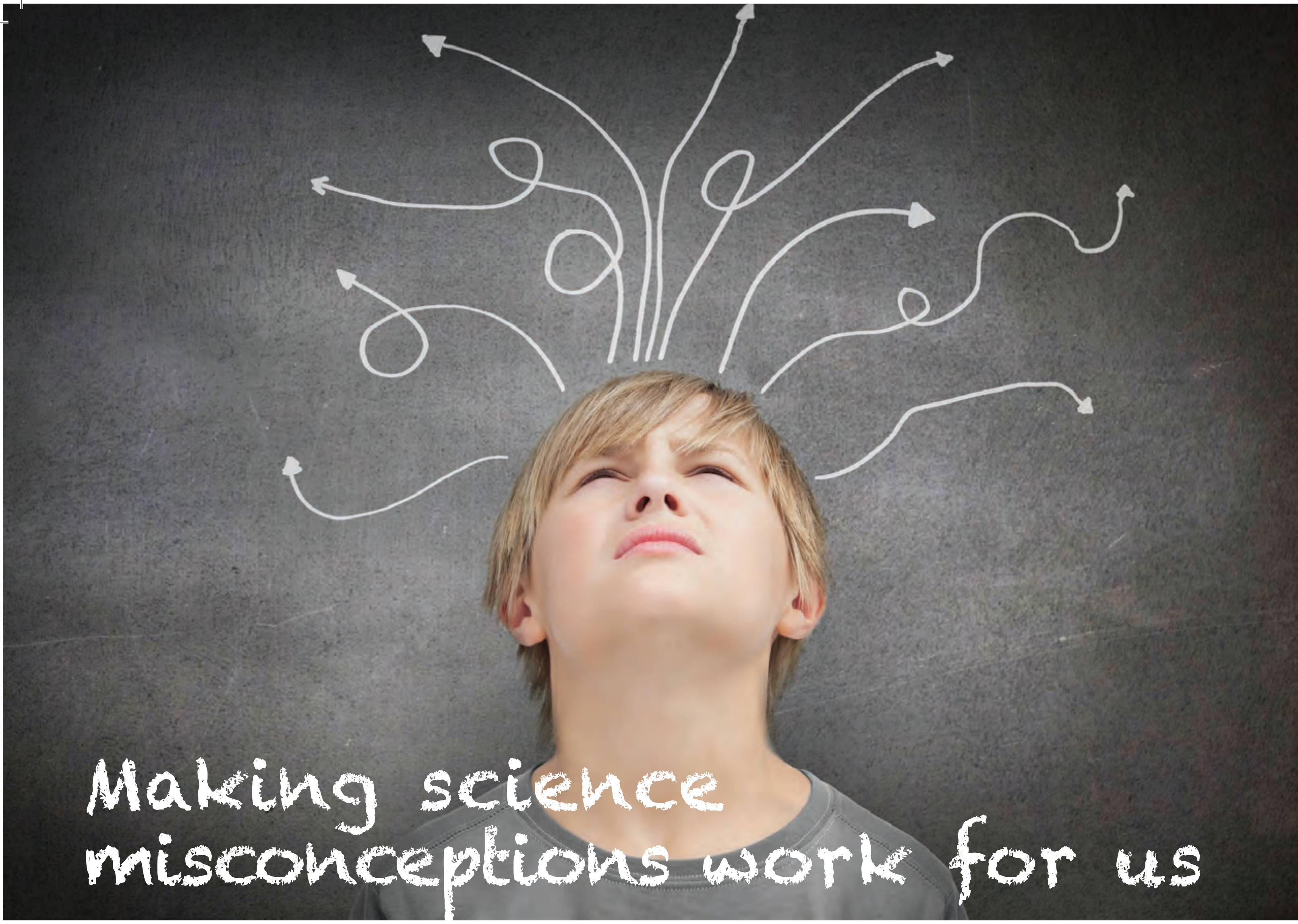

Making science misconceptions work for us

Katrina Elliott and Anne Pillman

This paper explores strategies for teachers to work with science conceptions, both those consistent and those inconsistent with western science understanding. It emphasises the value of teachers checking their own and their students' prior understanding of concepts to be learnt. A past approach of educators has been to replace old beliefs with new ones consistent with western science understanding. The approach outlined here is to develop learners' understanding of both beliefs and the knowledge of when to use them. Drawing on evidence from the latest research, specific strategies to respond to this have been suggested.

INTRODUCTION

"*The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly.*" (Ausubel, 1968, p. vi)

In 1968, David Ausubel (an educational psychologist) reminded us of the importance of the beliefs that students bring to learning. In the nearly 50 years since then, research has continued to show the value of building on learners' prior knowledge. This is recognised in instructional models like the 5Es, used in the PrimaryConnections and Science by Doing programs (Australian Academy of Science), and the Interactive Teaching Approach (Osborne & Freyberg, 1985). From different viewpoints, these beliefs that students bring have been referred to as misconceptions, alternative conceptions, naïve knowledge and prior knowledge to name a few. In this work, we use the term misconception to refer to a belief not consistent with western science, but we are concerned more with the 'teach him accordingly' part.

In over four decades since the publication of Ausubel's book, there has been considerable research into students' conceptions both before and after instruction. Researchers have documented stages in development of science concepts e.g., understanding of the Earth (Nussbaum & Novak, 1976), mapped the prevalence of misconceptions with both teachers and students (Burgoon, Heddle & Duran, 2011), and proposed models for how these are acquired, maintained and changed (Posner, Strike, Hewson, & Gertzog, 1982; Ohlsson, 2011; Dawson, 2014). Sadler, Sonnert, Coyle, Cook-Smith, & Miller (2013) demonstrated that teachers who knew the common misconceptions of their students were more effective in developing students' understanding than those who did not (at least for students with relatively good literacy and numeracy skills) but the research didn't address the question of what these teachers did with their knowledge that made them effective.

Although the practice of eliciting students' prior knowledge is incorporated into some current teaching models like the 5Es (PrimaryConnections and Science by Doing, Australian Academy of Science), feedback from many teachers suggests that they are unsure what to do with this information. Four possible responses to misconceptions could be described as follows:

1. Ignore or avoid the misconceptions and teach the science concepts.
2. Recognise the misconceptions, but not do anything with them and teach the science concepts.
3. Tell learners that their ideas are wrong and teach the correct concept.
4. Actively use the misconceptions to compare them with science concepts and develop awareness of how both the misconception and science concept are appropriate in different contexts.

This paper investigates ways of working with the fourth option in classrooms.

MODELS OF CONCEPT LEARNING

We have found it useful to distinguish between two learning scenarios: firstly, that scenario in which the learner's existing knowledge is simply extended by new knowledge, with no conflict between them. An example of this might be when students learn about a new kind of insect they have discovered living in the schoolyard. Secondly, and in contrast, is a scenario where learning directly conflicts with learner's existing beliefs. Consider when when a student, who for all of their life has observed the sun move across the sky over the course of a day, is presented with the idea that the sun remains still and the Earth rotates. This is in direct conflict with their pre-existing beliefs and Ohlsson (2011) describes several possible responses from the learner.

1. Discredit the source e.g., "*What would they know? That plastic ball isn't the Earth.*"
2. Boost existing thinking e.g., "*It's obvious, everyone says so, every day you see the sun move.*"
3. Make an exception e.g., "*It's different in this case. It's just a school thing.*"
4. Inventing a way to explain it while leaving the core concept intact e.g., "*Maybe this happens here, but … the Earth might be round, but the sun still moves around it.*"

Faced with pushback like this, teachers may be unsure how to proceed. Common responses include avoiding students' existing beliefs altogether or telling students clearly they are wrong and that they need to think differently. Neither of these approaches has been shown to be widely effective.

In contrast to the strategy of keeping the beliefs separate is Ohlsson's suggestion that both beliefs need to be activated at the same time and then the one which is used will depend on the opportunities each has had to prove its use. Practice with the new science concept is necessary to stop learners reverting to their old ideas. As well as emphasising the value of repeated practice with new ideas, Dawson's (2014) conceptual mediation takes this a step further, suggesting that the new idea needs to be taught in isolation initially until it is established and then practice should include comparison between the two ideas. This is aimed at developing an understanding of contexts in which it is appropriate to use each model. The focus is on strategic use of the most appropriate way of thinking rather than replacement of one with another. Continuing with the Earth and sun example, we want learners to know that although the sun appears to move across the sky, and that this can be used to estimate the time of day, in reality, the sun stands still while the Earth rotates. Thinking like this is needed to explain seasons, phases of the moon and other things to do with the Earth in space.

Far from avoiding or marginalising the existing belief, both of these strategies use it as a springboard for further learning.

WORKING WITH CONCEPT LEARNING IN THE CLASSROOM

To best support students with concept learning, teachers might consider the following.

(a) Their own clarity around the concept that students are expected to know.

This involves: what the concept looks like at this level, what is not part of it and its relevance to the lives of students. It also includes a range of contexts in which the concept may be applied. For example, the Australian Curriculum for Year 5 physical sciences calls for students to explore phenomena associated with light. This might include shadows, reflection, absorption, transmission and refraction. It does not involve heat or electrical energy which is often associated with light. Students might see this in stage lighting, cycling safety gear and periscopes to name a few contexts.

(b) What students might have observed in their past experiences in and out of school.

In the light example, students will probably be familiar with torches, mirrors and cellophane as sources, reflectors and transmitters respectively.

(c) Strategies for eliciting students' current thinking.

While common misconceptions can be anticipated, checking on those of the current cohort of students will enable teachers to specifically target those misconceptions. Programs such as 'PrimaryConnections' and 'Science by Doing' use a range of strategies for eliciting prior knowledge. Some use the same task at the beginning of the unit for prior knowledge and at the end of the unit for their summative assessment, allowing both students and teachers a clear indication of growth in learning. In the light example, students could be asked: *What reflects light?*, and they may respond that only shiny surfaces reflect light.

(d) Pedagogical questions to challenge this thinking.

Misconceptions are generalisations students have made about their observations. They represent students' attempts to make sense of their world and are the best thinking they have available. To extend or challenge this thinking, teachers will need to put learners in situations where it doesn't work and offer the science concept as an alternative. Students could be asked to shine a torch at a range of surfaces and notice what, if any, evidence of reflection they saw in the surface and on the table in front of it. They could compare the difference in reflection between shiny and dull surfaces.

(e) Learning experiences to practice using the new thinking.

Learners will then need practise in using the science concept in situations where it is useful for this to become as established as the alternative conception was. This might happen if learners were asked to use reflection to explain which safety gear is visible with, and without, car headlights. Knowing that at least some students believed that reflection was a phenomenon limited to shiny surfaces enables teachers to use questions that specifically target this thinking and organise experiences to practice using the idea that almost all surfaces reflect light to some degree.

f) provide opportunities for students to articulate when and why each version is useful.

Further examples of this are available in an online resource *Bringing it to Life: Science Misconceptions* (available from http://www.acleadersresource.sa.edu.au).

A final note of caution: altering concepts takes continued exposure to concepts in a variety of contexts. Teachers should revisit the concept over time in as many different ways as they and their students can find.

REFERENCES

Australian Academy of Science. *PrimaryConnections*. Retrieved January 19, 2014 from http://www.primaryconnections.org.au

Australian Academy of Science. *Science by doing*. Retrieved January 19, 2014 from https://www.science.org.au/learning/schools/science-doing

Ausubel, D.P. (1968). *Educational Psychology: A Cognitive View*. New York: Holt, Rinehart & Winston.

Burgoon, J. N., Heddle, M. L., & Duran, E. (2011). Re-examining the similarities between teacher and student conceptions about physical science. *Journal of Science Teacher Education. 22*(2), 101–114. DOI: 10.1007/s10972-010-9196-x.

Dawson, C. (2014). Towards a conceptual profile: Rethinking conceptual mediation in the light of recent cognitive and neuroscientific findings. *Research in Science Education. 44*(3), 389–414. DOI: 10.1009/s11165-013-9388-4.

Ohlsson, S. (2011). *Deep Learning: How the Mind Overrides Experience*. Cambridge University Press, Cambridge, England.

Osborne, R., & Freyberg, P. (1985). *Learning in science: The implications of children's science*. Auckland: Heinemann.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Towards a theory of conceptual change. *Science Education. 66*(2), 211–227.

Nussbaum, J., & Novak, J. D. (1976). An assessment of children's concepts of the Earth utilizing structured interviews. *Science Education, 60*(4), 535–550.

Sadler, P.M., Sonnert, G., Coyle, H.P., Cook-Smith, N. & Miller, J.L. (2013). The Influence of Teachers' Knowledge on Student Learning in Middle School Physical Science Classrooms. *The American Education Research Journal.* Published online before print March 6, 2013. DOI: 10.3102/0002831213477680.

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