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Enhancing primary science teaching: Interconnections of content, policy and practice in a New Zealand professional learning and development programme

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Abstract

This paper reports on an ongoing professional learning and development (PLD) initiative in New Zealand. The Academy is designed to provide primary and intermediate classroom teachers with the knowledge, materials and support needed for effective delivery of *The New Zealand Curriculum*'s science subject area. Specifically, this paper reports on the Academy's interconnections of government policy, professional learning and development, teachers' practice and students' learning. Results indicate how relevant, useful and meaningful education through science has influenced classroom teachers' practice. The implications support the critical importance of effective connections between content, policy and practice in the ongoing development of teaching practice.

Keywords: professional learning and development; primary education; science education; primary teachers

Introduction

2012 was a watershed year for science and primary science education in New Zealand. Five organizations took a nationwide look at science. The New Zealand government launched a nationwide inquiry into the challenges facing science in the country (Gluckman, 2013). The Education Review Office (ERO) (2012) reported that approximately 70 per cent of the schools they investigated did not have teachers capable of effectively delivering science. In a report to the Ministry of Education, Hipkins and Hodgen (2012) noted that more than half of New Zealand teachers did not understand the changes in the science subject area as a result of the 2010 full implementation of *The New Zealand Curriculum* (Ministry of Education, 2007). The National Monitoring Study of Student Achievement (NMSSA) (EARU and NZCER, 2013), tasked with assessing and understanding student achievement across the curriculum at Years 4 and 8 (students aged 9 and 13) in New Zealand English-medium schools, focused on science. NMSSA reported Year 4 students were more positive about their science experiences than Year 8 students, while less than half of the Year 4 and 8 teachers surveyed indicated they were happy with the way they teach science. And, the Sir Paul Callaghan Science Academy (the Academy) was launched to support teachers for relevant, useful and meaningful science in their classrooms (Kennedy *et al*., 2015).

The intention of the National Science Challenges (Gluckman, 2013) was to find innovative solutions to the issues facing New Zealand. However, these challenges raised the more

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important concern as to where New Zealand's future scientists and science innovators would come from. Several national data sources have noted how New Zealand has been experiencing a decline in students' enjoyment of and engagement with science (Bolstad and Hipkins, 2008; Cooper *et al.*, 2010; EARU and NZCER, 2013). Bolstad and Hipkins (2008) noted that while approximately 70 per cent of Year 4 students enjoy science, this drops to less than 30 per cent by Year 8 and then to less than 10 per cent by the time they graduate from high school. It has been reported that up to 50 per cent of high-school graduates only take science at the tertiary level as requirements for their degree programme (Hipkins and Bolstad, 2005).

The New Zealand Curriculum (Ministry of Education, 2007) is the national curriculum for English-medium schools, which accounts for approximately 95 per cent of all school-aged students (Education Counts, 2016). This curriculum was required to be implemented fully by the start of the 2010 school year. In New Zealand, primary teachers are expected to be able to deliver all eight subject areas of the curriculum: English, the arts, health and physical education, learning languages, mathematics and statistics, social sciences, technology and science from New Entrant to Year 8 (students aged 5 through 13). ERO (2012) noted, however, that only 27 out of 100 schools investigated had generally (n = 24) or highly (n = 3) effective science programmes. The 73 schools with less than effective science programmes demonstrated a range of issues, such as: a lack of leadership in science; science being a low priority in the school; teachers not implementing the 2007 curriculum appropriately; or the school's science programme lacking coherence or continuity. While this document was required to be fully implemented in 2010, it was estimated that less than half of New Zealand's teachers were prepared for this curriculum change (Hipkins and Hodgen, 2012). These findings were reflected in the NMSSA (EARU and NZCER, 2013) report.

The NMSSA's purpose is to provide a nationwide snapshot of Year 4 and 8 student achievement and factors that are associated with achievement. There were four components of the 2012 assessment of science. First was a measure of the knowledge, understanding and communication of the four content strands of science for approximately 2,000 students in each year group. Second was a measure of understanding of the curriculum's overarching strand of the Nature of Science for approximately 700 students in each year group. Third was an assessment of students' attitudes and learning opportunities in science. Finally, there was an assessment of teachers' perspectives on science teaching and learning. In 2012, 186 Year 4 teachers and 123 Year 8 teachers participated in the NMSSA study.

The NMSSA (EARU and NZCER, 2013) report noted that while nearly 70 per cent of the Year 4 and 80 per cent of the Year 8 teachers personally enjoy science, only about 45 per cent of the Year 4 and 50 per cent of the Year 8 teachers felt happy with the way they taught science. Similarly, approximately 44 per cent of Year 4 and 50 per cent of Year 8 teachers felt they had the necessary knowledge and skills to teach science to a diverse range of students. Of concern is that almost 50 per cent of Year 4 and 33 per cent of Year 8 teachers reported that their students participated in science experiments once a year and only 33 per cent of Year 4 and Year 8 teachers reported that their students participated in science experiments once a term (that is, four times a year). The NMSSA's (EARU and NZCER, 2013) findings were generally consistent with the Trends in International Mathematics and Science Study (TIMSS) 2010/11 results (Kirkham and Caygill, 2016).

More importantly for this paper, the NMSSA (EARU and NZCER, 2013) report highlighted that about 25 per cent of Year 4 and 20 per cent of Year 8 teachers had not had any science professional learning and development (PLD) within the five years previous to the study. These five years (2007 to 2012) corresponded to *The New Zealand Curriculum* being delivered to schools in 2007 for the three-year implementation period. Even more troubling, just over 20 per cent of both year groups reported never having had any science PLD.

Theoretical framework

This paper's theoretical underpinnings align with the understanding that teachers in general (Donovan *et al*., 1999) and science teachers (van Driel *et al*., 2014) learn in much the same way that their students learn. Learning is a gradual process involving both formal and informal learning, building on prior knowledge leading from simple to complex understanding. The vision set out by the Ministry of Education is for New Zealand youth to grow into 'confident, connected, actively involved, and lifelong learners' (Ministry of Education, 2007: 8). As a result, New Zealand teachers need to enhance both their teaching skills and knowledge throughout their careers in order to meet the needs of their students through ongoing PLD.

Teachers become quite adept at reflection in-action (those on-the-spot teaching decisions based on student engagement) and reflection on-action (taking time after teaching to evaluate what went well, what could have been done differently and where to go next in teaching). Teachers need to be critically reflective, so that they build upon reflection in-action and reflection on-action, leading to reflection for-action (Thompson and Pascal, 2012). Critically reflective teachers consider not only their own assumptions, beliefs, values and opinions on the content and context of learning but also their students' beliefs, values and opinions.

Critical reflective teachers are important, as Jeanpierre *et al*. (2005) reported that professional development was not effective for most teachers. They then highlighted the importance of the content of science teacher professional development, as it needed to 'carefully integrate science content knowledge and science process skills' (ibid.: 671). Then in 2014, Luft and Hewson presented an updated review of teacher professional development programmes in science, building on Hewson's previous work. Luft and Hewson reported that research was not needed on the continued pushing of the importance of collaboration or on whether professional learning developments are successful. They did note, however, that it would be important to understand the connections between policy, professional development programmes, teachers and students.

PLD should help teachers be more effective in supporting students' learning by facilitating teachers improving not only their knowledge and practice but also their conceptions and beliefs (Furman Shaharabani and Tal, 2017). Furman Shaharabani and Tal support New Zealand's Timperley *et al*.'s (2009) assertion that effective PLD required both sustained and intensive, rather than short-term, programmes.

Furman Shaharabani and Tal (2017) underline how PLD focusing on science teachers has a significant impact on teacher development, including on how they implement and use innovative curricula. As stated, *The New Zealand Curriculum* is the government's policy document for all English-medium students in New Zealand. It is now a single document covering all subject areas. It replaced the previous curriculum documents that separated each subject area into its own document (see, for example, science (Ministry of Education, 1993)). These 1993 documents contained a list of activities that students in each year group should be able to accomplish. *The New Zealand Curriculum* does not contain a single activity. It requires each school to design, plan and implement a curriculum focused on students as 'lifelong learners who are confident and creative, connected, and actively involved' (Ministry of Education, 2007: 4). This curriculum policy document should have altered the way teachers teach science. Unfortunately, a national monitoring of students' achievement report (EARU and NZCER, 2013), a governmental review of schools (ERO, 2012) and a Ministry of Education report (Hipkins and Hodgen, 2012) highlighted that this was not happening for many New Zealand students in science. Fortunately, a new PLD initiative was launched in 2012 to support primary and intermediate teachers, the Sir Paul Callaghan Science Academy (the Academy).

This paper's research questions explore:

1. How does the Academy's PLD initiative change participating teachers' perceptions of the nature of science?
2. How does the Academy's PLD initiative change how science is taught in their schools?

The Academy as the connection of policy, PLD and teachers' practice

In 2014, PLD and its funding policy changed in New Zealand. The Professional Learning and Development Advisory Group (2014) provided guidance to the New Zealand government on the future direction of PLD. The Professional Learning and Development Advisory Group noted that effective PLD improves student outcomes. Their assertion was based largely on New Zealand's own Best Evidence Synthesis on PLD (Timperley *et al*., 2007). As a result, science PLD funding changed from contestable funding within each school to centralized government-funded programmes. The Academy was one of the funded PLD programmes.

John Loughran (2014) highlighted that many primary teachers do not have a deep or comprehensive science knowledge base. He then went on to report on how Schibeci and Hickey (2000) noted that addressing just this scientific knowledge dimension did not lead to better teaching practice, as there were also professional and personal dimensions. The requirement for New Zealand PLD to address all three dimensions became explicit in 2014, as centrally funded PLD programmes are framed by the following six principles (see Professional Learning and Development Advisory Group, 2014):

1. Professional learning is supported and embedded in a coherent learning system at both school and system levels, with the active involvement of leaders, teachers, students, boards of trustees and family/whānau in partnership around a shared focus on priority goals.
2. Professional learning builds motivation and collective responsibility through systematic evidence-informed inquiry.
3. The inquiry process develops adaptive experts who are culturally responsive and who have the knowledge and skills in learning, assessment and pedagogy that have been established as effective in improving learner outcomes, along with developing deep content knowledge underpinning the national curriculum, and using a range of expertise both internal and external.
4. Multiple opportunities to learn and practise in real contexts with support occur over an extended period of time with constant checking to ensure the opportunities are making a difference to learners.
5. Sustained improvement in learner outcomes requires leaders and teachers to have sound theoretical knowledge and to be confident and competent about creating, developing and sustaining a culture of ongoing improvement.
6. Sustained improvement at the system level requires disciplined innovation with embedded research and development, with the information used to develop a coherent system infrastructure and the strategic uses of resources.

As a result, the Academy's explicit goals are to create recognized school-based champions and leaders of science who are:

- engaging and enthusiastic
- highly skilled, capable and confident
- aware of the relevance and interconnected nature of science
- inspirers of the science achievers and citizens of tomorrow.

The role of these teachers is to fuel students' interest in science through awareness of:

- how science is the key to almost everything this country must do
- the impact of science on all New Zealanders
- the wide variety of science careers available and the many paths to becoming a scientist
- the importance of a science-literate society
- the vibrancy of people working with science today.

The Academy begins as an intensive, in-service, four-day, professional learning and development programme for teachers of primary and intermediate students (Kennedy *et al*., 2015). The Academy targets schools' science leaders or those identified by their schools as having the potential to be science leaders. These teachers participate in a careful and considered programme delivered in a four-day workshop building on their proven teaching abilities to enhance specific science content knowledge. The Academy provides a forum for open exchange and engagement of best practice in science teaching to support both content knowledge in general and specific content to support students' learning (Penuel *et al*., 2007). The Academy supports change in teaching practice with ongoing interaction and support, via a proactively enriched alumni network and post-Academy programme.

Teacher participants

Teachers were nominated by their respective schools to participate because of their position within the school as leaders in science or their potential in science leadership. Because of their leadership or potential leadership roles, participating teachers have the greater ability to lead implementation of initiatives within their schools, to disseminate ideas, and to inspire and mentor their colleagues and in turn facilitate learning for students. This paper reports on 119 out of 130 (91.5 per cent) teachers in the 2015 academies who agreed to participate in the study, both their workshop and the follow-up one-year later; 97 (81.5 per cent) were female and 22 (18.5 per cent) were male. Statistically more males participated in the Academy as in New Zealand in 2015, 86.02 per cent of all primary teachers were female and 13.98 per cent were male (Education Counts, 2017).

Table 1: Teacher participants

	N	Range	Minimum	Maximum	Mean
Age	119	43	23	66	45.1
Years teaching	119	39	1	40	15.0

These participating teachers taught across the full range of primary years (New Entrant to Year 8), and all had at least one year of teaching experience (see Table 1). Table 2 presents the range of teaching year levels of the participating teachers. New Entrant classes (students aged 5) are primary-school-based bridging classes from Early Childhood Education into the compulsory primary education classes that begin with Year 1 (students aged 6). In addition, two teachers from full secondary schools (schools offering Years 7 to 13) attended as a means to improve their science teaching to their students in Years 7 and 8 (see Table 2).

Table 2: Participating teachers' teaching level

Year level of teaching	Frequency
NE	3
1	9
2	6
3	16
4	28
5	13
6	13
7	19
8	10
9	2

Methods

Data collection

The Professional Learning and Development Advisory Group (2014: 3) reported that PLD 'should advance and support the intent of the national curriculum documents … PLD involves not only learning about new ways of doing things, but also impacts on how teachers think of themselves as professional educators'. Evaluating how the Academy effectively contributes to the evidence base for ongoing improvement necessitated a methodology that would determine participating teachers' pre-existing conceptions and beliefs and then how the Academy has impacted them one year later. Therefore, two surveys were selected: the Nature of Science as Argument Questionnaire (NSAAQ) (Sampson and Clark, 2006) and the Science Curriculum Implementation Questionnaire (SCIQ) (Lewthwaite and Fisher, 2004). The NSAAQ indicates a teacher's understanding of the nature of science, which provides the focus for science learning. It should be noted that the NSAAQ's nature of science relates to science's way of knowing and values, and the beliefs integral to scientific knowledge (Duschl and Osborne, 2002). The SCIQ indicates a teacher's perceptions of science in their school.

The NSAAQ was used to measure key aspects of the participating teachers' epistemological understanding of the nature of scientific knowledge, specifically how they describe the nature of scientific knowledge to include the source and validity of this knowledge. Therefore, the NSAAQ includes four specific aspects of the nature of science: (1) the nature of scientific knowledge; (2) how scientific methods are used to generate that knowledge; (3) how that knowledge is evaluated; and (4) whether participants believe science is a socially and culturally embedded practice. The NSAAQ has established validity and reliability internationally (Sampson and Clark, 2006) and domestically (Rice, 2012). Each question presents two contrasting views, one from a naive perspective, the other from an informed perspective, with a five-point scale separating the two statements. Sampson and Clark's NSAAQ was developed from Lederman *et al.*'s (2002) research that highlighted what were more naive and what were more informed views about the nature of science. For the NSAAQ, participants choose either: 1 (Viewpoint A not B) or 5 (Viewpoint B not A), indicative of agreement with the specific view, or 2, 3 or

4 as a weighted response to either view (2: A more than B; 3: A equal to B; 4: B more than A). Questions in which the viewpoints were reversed were recoded so that all questions are reported with a viewpoint of 1 aligning with an informed point of view, while a viewpoint of 5 is a naive perspective.

The SCIQ was chosen to measure seven aspects of school implementation of the science curriculum: professional support, resource adequacy, time, school ethos, professional adequacy, professional knowledge and professional attitude. The first four are extrinsic factors, while the last three are intrinsic factors influencing science programme delivery. Participants used a five-point scale (1: Strongly disagree; 2: Disagree; 3: Neutral; 4: Agree; and 5: Strongly agree) to indicate their responses to the survey statements. The SCIQ has established reliability and validity in identifying the multifaceted combination of these seven factors influencing science programme delivery in schools (Lewthwaite and Fisher, 2004). Significantly for the present study, the SCIQ was developed in New Zealand for the teaching of science as a part of each teacher's professional role.

Informed consent was obtained from all individual participants included in the study. Paper surveys were offered to the Academy's teacher participants prior to the start of their workshops. This was done in order to determine what their conceptions and beliefs were for both their understanding of the nature of science and their school's science programme prior to any workshop content. These surveys were offered again online one year later through a secure software system (Qualtrics) to determine what impact, if any, the Academy had had on how they understand the nature of science and how their school implements its science programme.

Data analysis

Survey results from Time 1 (2015) and Time 2 (2016) were input into the Statistical Package for the Social Science (SPSS) version 22. SPSS was used to conduct descriptive statistics for demographic information of the participants and paired-sample *t*-test of surveys from Time 1 and Time 2.

The *t*-test of mean scores on the NSAAQ found a significant difference, t (degrees of freedom 25) = 5.63, $p<.001$. The *t*-test indicates that one year later the participating teachers held a more epistemological understanding of the nature of scientific knowledge ($M2 = 1.82$, $SD = .74$) than before their Academy workshop ($M1 = 2.11$, $SD = .79$).

The *t*-test of mean scores on the SCIQ found no significant difference. The SCIQ subcategory for professional knowledge (PK) was the only subcategory to have any significance, t (degrees of freedom 9) = 4.273, $p<.05$. While the participating teachers did not report their schools having a significant change in how science was being delivered after their Academy participation, the teachers themselves did report a significant change in their own professional knowledge ($M2 = 2.85$, $SD = .22$; $M1 = 2.98$, $SD = .18$).

Discussions

As stated, the Academy was designed to be an interconnection between New Zealand's policies, what is effective PLD and how to support teachers' ongoing practice. This paper reports on how the Academy's interlinking content, policy and practice impacted on its 2015 participating teachers and their schools one year later (see Figure 1).

Figure 1: The interlinking of content, policy and practice

Content–policy–practice in PLD

While Loughran (2014) noted that many primary teachers lack sufficient science content knowledge and that PLD addressing only this dimension does not lead to better teaching practice, this has been consistently one of the top three reasons mentioned by Academy teachers when asked what the problems with science teaching in their school are – the other two reasons being lack of resources and a crowded curriculum. ERO (2012) explicitly noted that this perceived limitation in knowledge of science content, compounded with perceived lack of resources for science, has resulted in many students not experiencing effective learning in science. The Academy provides participating teachers with multiple opportunities to learn (Principle 4 of *The New Zealand Curriculum*) through learning based on research and development (Principle 6).

Providing opportunities to learn that are based on research and development involves not simply presenting teachers with a list of activities that work, but requires working with teachers to explore aspects of the nature of science in classroom practice both practically and realistically. Specifically, through collaborative exploration and discussion, teachers use activities to gain a better understanding of the nature of scientific knowledge, how scientific methods are used to generate that knowledge, how that knowledge is evaluated, and how science is a socially and culturally embedded practice. This is done first through expert classroom practitioners showing what effective education through science is, and then demonstrating how to incorporate *The New Zealand Curriculum's* science subject area in classroom practice. Finally, through collaborative sessions, participating teachers develop units of work that they are able to take into their own classrooms.

Teachers should now be focusing their students' learning through *The New Zealand Curriculum's* Nature of Science using whatever science content is appropriate. Specifically, the Ministry of Education directs schools to design and implement a curriculum grounded in relevant, useful and meaningful learning (Principle 1).

The New Zealand Curriculum has eight principles that are the foundations of decision-making by both the school and its teachers (see Ministry of Education, 2007). While the eight principles guide the decision-making process in regard to what content is in the school's curriculum, *The New Zealand Curriculum* explicitly incorporates those best practices selected by the Ministry of Education. These were chosen as they have well-documented evidence that they have a positive impact on a student's ability to learn, achieve and support the unique characteristics of New Zealand (Principle 2). The interconnection of content–policy–practice in PLD necessitates that participating teachers understand what these best practices are and then how to incorporate these into their own practice effectively.

While the Ministry of Education explicitly incorporate seven pedagogies as best practice, Teaching as Inquiry is the overarching practice in which the other six manifest. Ausubel (1968) highlighted that teaching is only one of the conditions influencing learning. He then argued that while teaching and learning can be analysed independently, 'what would be the practical advantage of doing so?' (Ausubel, 1968: 12). In the New Zealand context, this co-joint evaluation of teaching and learning is Teaching as Inquiry. The curriculum positions three questions the teacher asks of his or her own teaching practice (see Ministry of Education, 2007: 35):

- What is important given where my students are at? – focusing inquiry
- What strategies are most likely to help my students learn this? – teaching inquiry
- What happened as a result of the teaching and what are the implications for future teaching? – learning inquiry

These three guiding questions form the basis of Teaching as Inquiry. Most important for teachers is that they learn to ask themselves these questions moment by moment as the teaching takes place, so as to be critically reflective about how their teaching and the established classroom environment is impacting on students' learning.

Evaluation of PLD one year later

In addressing this paper's research questions, the NSAAQ addresses four areas of the nature of science, while the SCIQ has seven areas. The NSAAQ noted significant differences in how the Academy's participating teachers understood the nature of science prior to their participation and then one year later. For the SCIQ, only the subcategory of professional knowledge saw a significant difference. A more nuanced investigation reveals how the Academy has impacted its teachers.

The NSAAQ asks participants to indicate their positions between the two viewpoints. For example, Question 3, Viewpoint A: 'Scientific knowledge is subjective'; and Viewpoint B: 'Scientific knowledge is objective'. Prior to the Academy, the participants had a mean score of 3.21 (SD = 1.13), indicating that there was a wide range of viewpoints around an approximately neutral mean score. One year later, these same participants responded with a mean score of 2.40 (SD = .80). A score closer to 1 aligns with how New Zealand positions science in primary and secondary education (see Science Learning Hub, 2011). All students in New Zealand need to obtain an understanding of scientific enterprise that does not depend on expertise in science. Students do not all need to be science experts; however, they all need educational learning opportunities through science to facilitate their responsible participation in society. The Academy facilitates this though providing the opportunities initially through the face-to-face workshops and then through the ongoing online community of practice for classroom teachers.

One explicit intention of these workshops is to demonstrate to the participating teachers how to challenge not only what they think they know but also who, where and/or what the source of this knowledge was, that is, to develop their scientific literacy. Scientific literacy is defined as:

> an individual's scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues, understanding of the characteristic features of science as a form of human knowledge and enquiry, awareness of how science and technology shape our material,

intellectual, and cultural environments, and willingness to engage in science-related issues, and with the issues of science, as a reflective citizen (OECD, 2009: 14).

Participating teachers' responses to Question 24 (Viewpoint A: 'A scientist's personal beliefs and training influence what they believe counts as evidence'; Viewpoint B: 'What counts as evidence is the same for all scientists') and Question 26 (Viewpoint A: 'It is safe to assume that a scientist's conclusions are accurate because they are an expert in their field'; Viewpoint B: 'A scientist's conclusions can be wrong even though scientists are experts in their field') demonstrate their developing scientific literacy. Prior to their workshops, teachers' responses were M = 2.87 (SD = 1.12) and M = 2.10 (SD = .94), respectively. Before the workshop, the teachers held an almost neutral mean score for Question 24, and after Question 26 was recoded a response of more informed than naive. One year later, the same teachers reported shifts in how they use, interpret and acquire new knowledge (Question 24: M = 2.18, SD = .09; Question 26: M = 1.40, SD = 1.06).

This combination of collaborative workshop and then ongoing collegiality is making a difference, as noted by the only subcategory of the SCIQ to have a significant change, professional knowledge. The participating teachers reported a neutral response ($M1$ = 2.98, SD = .18) about their colleagues' understanding of science knowledge and effectiveness in teaching science. One year later, the same participating teachers were more negative in how they reported their colleagues' abilities ($M2$ = 2.85, SD = .22). It would appear that the participating teachers have gained a stronger understanding of the nature of science, and of *The New Zealand Curriculum's* view of the Nature of Science, and therefore are more critical of how their schools are implementing science.

Content–policy–practice in classrooms after PLD

The Academy begins with the four-day programme to facilitate participating teachers' learning. It continues with the Alumni Network (see www.scienceacademy.co.nz/index.php), where teachers are able to engage with each other and previous participating teachers. The Alumni Network provides opportunities for participants not only to support each other but also to continue to develop their own knowledge and skills (Principle 3) and continued improvement of teaching practice (Principle 5).

It is through the Alumni Network that the ongoing development of teaching practice is supported. As noted, Loughran (2014) indicated that only addressing teachers' lack of content knowledge is insufficient. Professional learning and development is an ongoing process. Davis *et al.* (2016) noted that it was not only a teacher's beliefs and ideas about teaching that influence the decisions they make in regard to curriculum material, but also his or her previous experiences. In the New Zealand context, this is the national curriculum.

It should be noted that science in the 1993 New Zealand curriculum framework focused on doing science in a scientific manner, with the explicit intention of developing scientific skills and attitudes through investigation (Ministry of Education, 1993). The final objective was for students to be able to carry out a complete scientific investigation, starting with focusing and planning, then information gathering, and finally processing and interpreting this information to reach the reporting stage. To achieve this, the Ministry of Education encouraged classroom teachers to incorporate a number of predetermined activities into their programmes. This may account for why students from 1995 through 2007 viewed science as transmissive, decontextualized and unnecessarily difficult (Bolstad and Hipkins, 2008).

As noted, approximately 25 per cent of New Zealand's Year 4 and Year 8 teachers reported having had no science PLD between 2007 and 2012 (EARU and NZCER, 2013). This was reflected in the ERO's (2012) reporting that 73 per cent of the schools they investigated were delivering less than effective science programmes. In Alumni Network discussions, in planning for student learning teachers now ask reflective questions such as:

- What assumptions are we as teachers making about this unit?
- What experiences are students taking away from this unit?
- How well are we preparing students to be scientifically literate?
- How are we assessing our students to see the relevance of what they are being taught?

Most notably, teachers are now questioning previous school policies and practices. As one teacher noted, neither she nor anyone at her school really used the 2007 curriculum. When this document was released, she and her school rewrote their programmes to adapt them to reflect the curriculum's Key Competencies (the five key competencies that allow people to live, learn, work and contribute as active members of their communities), not the Nature of Science. She now realizes that she and her school had pushed the Nature of Science aside to focus on content. Now, she and her school are working to ensure the students understand why the science is relevant to their lives, through the Nature of Science alongside the Key Competencies. This has resulted in recreating their programme to focus on depth of learning, literacy for learning and a reason to have and use personal devices for learning. As teachers develop their own critical reflectivity, their students are more able to engage in the effort necessary to get actively involved in their own learning.

Final comments

Luft and Hewson (2014) noted that we do not need research about whether professional development is successful. They did note that research on the connections between policy, PLD, teachers and students is important. The Academy provides a forum for exchange, encouragement and dissemination of best practice in primary and intermediate science teaching. The Academy aims to equip the primary or intermediate teacher with skills, resources and techniques to gain confidence in delivering the science curriculum. This is followed by ongoing interaction, support and enrichment via the Alumni Network and post-Academy programme.

It was because of their participation in the Academy that these teachers now report building upon what their students already know and have experienced to support their ability to integrate new learning across learning areas, with prior knowledge, home practices and the wider world. These participating teachers now demonstrate more effective teacher practices by stimulating the curiosity of their students. They also know that students learn best when they know what they are learning, why they are learning it and how this new material is relevant to their lives. More importantly, these teachers know how to challenge what their students think they know about their world and their participation in their world.

This paper has highlighted how the Academy impacted on the participating teachers' understanding of New Zealand content, policy and practice of education through science. It should be noted that since 2012, just under 600 teachers have been given the opportunity to undertake this workshop. In 2015, there were 26,750 teachers in primary and intermediate classrooms in New Zealand (Education Counts, 2017). With only approximately 2 per cent of teachers having the opportunity to undertake this PLD, this may account for why participating teachers' own knowledge of science and how to deliver science effectively has been significantly impacted by the Academy, while their schools have not. As more teachers benefit from this PLD, it is anticipated that this will then be reflected in the 2017 NMSSA second cycle investigating both New Zealand teachers' and students' interest in, and awareness of, science.

Notes on the contributor

Steven Sexton is a senior lecturer in the University of Otago's College of Education. After several years as a practising teacher, he now works in initial teacher education. His research interest areas are education through science, teacher cognition and heteronormativity in schools. He has been involved with the Academy since 2012 as one of the participating expert teachers in how to bring effective science into the classroom through *The New Zealand Curriculum*'s Nature of Science.

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