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Building a science curriculum with an effective nature of science component

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Introduction

This paper places two decades of science curriculum reform in New Zealand in the context of international debate about the "nature of science" (NOS) as a driver of change in the science curriculum. It briefly outlines the sorts of changes NOS was expected to achieve, why these changes were seen to be a good idea and challenges faced by would-be reformers in other nations. Narrowing the focus to New Zealand's experiences, the paper then outlines in somewhat more detail the structure and scope of the reform-oriented 1993 science curriculum, and traces the evolution of this document into the science learning area of the 2007 New Zealand Curriculum (NZC). A high-level analysis of what has actually changed (or more specifically what has not) informs the more speculative final section. An "effective" curriculum will be one that achieves the sorts of changes intended by the NOS reformers. Knowing what we know now about the impact of our two recent attempts at science curriculum reform, what should we do next and why?

Advocacy for NOS: The international background

Internationally, advocacy for NOS has come and gone intermittently ever since there was a school science curriculum.[1] Adding a NOS component to school science is seen as a way to address several persistent challenges in science education. One concern is that too many students experience science as irrelevant and difficult, with the result that they stop learning it as soon as they can. In this case a NOS component is intended to make science both more *engaging* and more *equitable* (i.e., enabling learning success for students from diverse backgrounds). Another challenge is that all citizens need some insights into how science operates as a knowledge system, and the scope of its basic "big ideas" (i.e., how science explains natural events), as part of their education for current and future citizenship. In this case NOS is intended to provide a foundation for *democratic participation* and for sound *personal decision making*. Persistent concerns about the need to keep nurturing a talent pool of future scientists are also indirectly addressed by advocacy for NOS: equitable opportunities in science potentially broaden the talent pool of future science workers, and scientists are citizens who face the same sorts of challenges in their everyday lives, and outside their own specialist areas, as everyone else. Also, providing experiences that give students a realistic feel for what a career in science could be like, and the ways in which science can serve important societal needs, appeals to the idealism that many adolescents bring to their choices of possible future careers.[2]

Amongst science educators, learning judiciously selected "content" of science is seen as necessary but not sufficient to achieve greater engagement, relevance, active use of science learning in real life contexts or for maintaining interest in science-related employment possibilities. A NOS curriculum component potentially adds important insights into matters such as: how science

[1] Lederman (2007) provides a comprehensive overview of the history of NOS as a component of science curricula around the world.

[2] See, for example, Boe, Hendriksen, Lyons, & Schreiner (2011).

actually works in the world; how to recognise claims that are worthy of trust from those that are not; and how to make considered personal choices when science itself cannot determine a definitive course of action (e.g., because it depends how risks are weighted, or because a situation is complex and likely outcomes are not yet known).[3] However, none of these challenges can be fully addressed just within the boundaries of science learning. For example, concepts from media studies are very helpful when evaluating conflicting media messages related to a science issue,[4] and a sound feel for statistics, which mathematics educators would say builds only slowly across many rich mathematical experiences/years of schooling,[5] is very helpful when evaluating dubious quantitative evidence claims. In these ways, NOS can help support *curriculum coherence* by creating meaningful links between science and other discipline areas.

Have NOS initiatives actually achieved these goals?

A theoretically compelling argument for NOS is easily built. However, it is common for researchers to report that using a NOS curriculum component to effect actual changes in teaching and learning is a much more difficult matter. Put plainly, this type of curriculum reform is easier said than done. Various reasons why this might be so have been advanced in the international literature.

Lack of teacher knowledge about NOS is frequently assumed to be a barrier to real and enduring NOS-supported change.[6] Typically, teachers' own education in science did not include a NOS component and this creates a sort of double barrier: they need to make a specific effort to learn a new *type* of content[7] but they also need to learn to think differently about what it looks like to *be a successful learner* of science: what sorts of outcomes should be valued and what classroom learning experiences should look and feel like. Both are formidable challenges for busy teachers. The need for additional knowledge from different discipline areas (e.g., media studies for science in news; statistical and graphical literacies for working with data) compounds these professional learning challenges.

Some professional learning initiatives have been built around developing consensus lists of abstract NOS ideas as simple *propositions* that teachers might easily remember.[8] Examples

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3 Some science educators have recently begun working backwards from these sorts of outcomes to produce lists of key insights that students need to build via direct experiences of wrestling with real issues (for example, Allchin, 2011).

4 Two researchers from Northern Ireland have built a strong programme of research and development work at the science/media studies intersection (see, for example, McClune & Jarman, 2011).

5 See, for example, Neill (2012).

6 Again, Lederman (2007) provides a comprehensive summary of endeavours to address this issue—and reports on their persistent lack of success in gaining any real traction in classroom change.

7 Teachers are typically very active in attempting to keep up to date with science content knowledge, so it is not the new learning per se that is at issue here.

8 In America this consensus building was managed by the American Association for the Advancement of Science (AAAS) and the original list of propositions (since refined and updated) appeared in a book called *Science for all Americans*. In the UK a consensus-building Delphi methodology from sociology was used to produce a similar list of propositions.

include “scientific knowledge is durable” and “scientific ideas are subject to change”.[9] These propositions are typically stripped back statements devoid of important qualifications and clarifications. I have deliberately chosen two that show the potential for contradiction unless their expanded meaning is well understood. Critics have argued that personal support for a proposition can reside at either a naive or a sophisticated level of philosophical thinking and it is not possible, without deeper conversation, to tell the difference between the two. For this and other related reasons, in the last several years there has been growing critique of using philosophical propositions as the foundation of professional learning and curriculum reform.[10] Proponents of an alternative approach argue for NOS knowledge drawn more widely from the social sciences (i.e., not just philosophy) and specifically from a field called Science Studies that investigates what scientists actually do, not just what they say they do.

Notwithstanding debates about what sort of NOS knowledge is needed, there are indications that gaining new professional knowledge and skills is necessary but not sufficient to support real change in teaching and learning. For example, when teachers have successfully completed NOS courses, they may still not institute the sorts of changes their teacher educators have hoped to see. At the very least they are reluctant, and some teachers show outright resistance. Why? Various reasons have been proposed:

- NOS-related learning goals are unfamiliar and hence require a level of conscious decision making that default teaching of content-as-usual does not necessarily demand.
- In the absence of exemplars that show how specific NOS knowledge can combine with specific science concepts/skills to build specific sorts of outcomes, teachers are being asked to join a lot of dots for themselves. Many will remain unconvinced that such changes are a good idea.
- When teachers perceive that traditional gate-keeping roles are the predominant purpose for inclusion of sciences in the curriculum they are likely to see NOS-inspired changes as “dumbing down” rigorous learning.[11] It is hard to sustain innovative reforms in the face of conservative pressures.

There is no reason to believe that New Zealand has been any more successful than other nations in addressing these challenges. But we certainly have tried, as the next sections of the report now outline. To understand how NOS is shaped in NZC, and how this curriculum innovation has been interpreted by teachers, we need to briefly revisit important developments across the last two decades.

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9 See Rutherford and Ahlgren (1990, Chapter 1). (There are no page references in the online version.)

10 Lederman (2007) notes that there is no empirical evidence to link learning of the propositions to the sorts of citizenship outcomes they are assumed to foster. Allchin (2011) notes that teachers can hold misconceptions about some NOS propositions (specifically relationships between theories and laws) and in any case knowing the correct versions of these is not necessarily helpful in addressing authentic socio-scientific controversies.

11 This has certainly been the experience in the UK where an innovative *21st Century Science* curriculum has been controversial, even though its development was very well supported at all levels of the system, including provision of textbooks and extensive teacher support materials, and the shaping of specific high-stakes assessments to reflect its aims and intended outcomes.

Shaping a national science curriculum for New Zealand in the 1990s

The model of an outcomes-focused national curriculum for all levels of compulsory schooling was first introduced in the early 1990s and *Science in the New Zealand Curriculum* was published in 1993. This book-length document specified the science content to be taught in some detail. Shaping this content in terms of outcomes was new but the scope of that content largely remained as it had been in at least the preceding several decades. One exception was the addition of a somewhat eclectic mix of ideas from geology and astronomy.[12]

Two integrating strands were a second new feature of the 1993 curriculum. A "weaving" metaphor was used to show how these new strands would work together with the traditional content, presumably so that the sum was more than the parts, which in turn implies that the NOS strand would change the focus of the content teaching. However, there was a lack of specific direction about what such change might look like, and what specific purposes (and hence outcomes) it might serve. One of the two integrating strands was structured in four sections intended to reflect the main types of activity in the (sequential) stages of every science investigation.[13] The intent was to encourage more open investigative work in classrooms where students would have more realistic experiences of what it might feel like to "work like a scientist".[14] Instead, this familiar structure appeared to more often reinforce the common idea that there is one unitary "scientific method".[15] This in turn supported the impression that traditional recipe-style practical work would meet the curriculum intent. Those teachers who thought this could say in all sincerity "we already do that".

The second integrating strand represented New Zealand's first overt attempt at introducing a NOS component into science education. At the time a focus on technology education was relatively new and a curriculum document specifically for the technology learning area was still some time in the future. For the meantime, technology's strong relationship with science opened up some curriculum space. The new strand was called "Making Sense of the Nature of Science and its Relationship to Technology".[16] This, too, can be seen with hindsight to have reinforced traditional

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12 This innovation was hotly contested by traditionalists who saw these science disciplines as peripheral to the school science curriculum.

13 This is easily and memorably stereotyped by teachers as "aim, method, result, conclusion". Note that the titles in the science curriculum cued a broader range of practical activities: "focusing and planning"; "information gathering"; "processing and interpreting"; and "reporting".

14 This intention is elaborated in one chapter of the book *Developing the Science Curriculum in Aotearoa New Zealand* (Haigh & Hubbard, 1997).

15 This belief, which is commonly held by science teachers in many nations, has been a focus of critique by science educators over several decades now (see, for example, Jenkins, 1996).

16 The "making sense" phrase was included in every strand and reflected the influence of constructivist learning theory on how the overall curriculum was shaped. The emphasis given to teaching concepts wrapped up within relevant contexts was another manifestation of this theoretical influence. The assumption was that students would see the abstract conceptual learning as more relevant to their lives and hence the content of the curriculum would make more sense to them. Bell and Baker (1997) collected multiple perspectives on the building of the 1993 curriculum and a chapter which I co-authored focuses on the use of contexts (Hipkins & Arcus, 1997). I would write this quite differently now. In the event, the very idea of constructivism generated more heat than light, in part because some people took it to be a theory of pedagogy rather than a theory of learning.

thinking. There is evidence that shows that this new strand did not prompt much, if any, curriculum change. Science teachers have always used technological applications to illustrate the usefulness of scientific discoveries and they continued to do so. When *Technology in the New Zealand Curriculum* appeared in 1995 some science teachers assumed that the NOS strand had outlived its relevance and could now be safely ignored.[17]

In response to these challenges, the Ministry of Education (MOE) attempted to resource the less familiar NOS aspects of the new strand. A website called Science IS was developed to support teacher professional learning.[18] It had two main components: one part described basic NOS propositions, based on the international work mentioned above, and linked these propositions to the new NOS strand; the other part took traditional learning activities and showed how they could be refocused to include a NOS component.[19] Each activity was hyperlinked to one highlighted NOS proposition: the intention was that the two parts of the website would be explored in tandem and teachers' NOS knowledge would build as they included the tweaked activities in their day-to-day work. With hindsight, it is easier to see how the good intentions of this design were subverted in practice. What was not made clear was *how* and *why* a NOS component could change the nature of the overall outcomes sought. Building new knowledge *about* the proposition in focus was the NOS outcome unintentionally implied by the website design because the conceptual outcome remained unchanged. Thus the Science IS approach arguably acted to reinforce the impression that NOS adds additional content, and abstract content at that, to an already demanding learning area.

Two further developments during the 1990s help explain how the science learning area in general, and the NOS strand in particular, took shape during the construction of NZC in the early 2000s. The 1993 document described learning outcomes from Year 1 to Year 13 but senior subject specialists were not satisfied that the four contextual strands provided sufficient detail on which to build their specialist courses, especially in Years 12 and 13. MOE was persuaded to create three separate specialist curricula: one each for physics, chemistry and biology, covering curriculum levels 6–8, and these appeared in 1994. Although most students continued to study one combined science course at Year 11 (level 6) the three supplementary curricula allowed for expanded specialist courses at this level as well.[20] In a telling development, all three specialist subject curricula dropped the NOS strand of the full science curriculum.[21]

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17 The National School Sampling Study, conducted for MOE by the University of Waikato, captured science teachers' curriculum thinking at the end of the 1990's decade of curriculum change (McGee et al., 2003).

18 The title was a play on words. Science is … cues discussion about its nature as a knowledge-building discipline. Science IS references the Integrating Strands of the 1993 science curriculum.

19 The full set of propositions and their accompanying discussion was recently migrated to Science Online. Some of the activities also remain and have been updated to link to NZC.

20 Learning areas whose curricula were developed later in the decade did not follow this pattern. For example, no separate curriculum documents were created for history, geography and economics, even though these had been combined under the umbrella of the Social Sciences learning area (see Bolstad & Gilbert, 2008, for a critque of the structure of the senior secondary curriculum and its development in the recent past).

21 One of the biology writers recalled that they initially saw the main science curriculum as the overarching framework, which meant the integrating strands could be taken as already given. Part way through the

The second relevant development concerns the timing of the appearance of the overarching 1990s curriculum framework.[22] This slim stand-alone framework document introduced precursors to the vision, values, key competencies and principles[23] that constitute the high-level front-end components of the current NZC framework. Significantly, this first curriculum framework did not appear until 1993: after both the mathematics and English curricula had been completed, and very late in the day for science. The essential skills that foreshadowed the key competencies[24] appeared belatedly as a list at the back of the 1993 science curriculum. There was no opportunity to really process these and show how they might actually change the focus of science teaching and learning. In the light of our experience since, it seems plausible now to argue that the seeds of a "we already do that" response to the key competencies were sown at this time. This is relevant to the NOS discussion because learning that meets NOS goals is highly likely to simultaneously stretch students' competencies in new and demanding ways.[25]

Shaping science during the co-construction[26] of NZC

Early in the new century NZC began to be developed in response to a range of pressures.[27] The pressure to reflect wider societal changes within the structure of the national curriculum was an important driver in the reshaping of the 1993 Curriculum Framework into the "front end" of the integrated NZC framework.[28] A focus on supporting students to become "21st century learners"

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development MOE specifically requested that the integrating strands be added, which no doubt explains the belated positioning of investigative skills at the end of all three documents. Biology already includes a focus on biotechnology so the curriculum developers believed they had already met the main intent of the 1993 NOS strand in some of the new content objectives they had developed. Chemistry was similar but physics was slightly different in that this contextual area already had a "process" strand and this provided an opportunity to weave empirical NOS references throughout the new specialist physics document. For example, Aim 2(a) of physics states that "students will appreciate the nature of theories and models in physics" (p. 14) and Achievement Objective 6.2(a) is "explore the use of experimental evidence in developing theories and models" (p. 16). With hindsight, one of the physics writers now thinks that they concentrated on empirical aspects of NOS and neglected the social and cultural aspects of science.

22 Ministry of Education (1993).

23 But not so much the advice on effective pedagogy—this development, new to NZC, was prompted by emergent findings from the fledgling Best Evidence Synthesis programme (Cubitt, 2006).

24 When NZC was first introduced, the international keynote speaker at an NZCER conference on key competencies warned that positioning them as *replacements* for the essential skills would narrow their scope and prevent them from achieving their potential to transform aspects of the curriculum (Reid, 2006; Webber, 2006). NZC itself was also clear on this point: "More complex than skills, the competencies draw also on knowledge, attitudes, and values in ways that lead to action" (Ministry of Education, 2007, p. 12).

25 In two different places in NZC key competencies are described as means to other valued learning ends, as well as valued ends in themselves.

26 Cubitt (2006) explains that MOE aimed to involve as many teachers, school leaders and educational organisations in the construction process as they could manage. This was done to maximise understanding of the intent of the changes and to try to ensure sustainability of ongoing changes during the implementation phase.

27 Cubitt (2006) summarises four main goals for the Curriculum Project: refining and clarifying outcomes; adding a focus on effective teaching; strengthening school ownership of the curriculum; and strengthening partnerships with parents and communities.

28 In the foreword to NZC the Secretary for Education specifically mentioned more complex workplace demands, the availability of more sophisticated technologies and the increasing diversity of our population

was given expression via a one-page vision statement,[29] a set of eight principles to underpin curriculum decision making, a set of eight overarching values to be encouraged, modelled and explored and a set of five key competencies adapted from those developed by the Organisation for Economic Cooperation and Development (OECD).[30]

The so-called *Essence Statements* were another new high-level feature of NZC. These encapsulated the intent of each learning area in one pithy statement that was intended to serve as a guide to "what matters most in each subject".[31] For science, this statement reads:

> In science, students explore how both the natural physical world *and science itself* work so that they can participate as critical, informed, and responsible citizens in a society in which science plays a significant role (Ministry of Education, 2007, p.17 emphasis added to highlight NOS reference).

In the context of this NOS discussion, two things are noteworthy about this statement. First, the *use* of insights from science learning for citizenship purposes is highlighted as the desired outcome in the structure of the *Essence Statement*. (Students learn … *so that* they can …). Second, *both* knowledge and NOS are seen as essential inputs if these types of outcomes are to be achieved. In this way the intention of the NOS strand of the 1993 science curriculum was symbolically positioned at the very heart of the science learning area of NZC. This explicit high-level signal of the importance of NOS in the curriculum is all very well: was it matched by a clear exposition of how it might play out in the actual development of the learning area detail? To address this question, I turn now to the work of the science curriculum team.

The Curriculum Stocktake had recommended that the number of learning objectives in each curriculum area should be substantially reduced. Primary teachers, in particular, were finding the full curriculum overwhelming in its detail and impossible to fully deliver. The team[32] assembled to work on the science learning area was initially strongly briefed that their mandate from the Curriculum Stocktake was limited to streamlining the 1993 curriculum content. After a whole decade of curriculum change, MOE was keen to minimise the impact of still more change, especially for primary teachers who would again need to get to grips with all the reworked curriculum areas. For this reason, substantive reworking of any learning area was strongly discouraged. The intention was to bring the bare-bones of the still recognisable learning areas together into one slim "framework" document. The work of every subject team began with this pressure to reduce and streamline existing content as a frame of reference.

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base (Ministry of Education, 2007, p. 4). In his supporting letter to the curriculum the Minister of Education expanded on these themes, mentioning rapid social and economic change, globalisation, new social roles and new forms of self-expression.

29 In the brief version: for students to become "confident, connected, actively involved, lifelong learners" (Ministry of Education, 2007, p. 8).

30 For an account of the translation of the OECD initiative into NZC, see Rutherford (2005).

31 This is how they were explained by a key MOE participant at the time (Cubitt, 2006, p. 206).

32 This team was predominantly composed of teacher representatives of the four discipline areas, and of primary science, with one or two tertiary science educators. An advisory group that met occasionally to respond to the working party's drafts had a wider representation, and included at least one scientist.

In the event, the science writing team did manage, over several iterative cycles of design, to successfully restructure the Planet Earth strand.[33] They also proposed merging the separate investigation and NOS integrating strands from the 1993 document. This was ostensibly done to reduce the number of achievement objectives, but in fact the team was aware that the NOS strand had not been understood, or enacted as intended, and they saw an opportunity to try again. At the same time, the team aimed to at least try to take account of parallel work being done on the front end of the NZC framework, and in particular on the early shaping of the key competencies.[34] A discussion paper commissioned by MOE sought to draft science-specific versions of the competencies and to show how these might align to other emergent features of the NZC framework such as the values and the "future-focused themes".[35] One sentence jumps out of this commissioned paper as particularly prescient:

> Put simply, asking what competencies are needed for science education is only a meaningful question if one is clear what purposes one wishes to achieve in science education. (Barker, Hipkins, & Bartholomew, 2004, p. 4)

This working paper recommended that the potential for the key competencies to refocus how teachers thought about *purposes* for learning could be developed via a really clear set of overarching aims for all the science strands in NZC. The team attempted to shape such aims, but for reasons of space and coherence across learning areas they were never included in NZC itself.[36] Instead, they were published as part of the stand-alone fold-out of the whole science learning area. Unanchored from the main NZC document, they were arguably easily lost sight of. This could be one reason that teaching the content of the contextual strands continued to be seen as the dominant purpose for learning science.

Of course the aims were never intended to be the *only* means to convey messages about purposes for learning science. As already noted, the *Essence Statement* did so quite unequivocally. However, its expanded two-page version listed four purposes. The very first of these "develop an understanding of the world, built on current scientific theories" (Ministry of Education, 2007, p. 28) directs attention to traditional content acquisition, perhaps just for its own sake. We could also argue that weaving the new NOS strand through the content strands should have sent strong

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33 The 1993 document contained a somewhat eclectic grab bag of ideas and concepts. After a decade of working with these, leading teachers were in a much better position to develop a coherent underlying conceptual structure for the strand.

34 My own position no doubt played a part here. I was a member of the science working party, and was simultaneously a member of the Education Reference Group for the development of the front end of NZC. In the latter capacity I helped draft the very preliminary definitions of the key competencies. With hindsight, I would now say my understanding was still limited: it would seem that developing a more nuanced understanding of key competencies is inescapably iterative and experiential (see, for example, Hipkins & Boyd, 2011), but it was at least an advance on beginning to think about them for the very first time.

35 These themes originated in working papers for the Curriculum Stocktake and at the time there were six: social cohesion; citizenship; education for a sustainable future; bicultural and multicultural awareness; enterprise and innovation; and critical literacy. These eventually morphed into four future-focused issues (sustainability; citizenship; enterprise; globalisation), listed under the auspices of the Future Focus curriculum principle, as topics to be explored.

36 Some learning area teams did not want to develop aims as well as achievement objectives.

signals that a rethinking of purposes for learning science was needed. However, the NOS strand of the 1993 curriculum had failed to do this because it was soon ignored, and it now seems that the 2007 version has fared only a little better.[37] Multiple competing pressures were being juggled by the writing team and this resulted in the NOS strand carrying a very heavy change burden:

- *Understanding about science* is the substrand that overtly addresses the lack of understanding of the NOS strand of the 1993 curriculum, by attempting to clarify what students should be learning about NOS. However, as outlined earlier in the paper, it is based on a "propositions" approach to building NOS knowledge. Continuing the 1900s structure of multiple discrete outcomes prevented an explicit "joining of the dots" to show how knowledge of these propositions might be useful for strengthening outcomes related to using knowledge for citizenship purposes.
- *Investigating in science* is the substrand that conveys rich possibilities for students' own learning experiences: that is, it goes well beyond the stereotypical mimicking of "the scientific method" that the investigation strand of the 1993 curriculum inadvertently perpetuated. Like the *Understanding about science* substrand, it draws some content from developments and clarifications of NOS that took place during the development of the Science IS website.
- *Communication in science* constituted a response to the development of "literacy across the curriculum" initiatives during the early years of the decade, and was simultaneously an attempt to exemplify some subject-specific implications for integration of the key competency *Using language, symbols and texts* into the science learning area. However, what literacy means in the context of science is a contested matter[38] and unravelling relationships between all the potential ingredients of this substrand within an overarching NOS framing is neither straightforward nor simple.
- *Participating and contributing* directly references the key competency of the same name and directs attention to the types of outcomes signalled in the *Essence Statement*. Again, a complex mix of contested curriculum possibilities and priorities are signalled—but not sorted—here.[39]

Given all the competing agendas outlined in just this short account of the NOS strand, benign neglect of its change intent (we have no evidence to suggest that teachers in general are actively opposed to the NOS strand and some are very interested) might seem like a rational response to an impossibly complex task. With this thought in mind, I turn now to what we do know about how teachers are enacting the science learning area of NZC.

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[37] Evidence for this claim is addressed in the next section of the report.

[38] Science can be a source of rich and interesting contexts for building basic literacy skills; in turn, basic literacy skills are enablers of science learning, including such activities as accessing media accounts of scientific activity and ideas; while "scientific literacy" conveys a whole different focus on understanding the practice and processes ("literacies") employed in the construction of scientific knowledge.

[39] During the consultation phase for NZC, this was the most controversial of the NOS substrands. Feedback to the writing party showed that some teachers took it to mean that they would need to encourage their students to take a direct part in protests etc. Rather than seeing the desired outcome as being a strengthening of competencies (as combinations of knowledge, skills, attitudes and values) for informed decision making (including building "action competence" where relevant) they appeared to see direct action per se as the outcome of the substrand.

How is NOS understood and enacted?

Because NZC was explicitly designed to enable school-specific curriculum development, there is no one easy way to address this question. The diversity of practice across schools means it is a bit like asking "How long is a piece of string?" However, we can draw inferences about how well NOS is understood and enacted across multiple sources of direct and indirect evidence.

A recent review of results from several rounds of participation in the Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) international assessment programmes does not suggest that *equity* challenges have been successfully addressed: many students still see no place for themselves in the sciences, and we have not made inroads into reducing achievement disparities in science.[40] Would-be reformers are still talking about the need for the sorts of changes NOS was always intended to address.[41]

An Education Review Office (ERO) report published in 2012 provides the most recent direct evidence of the state of science teaching in New Zealand's primary schools. ERO found that less than a third of the 100 schools reviewed had effective science programmes. In the schools that did not have effective programmes:

> Students experienced knowledge-based rather than interactive, investigative approaches, and did not have opportunities to learn concepts from the Nature of Science strand. (Education Review Office, 2012, p. 9)[42]

Yet to be published findings from the Curriculum Support project both endorse and shed more light on ERO's commentary. A member of our team has just completed interviews with 14 teachers in charge of science, from a range of primary and intermediate schools. Many of them said that teachers did not really understand the intent of the NOS strand, or how to use it in their programme planning.

A recent audit of curriculum support resources also found a lack of meaningful alignment between the intent of the NOS strand and the assessment focus of National Certificate of Educational Achievement (NCEA) achievement standards for Years 11–13. Since high-stakes assessment provides a powerful "message system" about the intent of a curriculum, this finding provides indirect evidence that the NOS strand is not being effectively integrated into the senior science subjects. However, it should also be noted that the Senior Subject Guides for science do include some specific, if generic, ideas about how to build a NOS component into teaching and learning.[43]

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40 On the contrary, higher numbers than the international average believe they are not very good at science. See the summary in Section 3 of *Inspired by Science* (Bull, Gilbert, Barwick, Hipkins, & Baker, 2010).

41 The report by the chief scientist, to which this paper is one response, is the most recent case in point (Gluckman, 2011).

42 The wording here is interesting. It could endorse existing impressions that NOS is primarily about adding new content to be learned. The same type of message is also evident in the "unpacking" of the NOS strand in the earlier ERO report on "capable and competent teaching" in primary science (Education Review Office, 2010).

43 Hipkins and Bull, with McGrail (submitted).

A recent online survey completed by around 300 teachers found that they were somewhat less confident about their ability to implement the NOS strand than the content strands. Tellingly, confidence levels were lowest overall for the *Essence Statement* which, as outlined earlier in the report, pithily joins the dots between NOS and content to refocus purposes for science teaching and learning.[44]

Google analytics data indicate that the Science IS website is still regularly accessed but teachers do not linger for more than a few seconds on the propositions materials. They do spend longer on the descriptions of how to tweak familiar learning activities to include NOS content.[45] Other websites with high NOS potential convey some mixed messages about the purpose of NOS in the curriculum. For example, the Science Learning Hub introduces the NOS strand as being important because "the curriculum requires it and research supports it" (i.e., because the curriculum "says so"). This message could easily be changed to focus on what the NOS was intended to achieve (i.e., to better "join the dots"), especially given the many interesting and current scientific activities documented on the website.

Commercial textbooks, ostensibly produced to support the science learning area in NZC, are still structured in the traditional manner, with chapters essentially divided up into the familiar content of science. In workbook materials that accompany these texts some token references to NOS are included, but in some cases these perpetuate known misconceptions about NOS propositions.[46]

There has certainly been a strong level of interest in NOS in New Zealand's small science education community. Several teacher educators, from different universities, have recently completed, or are in the process of completing, Master's- or Doctoral-level theses/dissertations in this area. However, any change they can or would wish to influence is likely to be adversely impacted by the trend towards fewer face-to-face hours for science-specific components of preservice programmes.[47]

Overall, then, there is little direct or indirect evidence to give us confidence that science in NZC has been more successful than the 1993 science curriculum in prompting and supporting changes in school science education.

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44 Hipkins and Hodgen (in press).

45 Again, more detail can be found in Hipkins and Bull, with McGrail (submitted).

46 These misconceptions are well known to researchers, but not seemingly to teachers (see Lederman, 2007). One example is the claim that a hierarchical relationship exists between theories and laws (i.e., theories are speculative and become laws when there is enough evidence). Another example is that doing science—per se—develops NOS. (This conflation is also implied in several NCEA achievement standards.) Science educators see knowledge, process (doing science) and NOS as three separate but interrelated parts of the curriculum.

47 This is an anecdotal comment, based on personal conversations with science educators from several of the universities.

Lessons to be drawn from the recent past

Given that the NZC science writing team was determined to learn from the experience of the 1990s decade and to be more explicit about the sorts of changes the NOS strand was intended to achieve, what might account for this continuing lack of actual change in teaching and learning? It seems likely that the intent of the new *structure* may have foundered on a combination of: mixed signals about purposes for learning science; the complexity of the double-integration required (front end of NZC with the learning area; content strands with the NOS strand); and the potential for mixed messages in the four quite different substrands of NOS.

This short account of the curriculum development process explains how a complex mix of events and agendas resulted in the three-tier structure that science teachers are now expected to navigate *with only minimal guidance and support:*

- The first tier of "contextual" objectives specifies the important content to be addressed in each discipline area. As a shortened version of the 1993 equivalents, this content arguably comes with all existing teacher assumptions about the importance and priority to be afforded to content learning intact.
- The second tier adds NOS dimensions that should be woven through the content, but with multiple competing agendas to be addressed there is no clearly evident best way to do this.
- Finally, the high-level third tier (the front end of NZC including the *Essence Statements*) does provide some signals about valued outcomes for science, but these will not constitute guidance for weaving a curriculum together unless teachers are disposed to pay serious attention to the messages of this tier and to prioritise them.

No current curriculum support materials clearly and explicitly join the dots across all three tiers so this would seem to be an important priority area for attention. With hindsight, it is easier to see that sequential rather than simultaneous development of the two halves of NZC might have allowed for some of the weaving together to have been achieved by the curriculum developers, rather than leaving it all for teachers to do after the fact.[48] However, even if we had been more successful in developing a more fully integrated curriculum there are no guarantees that a new structure will be sufficient to stimulate change. Indeed the evidence of the recent past, and of the 21st Century Science initiative in the UK, suggests that it won't.

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48 While timing will not be the only difference, it is interesting to contrast science with health/PE and the arts. As the last of the 1990s series, these curricula were developed well after the 1993 Curriculum Framework. Both learning areas appear to me (as a nonexpert in their underpinning disciplines) to have more successfully combined the front-half messages of NZC with the learning area detail. Each of these documents clearly specifies conceptual common ground across its various subjects: for example, health/PE/home economics are all informed by models of action competence, socioecological perspectives on health and an adapted view of the Māori concept of Hauora as an holistic way of thinking about wellbeing. These concepts are visibly infused through the achievement objectives. The social sciences attempted something similar during the development of the 2007 curriculum, developing common conceptual ground between geography, history and economics. However, no such common conceptual ground has been sought for the senior sciences and indeed we could argue that the development of specialist senior curricula in the 1990s acted to reinforce their separation.

We also need to see a mind-shift in teachers' curriculum thinking. It is interesting that useful recent breakthroughs in supporting teachers to enact NOS have begun with "backward planning": here researchers/curriculum developers have first thought very carefully about the types of outcomes they want students to achieve, assuming that high-level purposes for science learning are seen as more than just fine-sounding curriculum rhetoric. They then work backwards from these outcomes to arrive at clear specifications for what students need to learn.[49] Traditional planning, even when it includes NOS, tends to go the other way around: teachers determine the content they think is useful and then decide what aspects of NOS, if any, might be opportunistically woven in. In a similar vein some science educators are arguing for new curriculum explorations that begin by designing innovative assessment tasks that they hope will allow students to demonstrate the sorts of outcomes they have in mind. After these experimental assessments have been trialled, the researchers then work backwards from what the students actually did to more clearly describe achievable outcomes and learning challenges.[50] Once this has been done the curriculum developers should be in a better position to specify the teaching and learning implications for ensuring all students can experience success.[51] Addressing the current UK curriculum review, one science educator has summed up the challenge thus:

> For real improvement, we need to make clearer the kinds of learning we want—and that can only be done by showing explicitly the kinds of things we want learners to be able to do as a result of the teaching they experience. This is not an impossible task, just a very big one. (Millar, 2011, p. 181)

What do we try next?

This account of several decades of effort at constructing a change-leading science curriculum document shows very clearly that a well-structured curriculum cannot be the sole, or even the most important, stimulus for change. A document can be read and understood in multiple ways. Obviously it does not help if there are internal contradictions and tensions within the document, but these are almost inevitable given the contested nature of curriculum making, as captured in some of the footnote detail of this paper. Resolving some of these internal tensions could help, but what else should we try next, or instead?

A second theme running right through this account is the importance of teachers' curriculum thinking. How they understand their work is framed first and foremost by the *purposes* for which they think they are teaching science, and the sorts of learning outcomes they see as having value for learners. High-stakes assessments convey compelling messages about valued outcomes. Ensuring a more appropriate alignment between NCEA achievement standards, for example, and NZC would also help. However, this, too, is unlikely to be sufficient to support and sustain very different ways of thinking about purposes for learning science in the 21st century.

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[49] See, for example, Allchin (2011).

[50] NZCER researchers followed this type of process when designing the *Science Thinking with Evidence* assessments for Years 7–10. This test series shows one science-specific way of integrating the key competency of *thinking* into the taught curriculum. (Bull, Ferral, Hipkins, Joyce, & Spiller, 2010).

[51] See, for example, Millar (in press).

The paper has commented on the need for materials that “join the dots” between NOS and curriculum outcomes related to preparing students for their roles as future citizens. However, if teachers do not value such outcomes—or sincerely believe that they are supporting these types of outcomes when they teach only the content and processes of science—such materials, per se, are also unlikely to be an effective trigger for change.

Any materials produced to clearly illustrate the intent of the curriculum document would need to be well supported by carefully devised and sustained opportunities for teacher professional learning, both preservice and inservice. Unless and until teachers are both challenged and supported to change the ways they understand and enact science education in and for the 21st century, very little real change is likely to occur. This, we now believe, should be the number one priority.

References

Allchin, D. (2011). Evaluating knowledge of the nature of (whole) science. *Science Education, 95*, 518–542.

Barker, M., Hipkins, R., & Bartholomew, R. (2004). Reframing the essential skills: Implications for and from the science curriculum: Report commissioned by Ministry of Education, July 2004.

Bell, B., & Baker, R. (Eds.). (1997). *Developing the science curriculum in Aotearoa New Zealand*. Auckland: Longman.

Boe, M., Hendriksen, E., Lyons, T., & Schreiner, C. (2011). Participation in science and technology: Young people's achievement-related choices in late-modern societies. *Studies in Science Education, 47*(1), 37–71.

Bolstad, R., & Gilbert, J. (2008). *Disciplining and drafting, or 21st century learning? Rethinking the New Zealand senior secondary curriculum for the future.* Wellington: NZCER Press.

Bull, A., Ferral, H., Hipkins, R., Joyce, C., & Spiller, L. (2010). *Science thinking with evidence: Teacher manual*. Wellington: New Zealand Council for Educational Research.

Bull, A., Gilbert, J., Barwick, H., Hipkins, R., & Baker, R. (2010). *Inspired by science*: *A paper commissioned by the Royal Society and the Prime Minister's science advisor*. Wellington: New Zealand Council for Educational Research. Available at http://www.nzcer.org.nz/default.php?products_id=2647.

Cubitt, S. (2006). The draft New Zealand curriculum. *Curriculum Matters, 2*, 195–212.

Education Review Office. (2010). *Science in years 5 to 8: Capable and competent teaching.* Wellington: Author.

Education Review Office. (2012). *Science in the New Zealand curriculum: Years 5 to 8*. Wellington: Author.

Gluckman, P. (2011). *Looking ahead: Science education for the twenty-first century: A report from the Prime Minister's chief science advisor*. Auckland: Office of the Prime Minister's Science Advisory Committee.

Haigh, M., & Hubbard, D. (1997). 'I really know I have learned something': Investigative work in science education. In B. Bell & R. Baker (Eds.), *Developing the science curriculum in Aotearoa New Zealand* (pp. 53-65). Auckland: Longman.

Hipkins, R., & Arcus, C. (1997). Teaching science in context: Challenges and choices. In B. Bell & R. Baker (Eds.), *Developing the science curriculum in Aotearoa New Zealand* (pp.101-113). Auckland: Longman.

Hipkins, R., & Boyd, S. (2011). The recursive elaboration of key competencies as agents of curriculum change *Curriculum Matters, 7*, 70–86.

Hipkins, R., & Bull, A., with McGrail, R. (submitted). *Audit of science curriculum resources*. Wellington: Ministry of Education.

Hipkins, R., & Hodgen, E. (in press). *Curriculum support in science: Patterns in teachers' use of resources*. Wellington: Ministry of Education.

Jenkins, E. (1996). The nature of science as a curriculum component. *Journal of Curriculum Studies, 28*(2), 137–150.

Lederman, N. (2007). Nature of science: Past, present, and future. In S. Abell & N. Lederman (Eds.), *Handbook of research on science education,* (pp.831-879). Mahwah, NJ.: Lawrence Erlbaum.

McClune, B., & Jarman, R. (2011). From aspirations to action: A learning intentions model to promote critical engagement with science in the print-based media. *Research in Science Education, 41*(5), 691–710.

McGee, C., Jones, A., Cowie, B., Hill, M., Miller, T., Harlow, A., et al. (2003). *Curriculum stocktake, national school sampling study. Teachers' experiences in curriculum implementation: English, languages, science and social studies.* Wellington: Ministry of Education.

Millar, R. (in press). Improving science education: Why assessment matters. In D. Gunstone, D. Corrigan, & A. Jones (Eds.), *Valuing assessment in science education: Pedagogy, curriculum, policy* (provisional title). Dordrecht: Springer.

Millar, R. (2011). Reviewing the national curriuclum for science: Opportunities and challenges. *Curriculum Journal, 22*(2), 167–185.

Ministry of Education. (1993). *The New Zealand curriculum framework: Te anga marautanga o Aotearoa.* Wellington: Learning Media.

Ministry of Education. (2007). *The New Zealand curriculum*. Wellington: Learning Media.

Neill, A. (2012). Developing statistical numeracy in primary schools. *set: Research Information for Teachers, 1*, 9–16.

Reid, A. (2006). Key competencies: A new way forward or more of the same? *Curriculum Matters, 2*, 43–62.

Rutherford, J. (2005). Key competencies in the New Zealand curriculum: Development through consultation. *Curriculum Matters, 1*, 210–227.

Rutherford, J., & Ahlgren, A. (1990). *Science for all Americans*. New York: Oxford University Press.

Webber, B. (Ed.). (2006). *Key competencies: Challenges for implementation in a national curriculum.* Wellington: New Zealand Council for Educational Research.