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REVIEW ARTICLE

Science Education Professional Development for Primary/Elementary Teachers: A Tale of Two Systems

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ABSTRACT

This paper reports on the illuminatory and exploratory phase of a study into how two educational systems are interconnecting content, policy, and teaching practice into science professional development (PD). New Zealand implemented a new curriculum in 2007 for full implementation in 2010, which should have altered how science was delivered in primary classrooms. New Zealand, however, began limited PD in science education in 2012. The state of Arkansas in the United States of America endorsed the Next Generation Science Standards in 2015, adopted the new Arkansas K-4 Science Standards in 2016 and Years 5–8 in 2017. Arkansas, however, began its science PD in 2015. Through face-to-face discussions during PD sessions, this study investigated how the teachers were experiencing PD explicitly based on the interconnections of content, policy, and practice. The results of this first phase highlight how due to their participation in PD, teachers in both Arkansas and New Zealand are now talking about how they build on what their students' know and have experienced. The implications of this research note teachers not only need both the time and opportunity to experience learning but also support as they then implement their new learning into their own classroom practice.

KEY WORDS: science education; professional development; primary teachers; elementary teachers; curriculum

INTRODUCTION

As classroom teachers who have spent nearly 20 years each in the classroom, it is not surprising research indicated professional development (PD) was not effective for most teachers (Jeanpierre et al., 2005). Jeanpierre et al. (2005), however, highlighted the importance of the content of science teacher PD, as it needed to, "carefully integrate science content knowledge and science process skills" (p. 671). While Jeanpierre et al. (2005) were writing about secondary science teachers, they noted the importance of teachers having the same kinds of experiences as their students. Then in 2014, Luft and Hewson presented an updated review of teacher PD programs in science, also with a secondary science teacher focus, building on Hewson's previous work. Luft and Hewson reported that research was not needed on the continued pushing of the important of collaboration or that professional learning developments were successful. They did note that, however, it would be important to understand the connections between policy, PD programs, teachers, and students.

We have come to science education PD after years of classroom teaching practice. In 2017, the second author visiting from New Zealand was in the state of Arkansas (United States of America) to investigate how the Next Generation Science Standards (NGSS) were impacting science education as New Zealand and Arkansas are similar in land mass and population. Importantly for the present paper, New Zealand drafted a new curriculum policy for all English-medium school-aged students New Entrant-Year 13 (students aged 5 through 19) in 2007 for full nationwide implementation in 2010. Arkansas began the implementation of the 2013 NGSS for the Arkansas context in 2016. This is a three-stage implementation of these new standards: Kindergarten-Year 4 (students aged 5–9) in August 2016, Years 5–8 (students aged 10–13) in August 2017, and Years 9–12 (students aged 14–18 in August 2018). Most significantly, however, Arkansas began science education PD in 2015 to coincide with these changes to the Science Curriculum Framework (Department of Education, 2014), while New Zealand in a cost-saving decision terminated the local area primary science advisors who provided in-service teacher PD from 2009 to 2012 (Bull, 2014).

This paper is an exploratory and illuminatory study into how in-service primary/elementary (students aged 5–11) teachers are experiencing the intersection of science content, mandated educational policies, and effective classroom practice in both New Zealand and Arkansas. This study seeks to address the research question: How are PD programs in New Zealand and Arkansas based on ongoing workshops and support, relevant and meaningful hands-on activities, and PD designed around how students learn impacting teachers' classroom practice? In the New Zealand context, teachers implement science as part of a national curriculum document (Ministry of Education, 2007), while in Arkansas, the science curriculum framework is one of eleven subject areas (Department of Education, 2014).

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PD

Loughran (2014) highlighted that many primary/elementary teachers do not have a deep or comprehensive science knowledge base. While Loughran indicated that just addressing teachers' lack of content knowledge was insufficient, Davis et al. (2016) noted that it was not only a teacher's beliefs and ideas about teaching which influence the decisions they make in regard to curriculum material but also his or her previous experiences. Similarly, Hattie (2012) noted in his meta-analysis of maximizing the impact on learning the importance of the high-effect teacher's attitudes and expectation on students' learning. It was the things that teachers "with a certain attitude or belief system" (Hattie, 2012. p. 26) did that made them passionate and inspired teachers.

PD 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 (Shaharabani and Tal, 2017). Shaharabani and Tal (2017) underlined how PD focusing on science teachers has a significant impact on teacher development to include how they implement and use innovative curricula. While Sharabani and Tal focused on secondary teachers, their conclusions supported Timperley et al. (2009) assertion that effective PD was both sustained and intensive rather than short-term programs. Importantly, for the present study, Timperley et al.'s (2009) study investigated primary/elementary teachers.

New Zealand Context

The New Zealand Curriculum (Ministry of Education, 2007) is the current policy document for all English medium students in New Zealand. As such, this curriculum applies to 95% of all students in New Zealand aged 5–19 (Education Counts, 2016a). In its current form, it is a single document covering all subject areas. This curriculum document replaced the previous 1993 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 in that subject area. 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. p. 4). This policy document should have altered the way teachers teach science. Unfortunately, a national monitoring of Year 4 and Year 8 students' achievement report (NMSSA, 2013), a governmental review of Primary (students aged 5 through 11) and Intermediate (students aged 12 through 13) 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.

This document was required to be implemented fully by the start of the 2010 school year. It has been estimated that almost half of New Zealand's teachers were not prepared for this change (Hipkins and Hodges, 2012). This may be due in part to the fact that as the new curriculum document was being unpacked by schools, there were no locally based primary science advisors to support classroom teachers (Bull, 2014). This could account for why nearly half of all teachers in the 2012 cycle of the National Monitoring Study of Student Achievement (NMSSA) reported either not having had any science PD within the past 5 years, which coincided with the start of the 3-year implementation phase of the new curriculum in 2007, or as teachers they have never had any science PD.

The Arkansas Context

The NGSS are Kindergarten (K) - Year 12 science content standards. Finalized in 2013, these standards set the expectations for what students should know and be able to do equally in both science and engineering. They align with the Common Core State Standards for each grade and define what students must be able to do to show competency. The National Research Council (2012) stated that the overarching goal for science education was comprised of five components:

1. All students have some appreciation of the beauty and wonder of science,
2. Possess sufficient knowledge of science and engineering to engage in public discussions on related issues,
3. Are careful consumers of scientific and technological information related to their everyday lives,
4. Are able to continue to learn about science outside school, and
5. Have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology (see p. 1).

The Arkansas State Board of Education decided to use the NGSS as the foundation for their new K-12 science standards in 2014. As such, the Arkansas Department of Education (ADE) adapted the NGSS into standards suited to the Arkansas context. The new Arkansas science standards were completed in 2016. These standards reflect the following conceptual shifts:

- "Reflect science as it is practiced and experienced in the real world,
- Build coherently from Kindergarten through Grade 12,
- Focus on deeper understanding as well as application of content,
- Integrate core ideas, practices, and crosscutting concepts, and
- Make explicit connections to literacy and math" (Snyder, n.d., para. 2).

The state of Arkansas began implementation of these new science standards by phasing them over 3 years. Starting with grades K-4 in 2016, then grades 5–8 in 2017 and finally grades 9–12 will begin in 2018. To support the phasing of these new standards, the ADE noted that PD has been and will be provided to support schools in making these transitions.The ADE believes science education is essential and therefore seeks to ensure quality science education is available for all

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students. As such, the ADE began science PD in 2015, 1 year before the first phase of implementation.

Science Education PD

While Loughran (2014) may have highlighted that many primary/elementary teachers do not have a deep or comprehensive science knowledge base, he reported 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 difficulty arises as Michaels et al. (2008) had already noted "many elementary school teachers and science teachers in middle schools and high schools have not received the preparation and support they need to do the job they're being asked to do" (p. xiv). To address this issue, Moulding et al. (2015) highlighted that "PD should immerse teachers in science investigations" (p. 116).

"PD is key to supporting effective science instruction" (National Research Council, 2007. p. 6). Both the National Research Council and New Zealand's Ministry of Education recognize teachers' need relevant and meaningful hands-on opportunities to learn like their students (National Research Council, 2007; Professional Learning and Development Advisory Group, 2014). More importantly, teachers need to understand not only the content that they are presenting to their students but also the pedagogy behind how their students learn (Figure 1). As a result, science education PD for teachers must facilitate them in delivering relevant, useful, and meaningful science into very crowded, complex, and contested classrooms. "These needs represent a significant change from what virtually all active teachers learned in college and what most colleges teach aspiring teachers today" (National Research Council, 2007. p. 7).

The National Research Council (2007) noted that most teachers were not prepared for effective delivery of science in their classrooms. 10 years later, this was still true in both New Zealand and Arkansas. In the last teacher census in New Zealand in 2016, there were 26,750 primary teachers in NE-Year 6 (Education Counts, 2016b). In Arkansas, in the 2016–2017 school years, there were approximately 21,000 teachers in grades K-6 (ADE, n.d.). 2.43% of New Zealand primary teachers (650 of 26,750) have participated in the Sir Paul Callaghan Science Academy PD workshops, of which the second author is one of the facilitators. Similarly, in Arkansas, approximately 2.90% (610 out of 21,000) of teachers participated in the Grasping Phenomenal Science (GPS) PD workshops, of which the first author is one of the facilitators.

METHODOLOGY

In New Zealand, teachers undertaking science education PD participate in a 4-day fully-funded intensive workshop. These teachers then continue their ongoing development through involvement in an online Alumni network of participating teachers. In Arkansas, science specialist teachers participate in a series of fully funded science education PD workshops spread over the course of the school year. The GPS PD is usually 2–3 days workshop in the summer with follow-up days throughout the year. To evaluate the impact of PD programs in New Zealand and Arkansas based on ongoing workshops and support, relevant and meaningful hands-on activities and PD designed around how students learn impacting their classroom practice on classroom teachers necessitated the use of online surveys. Specifically, this methodology facilitates determining participating teachers' pre-existing conceptions and beliefs and then how their participation has impacted them over the course of a year.

New Zealand Survey Instrument

The Science Curriculum Implementation Questionnaire (SCIQ) (Lewthwaite and Fisher, 2004) was chosen for New Zealand as it measures seven aspects of school implementation of the science curriculum: Professional Support, Resource Adequacy, Time, School Ethos, Professional Adequacy, Professional Knowledge, and Professional Attitude. While the first four aspects of the SCIQ are extrinsic factors concerning the teacher's school, the last three explicitly are concerned with the teacher's science program delivery. Participants use a 5-point Likert scale (1 - strongly disagree, 2 - disagree, 3 - neutral, 4 – agree, and 5 - strongly agree) to indicate their responses to the 49 survey statements. The SCIQ has established reliability and validity. The SCIQ was developed in New Zealand for the teaching of science as a part of each teacher's professional role. The SCIQ is offered to participants before their first workshop and then again 1-year later through a secure online system (Qualtrics).

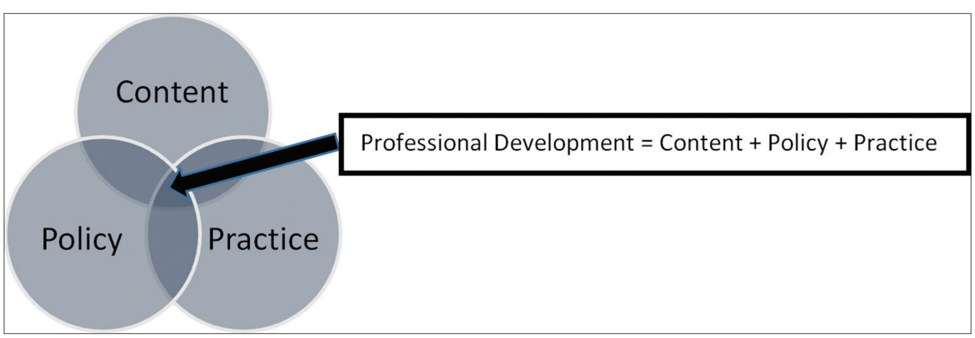

Figure 1: Professional development

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Arkansas Survey Instrument

Arkansas is a part of the "Partnership for Building Capacity for Improvement in Science Education" research study of the University of Colorado at Boulder's School of Education. The purpose of this research study is to develop and test resources to assist participating states in improving that state's science education program. As such, the questions are tailored to each state. Teachers are informed that only the efficacy of activities is being assessed not the individual's growth. The 27-item practical measures survey item (PMSI) is offered to participants using Google forms during their workshop as a pre-test and will be offered again as a post-test in June 2018 (Arkansas' school year runs from August to June) to determine the efficacy of activities in facilitating participating teachers' understanding of science and engineering practices, crosscutting concepts, and disciplinary core ideas. Teachers use a 5-point Likert scale (either strongly agree to strongly disagree or never to all of the time) to indicate their responses.

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The PMSI requests teachers to provide responses to how they perceive their ability in implementing the science curriculum framework. These questions align with the SCIQ in terms of investigating participating teachers' self-reporting of perceived professional adequacy, professional knowledge, and professional attitude. As both survey instruments are offered at the beginning of PD, they facilitate participating teachers a common ground for discussions not only during the PD workshops but also about their ongoing classroom practice.

This research study was founded on the contention that some aspects of the PD process are open to scrutiny, readily discussed, and debated. There are explicit policies and practices that guide the implementation of content. However, there are other dimensions to PD that are implicit, taken for granted, or unacknowledged as some areas may deal with issues of bias, relationships, competence, subjectivity, and consistency. For this reason, the study reported here was designed to be illuminatory and exploratory (Punch and Oancea, 2014) with the intention of answering the overarching research question, "How are PD programs in New Zealand and Arkansas based on ongoing workshops and support, relevant, and meaningful hands-on activities, and PD designed around how students learn impacting teachers' classroom practice?" Drawing from the New Zealand and Arkansas participating teachers' comments gathered in face-to-face discussions during PD sessions, this paper reports on how participating teachers are being influenced by their PD programs.

DISCUSSIONS

Mary (all names are pseudonyms) is a typical primary teacher in New Zealand. She is a white, middle-class, middle-aged female teacher in the Auckland area (New Zealand's largest city) and has taught for almost 10 years. She noted that she stopped taken science in high school after Year 10 when it was no longer a compulsory component. She explained her reasons for this decision, stating, "it was too hard and too inaccessible for the likes of me." She wanted science PD as she is now the science teacher in her school. Before her workshop participation, she reported a naïve level of understanding about the nature of science, "Even though I teach science at my school, I came to the academy feeling intimidated by the mysteries of science that lay beyond my grasp." After her participation, she highlighted, "the academy gave me something I never learnt at school, the simple joy of wondering about the world around me, and the profound satisfaction of pursing answers." The PD workshop works with participating teacher to support them in bringing relevant, useful, and meaningful science into not only their own classroom but also their school. As such, participating teachers are encouraged to go back to their school and support their colleagues.

Jane teaches in a rural New Zealand intermediate school of about 675 students. She commented on the benefits of her participation in the workshop. She highlighted, "it has re-sparked my love of teaching and also provided me with an ongoing resource bank to share with my colleagues and students." Unfortunately, Jane like many teachers who undergo PD, they see personal benefits that do not translate into their school community. As her participation allowed her to engage with how to integrate content, policy, and practice, just providing her colleagues with these resources did not provide them with the support they needed. Helen and her smaller elementary school of about 270 students realized any significant and long-term changes needed to be part of the school's strategic plan. While she undertook the same PD workshop as Jane, she has "run a number of successful staff meetings using the materials from the course." As she is working with her colleagues to understand how to integrate content, policy, and practice, she has seen a positive change. To ensure that this continues, she and her school have planned in-school PD sessions every term (New Zealand schools operate on four terms per year, each term approximately ten weeks) so that the teachers are able to experience for themselves the learning and then have the support and time necessary to implement this in their own teaching. As a result, "Science has radically changed within the school and students are loving it."

Wendy is one of the 28 teachers at her middle school which has 445 students. Her school is located in a small town of approximately 5000 people in Arkansas. In 2016, Arkansas began implementation of the new science standards in grades K-4 and this year is extending these into grades 5–8. Wendy with two of her colleagues are participating in the GPS workshops over the 2017–2018 school year. This was the second workshop in their series building on the previous month's workshop on how science and literacy can be integrated, standards mapping, and planning for learning. Teachers came to this workshop ready to talk about the science they were teaching.

For many of these teachers, their students now get a science class. Wendy noted that her Y5 class was apprehensive about science as first because they did not have positive experiences

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in their K-4 years, but now they are excited about science. She explained that she gets to teach her students science every other Friday for an 84-minute period so she has time to develop ideas and thoughts. Alisha also commented on her Y4 students' excitement and engagement. Her students focus on things they wonder about. Her students begin science class by asking questions about everyday phenomena such as "why is it like that?"

Like many of the other 21 teachers in the workshop, Wendy noted that the new science standards operate under the concept that "less is more." There is less content coverage expected by the standards to allow teachers and students more time to get to a greater depth in the content. The difficulty reported by many of the participating teachers in discussions was that "these standards are new and there is a great deal of uncertainty as many teachers are still using the old standards." Many of these teachers reported gaps in their own science knowledge, the school's lack of resources for teaching science, and a crowded schedule of teaching. Many of these teachers noted that their school administration did not even know the new standards and were actually hindering teachers trying to implement the new standards because literacy, especially reading, has been targeted as a priority over science because of the low reading scores on the ACT Aspire test.

In discussions, exploring how these teachers saw science and science teaching in their schools, more than half commented positively on their colleagues' ability, willingness, and preparedness to teach science. In fact, the only negative comments were from Donna a teacher who was placed by her school into a position of leadership for science. Donna, like Mary in New Zealand, has years of experience but self-confessed and she has little to no knowledge of science. However, both Donna and Mary were now providing their students with opportunities to practice process skills in every activity to make their science relevant, useful, and meaningful.

As all of these teachers were involved in an ongoing PD program, it was not surprising that they felt this opportunity was providing curriculum support. As noted, this was the first year of implementation for the Arkansas teachers in Years 5–8 but the second year for their colleagues in Years K to 4. Teachers in this PD cohort taught in Years 3–5, fourteen of the 21 reported teaching in Years 3–4, and should have begun their implementation of the new standards the previous year. Becky, like many of her colleagues, noted schools still focused a great deal of time on reading. This is, especially, true in the K-2 range where her school has an emphasis on reading and math with little to no room to promote curiosity. Adam noted the complication that many schools face with the ACT Aspire program (see https://blog.prepscholar.com/what-exactly-is-the-act-aspire). This begins in Year 3 and schools must prepare their students for this year-by-year measurement of their reading, English, math, science, and writing as this system allows schools to track individual student progress. In Becky's school, this means in years K-3 the subjects are integrated the best way a teacher is able through English and Math, then in Year 4 the subjects get broken apart and taught separately to prepare students for the ACT Aspire programme. Twyla agreed highlighting additional complications as her school's administration wants all her Year 3 students along with the other Year 3 students reading at the same time and doing math at the same time so that when they walk into the room, they know exactly what is happening.

As this is a new initiative in Arkansas, it is not surprising to the New Zealand author that issues raised by this cohort of teachers reflected those reported by ERO (2012) about New Zealand schools. ERO noted that those New Zealand schools with less than effective science programs had science as a low priority in the school, a lack of leadership in science in the school, teachers were not implementing the new curriculum appropriately, or the school lack coherence in its science program.

Fortunately, those teachers like Wendy who is getting PD are noting the benefits to not only their teaching but also their students. Teachers reported that science is now allowing different strengths of students to come out. They are now seeing students engaging in the science through observations, through communication, and actually doing things in class while they demonstrate the crosscutting concepts, science and engineering practices, and discipline core ideas (Moulding et al., 2015). As a result, these teachers noted that their students are now actually getting science classes and more importantly getting excited about these classes.

CONCLUSIONS

This study was not an attempt to report that PD works. Research, as noted by Luft and Hewson (2014), with this as the focus was not needed. They did, however, highlight that research on understanding the connections between policy, PD, teachers, and students is necessary. Previous studies have noted the importance of teachers' PD involving the same kinds of learning experiences as their students as they come to grasps with pedagogical content knowledge (Jeanpierre et al., 2005). For primary/elementary teachers, this is, especially, relevant as the National Research Council (2007) reported that this is not how most teachers were educated while in their initial teacher education programs.

Hattie (2012) highlighted that expert teachers are different from experienced teachers in the ways they challenge students' learning and to the depth in which their students are able to process information. As both authors are involved in science PD for primary/elementary teachers, what we do must result in teachers being more effective in supporting students' learning. Participating teachers' attitudes and beliefs about how they are able to implement science into their classrooms must improve. We support Shaharabani and Tal (2017) and Timperley et al. (2009) assertions that effective PD is both sustained over a period of time and intensive. Teachers not only need both the time and opportunity to experience learning but also support as they then implement their new learning into their own classroom practice.

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Fortunately, in New Zealand, the Ministry of Education has acknowledged the importance and necessity of science PD. Unfortunately, only a small percentage of teachers have been able to participate. Significantly, 1 year after participating in their PD, 90% of all participating teachers reported five significant changes to their teaching:

- I use what I learnt in the PD to assist other colleagues in their science teaching
- I have improved the types of questions used in my teaching
- I have improved the depth and richness of the science investigations used in my teaching
- I now have assessments based around the curriculum's overarching strand of the Nature of Science
- My science teaching has benefitted

As noted by two participating teachers 1 year after their workshops who did continue to receive and offer support through the online alumni network, "I now feel like I have a new focus, enthusiasm, and valuable skills I can share with colleagues" and "participation should be mandatory for every school." The NMSSA replicated their 2012 study in 2017. It is still hoped that even though 2.43% of primary teachers have had the opportunity to participate, there will be shifts in both student and teacher perceptions of science.

Similarly, the ADE has also acknowledged the importance and necessity of science PD. Moreover, like New Zealand, only a small percentage of teachers are able to participate. It is hoped that after their year of PD is completed in June 2018, these teachers will report significant changes to their teaching. Unlike New Zealand, these teachers are getting this PD at the time of their curriculum changes.

IMPLICATIONS

Barber and Mourshed (2007) argued, "you can have the best curriculum, the best infrastructure, and the best policies, but if you don't have good teachers then everything is lost" (p. 27). As noted, with approximately 25% of New Zealand teachers reporting not having any science PD from 2007 to 2012 and another 20% never having had science PD, it was not surprising that a 2012 Education Review Office study reported only 73% of schools were effectively delivering science. As one teacher commented in an online discussion neither she nor anyone in her school really used the 2007 curriculum document. Like many schools, their programs were rewritten to reflect the Key Competencies (the five skills/attitudes that the Ministry of Education believes allows people to live, learn, work, and contribute as active members of their community) not the Nature of Science that is now the overarching strand through which all science should be delivered. This new emphasis on the Nature of Science was pushed to the side as they continued to focus on the content areas (Living World of Biology, Material World of Chemistry, Physical World of Physics, and Planet Earth and Beyond) that they had been focusing on since the 1993 documents. Now after seeing how content, policy, and practice should be brought together, she and her colleagues are working to ensure students understand why the science they are doing is relevant to their lives. Most importantly, this has resulted in learning that now has a focus on deeper learning rather than more content, literacy for learning, and students having a reason to use personal devices.

GPS PD in Arkansas is in response to the changes in science standards, and while in its first stages of implementation, teachers are making encouraging statements. Teachers are taking ideas from their PD sessions into their classrooms but more importantly letting their students' guide how this is done. These teachers are noting how this is different to what they have done in the past and how they were taught science. This has led to lots of uncertainty as no longer a focus on content but pedagogy. They now are working on getting students to use reason, think, and make sense of what they are observing and doing.

Due to their participation in PD, teachers in both Arkansas and New Zealand are now talking about how they build on what their students' know and have experienced. These prior experiences are now part of how teachers connect students' new learning not only in science but also across learning areas to make students' learning meaningful. As these teachers have learned the importance of knowing both what they are teaching and why they are teaching this, their students are now able to better understand what they are learning, why they are learning about this, and how this is meaningful to their lives.

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