NEW ZEALAND COUNCIL FOR EDUCATIONAL RESEARCH
TE RŪNANGA O AOTEAROA MŌ TE RANGAHAU I TE MĀTAURANGA

Thinking in science

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The NZCER science education research programme currently has two streams. One has a theoretical focus and aims at generating new knowledge about what is important in a future-focused science curriculum and why it is important. The other stream has a more practical focus and explores what a future-focused science curriculum might *look* like. This working paper belongs to the second stream. It reports on a small-scale research project that investigated how a group of secondary teachers interacted with ideas for foregrounding thinking in science classes.

Background

The demands of the 21st century world, the characteristics of today's young people and recent developments in cognitive science all point to a need to think differently about schooling. Some researchers[1] are calling for a "thinking curriculum"—one which is *both* high in cognitive demand (conceptual learning, reasoning, explaining, problem solving are engaged in daily) *and* embedded in specific challenging subject matter (like science). Today's world requires *everyone* to be educated to a standard that was formerly reserved for the elite. *The New Zealand Curriculum (NZC)* (Ministry of Education, 2007) is a forward-looking document that gives teachers permission to make these changes, but it provides very little support as to what these changes might look like in practice.

In 2010, the New Zealand Council for Educational Research (NZCER) published a new science assessment resource called *Science: Thinking with evidence* (Bull, Ferral, Hipkins, Joyce, & Spiller, 2010) in an attempt to provide some support for teachers. Developing this resource challenged our thinking, making us realise how difficult it can be to let go of traditional ideas about what is important in science learning and teaching. Feedback from several teachers who used the test also identified a need for more support (than what is provided by the teachers' manual that accompanies the tests) for teachers to develop classroom cultures that nurture the development of *thinking* in science. In another project we also noticed that teacher-generated science assessments tended to focus largely on science content, even when the teacher had a professed interest in developing key competencies for 21st century learners. These experiences prompted us to explore further how teachers respond to the ideas about foregrounding thinking in their teaching, and what opportunities/challenges they report in attempting to implement and develop these ideas further in their schools.

What we did

The project consisted of two components:

- an intervention (workshop) component
- a research component.

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[1] See, for example, Resnick (2010).

Recruiting participants

Late in 2010 we advertised for Years 9 and 10 science teachers who might be interested in participating in this project. Approximately 60 teachers from all over New Zealand indicated that they would be interested in the project. In the end we invited interested teachers in one geographical area, with a wide range of different types of schools, to participate. By the time the project began in March 2011, however, several of the teachers who had originally shown interest were no longer able to participate, leaving only three teachers. At this stage we approached schools in the area that had not responded to the original invitation and also approached some teachers known to us personally. The final research group consisted of five[2] teachers—one from an integrated girls' school, one from an integrated boys' school and three from co-ed state schools (deciles 3, 5 and 6).

The intervention component

Because of the exploratory nature of this project, we purposely designed a very small-scale intervention. Our main interest was to see if any of a number of ideas about refocusing science teaching resonated with teachers and what might be fruitful areas for further exploration. The intervention consisted of a full-day workshop in March 2011. At this workshop there was a presentation that drew on the future-focused schooling literature and cognitive science to argue that it is important to focus on thinking in science classrooms. A number of articles were available if teachers wanted to read further on the topic. Possible teaching strategies for foregrounding thinking in their classrooms were also presented. Teachers then spent time working together to plan what they might do back in their schools. The workshop was facilitated by three NZCER researchers.

The research component

The research component of the project collected data on teachers' responses to the workshop. Discussions were audio-recorded and researcher notes and teacher written responses from the workshop were also collected. Participants were emailed regularly between March and the end of May, to gather data on what the teachers said they had been thinking about and doing in their classrooms. Teachers were also emailed specific questions and sent a questionnaire to fill in. One teacher volunteered to be interviewed and another to be observed teaching. Another teacher shared a video of her class working. Participants were also asked to keep a journal but to our knowledge this did not happen. In late May, teachers attended an after-school session where they talked about their "frustrations and delights" in trying to foreground thinking in their classrooms. Again, discussions were audio-recorded and researcher notes and teacher written responses were collected.

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[2] An additional teacher from one school also joined us for the first workshop but did not participate in any follow-up activities.

What the teachers said

The teachers seemed positive about their involvement in this project.[3] They said the project supported them to think differently about some of their classroom practices. In the initial workshop we stressed that teaching thinking in the absence of content rarely works. Thinking skills and knowledge are bound together.[4] This idea—that content is still important and thinking cannot be taught without it—really resonated with these teachers.

Teachers seemed to value the opportunity to talk together with other science teachers. They seemed to regret that the regional science teachers group is currently not active. No one, however, seemed really interested in participating in an online forum on NZCER's Shifting Thinking website.

One teacher, who had previously been involved overseas in a programme designed to enhance thinking in the classroom, talked about the need to *change the focus* of what you do, rather than *add more* into teaching. She advocated taking small steps toward changing practice rather than trying to change everything at once. This strategy of "starting small" also seemed to work in the workshop. A couple of the teachers who were finding it difficult to get started when they tried to plan a whole unit of work that foregrounded thinking, found it much easier when it was suggested that they just took one of the strategies[5] that had been introduced earlier in the day and adapt it to their chosen context.

In the final session teachers spoke enthusiastically about strategies they had tried in their classes. All the teachers in the group related examples of students interacting with each other in class. As a group they shared strategies for arranging the classroom and maximising opportunities for students to talk together. There was a feeling that it was desirable for students to interact and discuss ideas but that it would not work in all classes. Behaviour management appeared to be an important issue for most teachers.

When asked about other barriers to change, teachers mentioned the amount of time needed to make new resources. They also spoke about students not having enough time in class to reflect on what they were doing, although two teachers did suggest strategies they use to deal with this. One teacher spread practical work over two sessions so the class did have time to discuss results. The other said he sometimes just gave the students results rather than taking time for students to actually do the investigation at the expense of being able to talk about it.

High-stakes assessments were also considered a barrier to changing practice. Teachers expressed a perceived need to ensure students were prepared for the sorts of questions they would encounter in national assessments. Although in this group all teachers spoke enthusiastically in the last

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[3] One teacher reported that she had been motivated by her involvement in this project to seek funding for her college to do some research into how they were supporting the development of their students' thinking.

[4] For further discussion, see, for example, Willingham (2009).

[5] These strategies included the generic framework for supporting argumentation in classrooms developed by Jonathan Osborne, Sibel Erduran and Shirley Simon. Retrieved from http://eprints.ioe.ac.uk/653/1/Osborne2004Enhancing994.pdf

session about students working and talking in groups, there was a strong feeling that assessment still needed to be individual.

One teacher identified teachers' assumptions about what teaching and learning science is about as a barrier for change. Many of the teachers also said students were often reluctant to think about their learning. During the project various reasons were given for this. Some students were considered lazy, some were considered too used to being "spoon fed" and others not capable of thinking even though they try.

Several teachers felt their schools' current focus on more generic school-wide professional development impacted negatively on developing subject-specific expertise.[6]

What the researchers have learnt

Our research team is interested in influencing practice. We are keen to find ways to better bridge the gap between theory and practice. This project has contributed to our understanding of the issues we need to address as researchers in order to do this.

Clarity of what we mean by thinking

During this project it became clear to the research team that we needed to be much clearer about what we meant by "thinking". We did not at any stage define what we meant by "thinking" and, throughout the project, teachers gave examples to illustrate student thinking that made us realise that they were defining it in a variety of ways. For example, when teachers talked about the successes they had with students thinking during the term, examples included students working out how to write the symbols for chemicals—"using their brainpower for a change", a student explaining a concept to other students, students asking questions and students finding out answers independently. When asked, "How do you know when students are thinking?" teachers said things like "You can see the light bulbs go on", "Students ask questions that lead to the next concept you are going to teach" and "Students question and talk to each other."

These responses made us think more deeply about what thinking *in science* actually involves. What are the defining features of thinking in science? How is this sort of thinking different from any other sort of thinking? Until we are really clear about what we mean by a thinking curriculum, it is hard to see how teachers can be expected to do things differently.

Although *thinking* is one of the key competencies that *NZC* states "are the key to learning in every learning area" (Ministry of Education, 2007, p. 12) the word "thinking" does not actually appear in the science learning area in *NZC.* However, the reason given for teaching science is that "science is able to inform problem solving and decision making in many areas of life. Many of the major challenges and opportunities that confront our world need to be approached from a

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[6] One teacher noted that general professional development is enhanced if the facilitator has knowledge of the specific subject area.

scientific perspective, taking into account social and ethical considerations" (p. 28). Clearly, then, thinking is valued in the curriculum, but what does "good" thinking in science look like?

Bailin (2002) argues that dealing with problems or challenges critically involves drawing on a complex array of understandings ("intellectual resources") and that the particular intellectual resources needed for any challenge depend on the specific context. In science, good thinking would show respect for things that are valued in science; for example, accuracy of data, control of variables, reliability of resources and the validity of inferences.[7] Good thinking in science also requires knowledge of such concepts as necessary and sufficient conditions, correlation and causation and hypothesis and prediction. Background knowledge of the relevant topic is also essential for making reasoned judgements. The student also needs the disposition to deploy the resources available. An inquiring attitude and open mindedness are important. To think well in science then a student would draw on understandings about criteria, concepts and habits of mind as well as background knowledge.

Underlying assumptions

It seemed to the research team that we provided insufficient opportunities for teachers to examine their deeply held (and probably tacit) beliefs about what is important in education and learning. One of the recurrent themes in the transformational learning literature is that the learner needs to experience some sort of dissonance[8] that then encourages them to examine their existing assumptions. If these underlying beliefs are not examined there is a risk that new ideas are simply incorporated into existing frameworks. We are not sure that teachers in this project experienced the necessary dissonance.

When we looked at the data, though, we noticed that there were some examples of lack of congruence between what teachers said was important and how they talked about their practice. At the initial workshop, teachers spoke about the difficulty they had in encouraging students to think. They said students wanted to be "spoon fed" but that this was not helpful in a world where students would have to be able to break complex problems down themselves. Shortly after this discussion we presented the teachers with some items from the test, *Science: Thinking with evidence* (Bull et al., 2010). The initial response of many teachers was to try to simplify the task. For example, we presented teachers with the flow diagram below and asked, "What would students have to think about when answering questions related to this diagram?"

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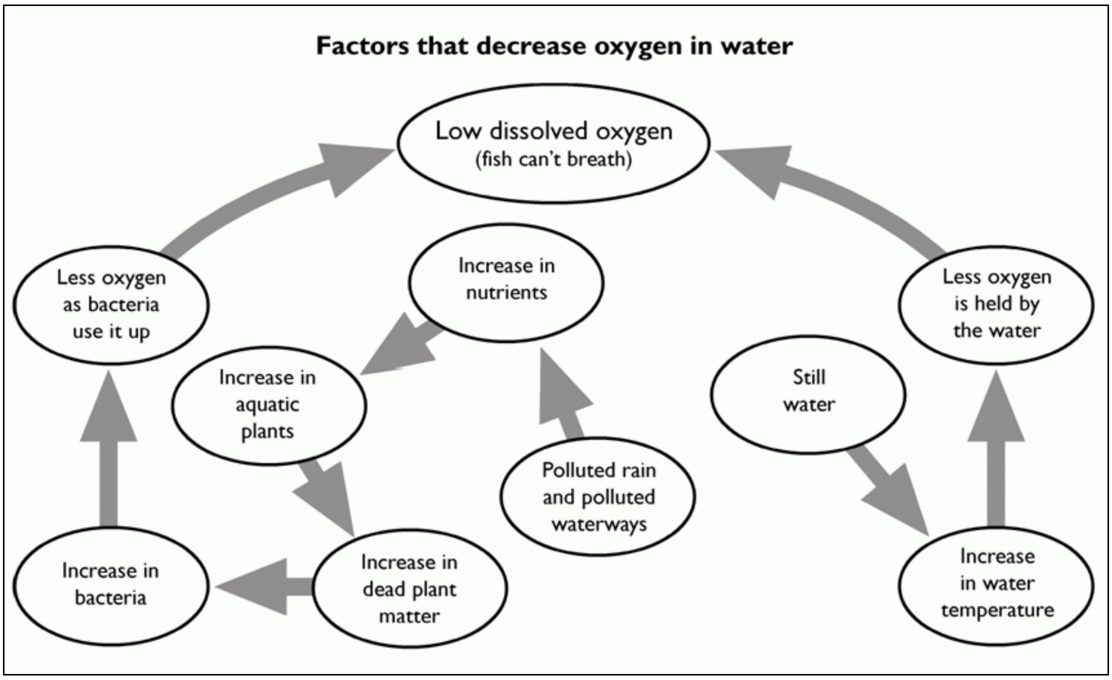
[7] This comes under the Nature of Science strand in *NZC*.

[8] See, for example, Mezirow and Associates (2000).



Rather than answering the question, teachers made comments such as:

> Students cannot look at a complicated diagram—it's a skill they don't have.
>
> There is a big variation in students' ability to interpret things visually—some just can't do it.
>
> I don't like the diagram because it has been folded in on itself. You have got a physical proximity between low dissolved oxygen and increase in nutrients which kids would find confusing.
>
> Even the font you have used is small.
>
> You could have made it more of a circular shape.
>
> Not laid out in a logical pattern. You have a dog leg here.

Drawing teachers' attention to this lack of congruence could have been helpful in bringing to the surface their underlying assumptions. At some level do teachers really believe their job is to simplify material for their students? Is getting the right answer more important than students learning strategies for making sense of complex situations for themselves?

Threshold concepts

We have begun to wonder whether there are certain "threshold concepts" in education that teachers need in order to see things in new ways. According to Meyer and Land (2003), "A threshold concept can be considered as akin to a portal, opening up a new and previously inaccessible way of thinking about something. It represents a transformed way of understanding, or interpreting, or viewing something without which the learner cannot progress" (p. 412). What are these threshold concepts in education? Recent research on learning has produced changed concepts of knowledge, and intelligence and new criteria for what counts as competent performance. For example, although individual performance still matters, much “knowledge work” involves collaboration with others (Resnick, 2010). If learning is understood as a social activity rather than something that happens just inside individuals’ heads, what counts as assessment needs rethinking. In this project, although talking about the benefits of students interacting with each other, most teachers seemed to think that only individual assessment was valid. Whilst this belief exists, class discussions are likely to be an “add on” rather than the “real work” of the class. Similarly, if the goal to provide an elite standard of education for everyone is to be realised, teachers (and students) need to believe that intelligence is learnable (rather than a fixed entity) and that students can become more capable.

One-off activities

During the initial workshop a number of strategies were suggested that teachers could try with their classes. These strategies seemed to be well received by the teachers and the approach of making small changes rather than trying to reinvent everything was certainly perceived as an enabler for change. However, in retrospect, we wondered about how helpful one-off activities really are. Can one-off activities really displace standard routines of practice? Perhaps it would have been more helpful to have designed a “unit of work” or a series of lessons and talked the teachers through this, unpacking our thinking behind the unit. Teachers could then have tried it with their own classes, modifying and adapting it to suit their situations before coming back as a group to discuss and develop it further. Perhaps this approach would have given both teachers and researchers more of a feel for the sort of changes that need to happen if we really are to realise the vision of a thinking curriculum for the 21st century and also provided teachers with more “ownership” of the project. Despite teachers saying that they found their participation in the research supported them to think differently about their teaching, we wondered how much relevance the project had for the teachers or whether it was really just one more thing to do for people who were already too busy.

Where to now?

This project has raised for us more questions than it has answered. It has, however, suggested some important next steps for us. We are still a long way from knowing what science classes in a thinking curriculum would look like—let alone knowing how to achieve it. We think this is a challenge that requires people with different expertise (teachers and researchers) to work in *partnership* for an extended period of time. As researchers, we need to develop more conceptual clarity around what “thinking in science” involves but we also need to work closely with teachers to work out what it might *look like* in practice and *how* these changes can be made.

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