NZCER
Rangahau Mātauranga o Aotearoa

Developing primary science teacher expertise:
Thinking about the system

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1. Introduction

In New Zealand in recent years there has been a resurgence of interest in science for both social and economic reasons. In the words of the Prime Minister's Chief Science Advisor:

> New Zealand must embrace science and technology and innovative thinking as a core strategy for its way ahead. There is no doubt in my mind that a population better educated in science, whether or not they will actually use science in their career, is essential. (Gluckman, 2011, p.8)

Gluckman considers science education at both the primary and secondary levels of the school system to be an essential prerequisite for developing an economy based on knowledge and innovation. However, there has been concern that the primary school system is not preparing students as well as it could in science.[1] Recent research suggests that many primary teachers do not feel confident about either teaching science or being able to access the support they need. In the 2012 *National Monitoring Study of Student Achievement in Science*, teachers reported a lack of confidence, low levels of professional support within schools, and limited access to targeted professional learning and development (PLD) (Education Assessment Research Unit & New Zealand Council for Educational Research, 2012). Similarly, 53 percent of principals responding to the 2013 *National Survey of Primary and Intermediate Schools* carried out by the New Zealand Council for Educational Research (NZCER) said that they could not readily access external expertise or knowledge in science (Wylie & Bonne, 2014).[2]

The majority of research has focused on the capacity of individual teachers and schools to enact effective primary science programmes and the support they might require. In contrast, the project reported on here takes a *systems* approach to thinking about the provision of primary science PLD.[3] It seeks to provide insights into how the various components of the system of primary science PLD provision might work collectively to produce more than the sum of the parts.[4] The research goal in this exploratory project is to determine who the players are in the primary science

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[1] The 2012 Education Review Office report *Science in the New Zealand Curriculum – Years 5–8* reported that effective practice in learning and teaching in science was evident in less than a third of the 100 schools reviewed in 2011. Key findings from the Trends in International Mathematics and Science Study (TIMSS) 2010/11 show that after increasing steadily between 1994/95 and 2002/03, the average achievement of New Zealand Year 5 students has decreased steadily back to 1994/95 levels.

[2] Only 26 percent of principals said they can readily access science PLD, and 17 percent said it was not needed.

[3] The need for a systems-level approach to enhancing teaching and learning of science was highlighted in earlier research into engagement between schools and the science community in New Zealand (Bolstad & Bull, 2013).

[4] For a discussion of the benefits of a systems approach to research in science education and an example of this in the UK, see Falk, Dierking, Osborne, Wenger, Dawson, & Wong, 2015.

PLD system in New Zealand, the roles they play, and the extent to which they are interconnected. These are all important aspects of a well-functioning system.

2. Method

The first step in this project was to establish categories of providers. Based on prior knowledge of the New Zealand context, the following categories were identified:

- primary teachers providing PLD for other teachers, either in their own school or in clusters
- Ministry of Education-funded primary science PLD providers
- pre-service teacher educators
- educators and out-reach workers attached to science organisations[5]
- other—this category included secondary teachers providing PLD for primary teachers, businesses and not-for-profit organisations providing PLD, and other independent providers.

A survey was designed to find out about the individual characteristics of the providers and the interactions between providers. Respondents were asked about their engagement with the science community, their qualifications and experience, the nature and spread of the PLD they provided, and their contact with other providers.

The link to the survey was advertised on NZCER's website, through social media and through existing contacts and science education networks. The survey was sent out in early September 2015 and was 'live' for 3 weeks. During the early stages of analysis an email outlining the emerging patterns in the data was sent out to all participants who had provided an email address. Some of these participants then commented (by email) on the data that had been shared, or provided more information on the nature of the PLD they delivered.

[5] This category was subsumed into 'other' during the analysis phase because only six respondents chose this category and some of those people were not in fact attached to science organisations.

3. Results and interpretation

Who are the players in the primary science PLD system?

Ninety-four people responded to the survey: 45 primary teachers leading PLD in science in their own schools or in a cluster of schools; 10 Ministry-funded primary science PLD providers; six pre-service teacher educators; and 31 other. Two respondents did not identify any particular group.[6] Of the 45 primary teachers who responded, three were from decile 1–3 schools, 19 from decile 4–7 schools and 21 from decile 8–10 schools or independent schools. The geographic spread of the schools was from Northland to Southland.

Qualifications

The table below gives a brief overview of the qualifications of the participants.

Table 1 **Qualifications of respondents**

Qualification	Percentage (n = 94)
Primary teacher training	65
Secondary teacher training	21
Postgraduate qualification in education	38
Science degree	37
Postgraduate qualification in science	17

Note: the percentages shown add up to more than 100 because many individuals held more than one qualification.

[6] It is difficult to judge how representative this sample is of the whole system of primary science PLD providers because we don't know how many primary teachers in New Zealand are providing PLD, or the range of independent providers. (In fact one of the aims of this project was to try to identify just who is providing PLD.) When the survey was sent out through existing networks, recipients were asked to forward it to any other providers they might know of in an attempt to survey the field more fully. Both the consortia that provide Ministry-funded PLD were represented, as were five out of the eight New Zealand universities. One of the questions in the survey aimed at the teachers providing PLD asked them to list the providers they had received PLD from in the last 5 years. All these providers answered the survey.

Prior experience

Participants were asked to think back over their careers and indicate which roles they had held at any stage.

Table 2 **Prior experience of respondents**

Roles	Percentage (n = 94)
Primary teacher	70
Primary teacher with responsibility for science	65
Senior leadership position in school	45
Adult education	42
Secondary teacher	30
Scientist	18

The results in the table above show that 45 percent of providers had some prior experience working in a senior leadership role in a school. However, when the responses were disaggregated into categories of providers, only 36 percent of the primary teachers (compared with 55 percent of the non-teachers) reported having ever held a senior leadership role in a school.

This pattern implies that many teachers providing PLD for their schools do not hold senior leadership positions, even though they may have responsibility for science. Although there is a case for distributed leadership in schools and providing opportunities for a range of staff to lead different curriculum areas, there is also strong evidence that support from the school leadership remains essential for effective PLD.[7]

The current Science Teaching Leadership programme,[8] which many of these teachers had participated in, recognises this issue and expects the school to make science PLD a school focus for 12–18 months following the teacher's return to school. It would be interesting to know how many schools do in fact make this a real focus, given the marginalised place of science in the primary curriculum, or whether science becomes one of a number of competing priorities as some respondents suggested.

Current positions

Only six out of the 94 respondents said the provision of primary science PLD was their full-time job. Another six said it was less than full time but at least 0.5 of their job. The majority of these

[7] See, for example, the BES on Teacher Professional Learning and Development.

[8] Funded through the Ministry of Business, Innovation and Employment and administered by the Royal Society of New Zealand

people were on fixed-term contracts. Fewer than half of the providers had previous experience working with adults.

Facilitating PLD is a complex job, requiring a range of different sorts of expertise.[9] Facilitators need a deep knowledge of curriculum and science education, and need to know about adult learning and development, be familiar with how both schools and the science community operate, and be well networked so that they can draw on relevant resources. This sort of expertise requires time and support to develop, and the current insecurities around the employment of many providers seem unlikely to encourage a commitment to the necessary growth and development.

What roles do PLD providers play in the system?

Nineteen of the 94 respondents said they had worked with more than 100 primary teachers (including pre-service teachers) in the last year. The majority of the pre-service teacher educators and Ministry-funded facilitators fell into this category. Two-thirds of all respondents reported having worked with between one and ten *whole school* groups in the last year.

Participants were asked to choose the model that best described the PLD they provided. A third of participants said they used a combination of different models, but almost as many (28 percent) said "one-off sessions" was the best description for the PLD they provided. Only 12 percent said they provided PLD that extended for at least 6 months.

So much emphasis on short-term PLD and one-off sessions is potentially a concern. Extended time to engage with new ideas and their implications for practice is necessary (but not sufficient) if teachers are to engage with deep learning (Timperley, Wilson, Barrar, & Fung, 2007). Are providers not aware of what the research literature says about effective PLD, or are there other factors at play? Is the lack of ongoing PLD a consequence of insufficient resourcing? For example, are providers doing this work on top of their 'day job', or are there too few people trying to cover too many schools? Some respondents in the survey indicated that the "crowded primary curriculum" meant there was little time for ongoing PLD in science when there are so many competing demands on teachers' time.

When asked to describe the main focus of the PLD they provided, 51 percent said it was about developing teachers' confidence to teach science and 29 percent said it was about developing understanding about the role of science in the curriculum. Six percent said developing teachers' engagement with the science community, and 5 percent said developing teachers' knowledge of science. There were substantive differences between the responses from different groups. For instance, 71 percent of teachers said the main focus was on developing confidence, but none of the pre-service teacher educators saw this as their main purpose.

[9] See Whatman & Bull, 2015, for a discussion about what it means to be a PLD facilitator.

Table 3 **The main focus of PLD among respondents**

	All (n = 94)	Teachers (n = 45)	Ministry funded (n = 10)	Pre-service (n = 6)	Other (n = 31)
Developing teachers' confidence to teach science	48	32	2	0	14
Developing understanding about the role of science in the curriculum	27	8	6	4	9
Developing teachers' engagement with the science community	6	1	0	1	4
Developing teachers' knowledge of science	5	3	0	0	2

Note: the table shows numbers, not percentages.

Although in reality any programme is likely to be a combination of these categories, the survey was designed to make participants choose one to get a sense of priority. Fifty-one percent of the whole cohort said developing teachers' confidence to teach science was their main focus.[10] It would be interesting to probe more deeply into what people mean by "developing confidence".

Follow-up emails from a small number of respondents revealed that, for some, developing confidence was about encouraging teachers who were struggling with an over-full curriculum just to "give something a go". For one respondent, developing teachers' confidence also involved becoming more familiar with the *New Zealand Curriculum (NZC).*

> Raising teachers' confidence—what do I mean by that?
>
> We did not have specific PD in Science since NOS [Nature of Science] was introduced. The PD I did started in term 4 2013 and went throughout term 1, 2 and 3 2014. One goal was to ensure teachers know and feel comfortable with hands on science focusing on the NOS—that's what I mean by raising teachers' confidence. How did I do it? Unpacking the curriculum, modelling science teaching/learning, providing and giving teachers' opportunity to get familiar with resources to take to their classrooms, using Kerry's arrow cards to help teachers and students focusing on a specific LI [Learning Intention] from the NOS strand and so on. (Personal communication)

In their 2012 survey of science teachers' use of curriculum resources, Hipkins and Hodgen concluded that it was likely that the relatively lower confidence being expressed by some primary teachers (compared with secondary teachers) related to their content knowledge of science. If this is the case, then arguably PLD that is designed to increase confidence should also focus on content, and perhaps the very small number of respondents naming content as their focus does not mean knowledge is not considered important. The role of knowledge within PLD could do with further exploration.

[10] Seventy-one percent of the primary teachers chose this option.

How connected are the different players in the system?

Teachers identified a range of science PLD opportunities they had participated in themselves within the last 5 years. Some teachers had participated in only one type of science PLD and others had participated in as many as seven. The median number was three. All except three of the teachers had participated in the Primary Science Teacher Fellowship programme or its replacement, the Science Teaching Leadership programme. (This very high number is not surprising for two reasons. Firstly, the Royal Society of New Zealand helped distribute the survey by sending the link to teachers on the programme; and secondly, the programme is designed to support its graduates to lead science PLD back in their schools.) Sixty percent of teachers also reported having participated in PLD run by the Science Learning Hub[11] and 40 percent had attended Ministry-funded cluster workshops. Fourteen schools (approximately a third) had participated in all three of these PLD opportunities. A range of other PLD programmes was mentioned by 10 or fewer participants.[12]

The providers of PLD generally reported having little contact with each other. Of the 10 Ministry-funded PLD providers, only one reported having contact regularly with any PLD providers or teacher educators outside their own consortium. Similarly, out of the six pre-service educators, only one reported often having contact with science educators at other universities and none reported interacting often or regularly with any other providers. Of the remaining 31 providers, only three reported interacting often or regularly with Ministry-funded providers, two with pre-service educators and three with PLD providers outside their own organisation.

It seems that currently there are some schools receiving a lot of PLD from a range of providers who have little or no contact with each other, and other schools are receiving very little PLD at all. What prevents more interactions between providers? Is it the competitive environment providers often work in, lack of confidence or time, lack of awareness of who else is working within the space, or is this simply something that is not considered important?

The project also investigated the connections between the PLD providers and science itself. Seventy-eight percent of participants said they read about science-related topics often or regularly, 67 percent said they thought about socio-scientific issues often/regularly, 56 percent were involved with science-related groups often/regularly, 41 percent had conversations with scientists often/regularly, and 20 percent visited science festivals and exhibitions often/regularly. Providers in the 'other' category were much more likely to have conversations with scientists than were teachers, Ministry-funded PLD providers or pre-service teacher educators.

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[11] The Science Learning Hub is a national project designed to support the effective teaching of science in New Zealand schools. It is funded by the New Zealand Government through the Ministry of Business, Innovation and Employment and managed by the University of Waikato.

[12] These included the Sir Paul Callaghan Science Academy, university outreach programmes, New Zealand Educational Institute, The Open Polytechnic, PLD provided by the local council, Ministry-funded school-based PLD, House of Science, initial teacher education, the Ministry-funded Learning and Change Network, and LENScience.

The lack of connectivity between educators and the science community is potentially concerning because science itself is rapidly changing, and the disconnection between school science and science in the real world is therefore likely to increase if there are no opportunities for the science and education communities to talk to each other. This lack of connectivity also raises questions about the extent to which these educators engage with science for their own personal interest. Given that the purpose of students learning science, according to *NZC*, is "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), it would seem important that the adults who are involved with science education are also scientifically literate and engaged.

4. Discussion

The overall picture drawn from the survey is that although there is quite a lot of activity in primary science PLD and a reasonable diversity of both providers and programmes, there does not appear to be much connectivity between the different players in the system. This lack of connectivity is concerning because it raises questions about the resilience of the system.[13] Resilience in human systems is demonstrated by trusting relationships between players and a willingness to work together to develop common goals and values (Falk et al., 2015).

So, to what extent does the primary science PLD community share common goals? Given the lack of connectivity between providers noted in this project, together with the non-prescriptive nature of *NZC*, it seems very unlikely that a clearly articulated purpose or direction will already exist among providers, although this project did not focus explicitly on this. Having a clear, shared understanding of the purpose of science education is important not only for the resilience of the system of primary science PLD but also because how the purpose of teaching science is thought about frames *how* science is taught—and what is valued.

If, for example, the purpose of teaching science is seen as primarily pre-professional training, then school science programmes (and associated PLD) are likely to concentrate on providing students with basic knowledge in the traditional disciplines of biology, chemistry and physics to get them ready for the next level of the education system. If, however, the purpose is to develop scientifically literate citizens, then programmes are more likely to focus on socio-scientific issues and nurturing interest and engagement.[14]

Although the stated purpose of teaching science in *NZC* is about developing scientifically literate citizens, the 2012 study by Hipkins and Hodgen (referred to earlier) found that many teachers were not clear about the purpose of science in *NZC*.[15] Even if teachers were familiar with the curriculum document and its 'essence statement', there still remain questions around what it actually means to "participate as critical, informed, and responsible citizens", what knowledge, skills, and dispositions students (and teachers) need, and what role primary education should play in the development of these attributes. Should programmes aim to develop an appreciation of science as a human endeavour—its history and philosophy—or should they aim to develop certain ways of thinking? Perhaps the focus should be on students gaining the knowledge necessary to be

[13] Resilience can be understood as the capacity of a system to deal with change and continue to develop. (For more about resilience, see, for example, Walker & Salt, 2006.)

[14] For more about the varied purposes of teaching science, see Bull, Gilbert, Barwick, Hipkins, & Baker, 2010.

[15] *NZC* states that "In science, students explore how both the natural and 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).

able to make ‘good’ decisions about their health or the environment, or perhaps science education should be simply about nurturing curiosity, or a combination of all the previous ideas. There appears to be an urgent need for science educators (both PLD providers and academics) to work together to develop a shared understanding of what the purpose of teaching science really is.

This is not a call for uniformity, or for a prescriptive curriculum, but for some *enabling constraints*. These are constraints that aim to keep a balance between sufficient structure and sufficient openness.[16] The purpose of these constraints would be to give a clearer sense of direction without sacrificing the creative possibilities that are inherent within *NZC*. These enabling constraints could, for example, consist of a set of agreed principles that can be enacted in a wide range of ways. Different PLD providers would still provide different types of support, but all would be attempting to nudge the system in a similar direction. This would be a way of maintaining the diversity of the system while building its connectivity and, in turn, increasing its resilience.

[16] For more about enabling constraints and complexity, see, for example, Davis, Sumara, & Luce-Kapler, 2008.

5. Final thoughts

Although the recent support for primary science PLD is welcome, it is unlikely that the fragmented system described in this small exploratory research project will be able to support major change. There are several possible ways forward. One could be to provide more opportunities for primary science PLD providers to both grow their own expertise and strengthen their connections with other providers and the science community. Another could be to develop a shared understanding of the purpose of science in the primary school.

In the 2011 report *Looking Ahead: Science Education for the Twenty-first Century*, the Chief Science Advisor recommended "that all primary schools should be encouraged to develop a science champion" (Gluckman, p. 5). He suggested that potentially this role could be networked between schools. The current graduates of the Science Teaching Leadership programme to some extent fulfil this role, but responses in this survey suggest that many are probably not well positioned to be able to effect sustainable change.

Instead of these science champion roles being occupied by keen teachers with a passion for science and who do the job on top of all their other responsibilities, what if they were occupied by specialists whose full-time job would be to lead and support science learning across clusters of schools? These people would need to have expertise in science education and to be experienced adult educators who are familiar with how schools work, but would also need to have strong links with the science community. If this type of structure were adopted there would, of course, also be a need to rapidly build a workforce that could fill these roles. Without such career pathways there are currently few incentives (or opportunities) for science educators to commit to the type of in-depth learning and development that is needed.

Ideally New Zealand will develop a primary science education system that produces

> young New Zealanders [who] are enthused by science and able to participate fully in a smart country where knowledge and innovation are at the heart of both economic growth and social development. (Gluckman, 2011, p. 1)

This will require building both human and social capital. It will involve developing a greater shared understanding about what the purpose of teaching science really is, and a sense of what science-enthused and participating young New Zealanders might *actually look like.* It will also necessarily involve PLD providers connecting with each other and working together towards this—behaving as a system—so that all young New Zealanders have the opportunity to participate fully in our society and economy.

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