Professional development and physics teachers' on-going learning needs

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Abstract

This study sought insight into the professional learning and development needs of physics teachers in New Zealand high schools. It used a mixed methods approach that comprised a national survey of high school physics teachers as well as interviews with high school physics teachers and physics teacher educators. Data from the teacher survey were analysed using descriptive statistical methods. Audio recordings from interviews were transcribed and analysed and used to triangulate and add depth to the survey data. Findings indicated that physics teachers were dissatisfied with the lack of formal professional development opportunities available to support their professional growth. There was a heavy reliance on personal critical inquiry and infrequent practitioner meetings to inform practice. Suggestions for how to support the professional development needs of physics teachers better are discussed.

Key words: Professional development; content knowledge; teacher learning; teaching as inquiry; physics teaching.

Introduction

To maintain excellence in their practice, teachers need to continually develop their knowledge and skills through professional learning and development (PLD). But it has been claimed that teacher PLD rarely lives up to expectations and there has been a call for a shift from professional development to professional learning which is capable of promoting on-going teacher and student engagement, learning and well-being (Timperley, 2011). This process examines teachers' practices and allows them to take control of their own professional learning through reflection (Timperley, 2011).

In the United States, Ingersoll (2003) used data from a survey conducted by the National Center for Education Statistics and found that teachers often leave the profession because they consider teaching to be too complex. He stated that about one third of teachers leave the profession within the first three years and about 40-50% leave within five years. Job dissatisfaction and lack of opportunities for professional advancement were among the reasons teachers gave for their departure. Mizell (2010) found that teachers are challenged by subject content knowledge, new instructional methods, advances in technology, and increasing student learning needs. PLD has the potential to enlighten them about new teaching strategies, skills, content and changes in standards and/or curriculum.

The results of the 2013 Teaching and Learning International Survey (TALIS) highlight that teachers' roles are changing and that their existing knowledge and skills may not match new needs and expectations. The 2014 Organization for Economic and Co-operative Development [OECD] report (OECD, 2014) emphasized the point that teachers provide the most important influence on student learning, yet they are often not developing the practices and skills necessary to meet the diverse needs of today's learners. Both reports show the importance of collaborative professional learning for teachers. Teachers who participate in such activities, report being significantly more confident in their abilities (OECD, 2014). If teachers are expected to prepare students to become lifelong learners, they themselves need to learn and develop throughout their career.

In the present study, part of a larger project (Buabeng, 2015), PLD was viewed from the position of Scheerens (2009) as the body of systematic activities to prepare teachers for their job, including initial training, induction, in-service training, and on-going professional learning within a school setting. A mixed methods methodology enabled an investigation of professional learning and development opportunities available to high school physics teachers in New Zealand and an evaluation of how well these activities were perceived by teachers to serve their needs.

Literature review

In general terms, professional development is the means by which individuals are supported to know more about the job they do and how to do it better. Mizell (2010) refers to PLD as being different types of educational experience associated with one's profession. He stresses that people from many different professions partake in PLD to acquire new information and skills to improve their performance. For teachers, professional development can be defined as "activities that develop an individual's skills, knowledge, expertise and other characteristics as a teacher" (Scheerens, 2009, p. 22). Thus, PLD is an on-going process throughout one's working life. Loucks-Horsley and Olson (2000) assert that PLD consists of teacher learning opportunities designed and implemented for the purpose of helping students to achieve learning outcomes.

Borko (2004) describes PLD as teachers' learning experiences that are essential to improve and enrich their knowledge of the subjects they teach. Expanding on this assertion, Mizell (2010) argues persuasively that college and university programs do not provide all the knowledge essential for graduates to become effective teachers. He views teacher learning as on-going and a process in which they learn through experience and reflection / action cycles – as well as through more traditional course work.

The need for PLD for teachers has been extensively reported in the literature. In the USA for example, PLD is seen as an important pillar for supporting science development. Reports from the 2000 National Survey of Science and Mathematics Education showed that most science teachers were not well prepared for the challenges of the classroom and in substantial need of PLD in a number of areas (Weiss, Banilower, McMahon, & Smith, 2001). The researchers reported that almost 60% of elementary and middle school teachers felt a need for professional development on how to use inquiry-oriented teaching strategies. Amongst middle school teachers, 67% reported a need to deepen their own science content knowledge, and 71% reported a need to deepen their understanding on how to use technology in science instruction. Many of the projects funded by the National Science Foundation (NSF) and the US Department of Education were identified as focused on improving teacher knowledge and skills (Banilower, Heck, & Weiss, 2007).

Using multiple conceptual and situative perspective approaches, Borko (2004) identified what is known about teacher PLD and proposed three phases of activities that the educational research community can engage with to support the delivery of high quality PLD for teachers. The first phase focuses on a single professional development program at a single site and seeks to understand the relationships between the teachers' participation in the professional development program and their learning. In the second phase, a single PLD program enacted by multiple facilitators at different sites is studied to gain insight into the relationships among facilitators, the professional development program, and the teachers as learners. In the third phase, evaluations of multiple PLD programs situated at different sites are researched and compared. Borko noted that the majority of today's professional development work has been at Phase 1. She suggests that Phases 2 and 3 help all four elements of a professional development system: facilitator; professional development program; teachers as learners; and context and therefore recommended that more attention be given to Phases 2 and 3.

Reporting on what makes PLD effective, Garet, Porter, Desimone, Birman, and Yoon (2001) indicated that PLD activities for physics and mathematics teachers that focused on content knowledge had an important positive influence on changes to teaching practice. Similarly, Banilower et al. (2007) commented that professional development programs that focus on subject-matter knowledge and on student learning within that subject were more likely to improve student learning. Further, providing teachers with opportunities to deepen their content and pedagogical knowledge when accompanied with high-quality instructional materials, improved teaching. Other researchers, for example Blank and de las Alas (2009), Blank, de las Alas, and Smith (2007), Darling-Hammond and Richardson (2009), and Hill (2009) have also stressed that PLD that focuses on developing the pedagogical skills of teachers to teach specific kinds of content, positively influence practice and student learning and achievement. In a review of twenty-five PLD programs for science and mathematics teachers across states in the USA, Blank et al. (2007) found that twenty-two of the programs focused on content knowledge. Most of the programs were positively rated by teachers for also providing useful pedagogical content knowledge.

PLD is seen as one of those strategies for improving teachers' knowledge of their subject area and their pedagogical competencies. But very few professional learning programmes have directly linked changes in teaching to changes in student learning outcomes. Bucher (2009) emphasized that good student academic achievement and better educated societies are the ultimate goals of education and to be able to achieve these, teachers must improve their competencies in the content areas they teach. Thus, the need for an increase in teacher content knowledge alongside pedagogical skills should be not be ignored.

Professional Development for Teachers

PLD that focuses on teacher subject-matter knowledge and pedagogical skills has been shown to have a positive impact on student learning and achievement (Banilower et al., 2007; Blank et al., 2007; Darling-Hammond & Richardson, 2009; Garet et al., 2001). There is growing research evidence that links the amount of PLD teachers receive positively with student learning outcomes (Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). Short-term workshops or one-off events, tend not to cause as great a change in teachers' practices and student achievement (Banilower et al., 2007; Garet et al., 2001; Wei, Darling-Hammond & Adamson, 2010). These researchers found that PLD activities that span a longer time period with a greater number of contact hours (an average of 8-14), and that require on-going reflection are more likely to bring a positive and more enduring change. In view of this, Darling-Hammond and Richardson (2009) advise that schools should make PLD a coherent part of their activities rather that the "traditional one-shot workshop" (p. 48). They further indicated that disparities sometimes exist between what teachers learned in professional development work and what they can in fact, put into practice in their classrooms, because of constraints of curriculum or assessment. So to avoid this situation, professional learning opportunities must be linked with the curriculum, assessment and standards.

Even though PLD is usually used to mean a formal process such as a conference, seminar, workshop or collaborative learning among members of a work team, it can also take place in informal contexts, such as discussions among colleagues, independent reading and research, observations of a colleague's work, and/or other learning from a peer (Mizell, 2010). Thoughtful planning and implementation is required for any PLD approach to be effective.

A number of important factors and/or inputs underpin the design and implementation of any effective professional development. Loucks-Horsley, Stiles, Mundry, Love and Hewson (2010) identified four key factors about the professional development design process that could help developers to make an informed decision. These are: knowledge and beliefs, context, critical issues and strategies.

Physics is one of the subjects in which students have to master complex skills and reasoning processes that are essential for scientific literacy. In order for this to be realised, teachers need to feel competent to create appropriate learning environments for their students. For teachers to be able to do this, teachers need opportunities for on-going professional development, especially those in which they (teachers) can learn what they need to know and how they can work with their students to achieve that goal.

Timperley, Wilson, Barrar, and Fung (2007) outlined effective contexts for promoting professional learning opportunities that impacted on a range of student outcomes. On how to teach particular curricula most effectively, Timperley et al. (2007) identified some discrepancies between prevailing discourses about what counted in learning and teaching and the approaches being promoted in the professional development. A paradigm shift – moving the focus from facts, procedures, and memorization to a process of student inquiry and the development of students' conceptual understandings, was proposed as the way forward. In support of this claim, Timperley et al. (2007) provide an example: as a results-focused teacher became more skilled in implementing inquiry-based approaches, student learning deepened. Consequently, the ways in which teachers thought about what constituted effective teaching and how students learn most effectively in mathematics and science, changed. Conceptions about teaching and learning may need to be challenged before teachers shift their focus on what and how they teach (Conner, 2015).

What Professional Development do Physics Teachers Need?

Professional development is viewed in this study from the point of view of Scheerens (2009) as the body of systematic activities to prepare teachers for their job, including initial training, induction, in-service training, and continuous professional development within school settings. The most frequently used analytical variables when attempting to explain why some teachers were more effective than others were mastery of subject matter and pedagogical knowledge. Additional components sometimes included were the appropriate use of teaching materials and media, as well as strategic knowledge about the application of teaching strategies (Geijsel, Sleegers, Stoel, & Krüger, 2009; Krauss et al., 2008; Scheerens, 2009).

Krauss et al. (2008) defined three main components of pedagogical content knowledge: knowledge of tasks, knowledge of students' prior knowledge and knowledge of instructional methods. These authors measured pedagogical content knowledge by means of an assessment centre type of approach, in which teachers rated real-life teaching scenarios in mathematics classes. Their results gave a basis for the hypothesis that teachers with more pedagogical content knowledge display a broader repertoire of teaching strategies for creating cognitively stimulating learning situations. Another interesting outcome was that, pedagogical content knowledge was highly correlated with subject matter mastery, thus suggesting that deep knowledge of the subject matter is indeed the critical precondition for pedagogical content knowledge. Even though the study was conducted in mathematics, the findings are by no means limited to that discipline alone.

Ideally physics teachers should participate in a variety of professional activities within the school context to stimulate both their own professional development and the development of the school (Scheerens, 2009). Acknowledging this raises the important question of which professional activities can improve teachers' practice effectively and which type of teacher learning needs should be addressed. Based on the research literature, the following professional learning activities, which are crucial for enabling teachers to deal with the rapid changes they face, can be distinguished: keeping up to date (collecting new knowledge and information), experimentation, reflective practice (giving and asking for feedback), knowledge sharing and innovation (Geijsel et al., 2009; Janssen & Van Yperen, 2004; Krauss et al., 2008; Kwakman, 2003; Scheerens, 2009). Research findings have also shown that teacher collaboration aimed at improving instruction and education is also relevant (Meirink, 2007). Co-operative and friendly collegial relationships, open communication, and the free exchange of ideas may be sources of emotional and psychological support for teachers of physics in promoting their professional learning and development (Toole & Louis, 2002).

Furthermore, research has shown that teachers' participation in decision making, which supports an 'organic' form of school organization, can have positive effects on teachers' motivation and commitment to change (Geijsel et al., 2009; Jongmans, Sleegers, Biemans, & De Jong, 2004). Learning is maximized if school staff, and teachers in particular, are provided with information on important school issues (Earl & Katz, 2006; Leithwood, Aitken, & Jantzi, 2006).

Methods

Design

This study employed a two-stage convergent parallel mixed methods design (Creswell & Clark, 2011) using both survey and case study techniques. In the first stage, a survey questionnaire was given to physics teachers throughout New Zealand and in the second stage, physics teaching and learning were examined in more detail by a series of case studies. It was the intention in this latter stage to move beyond the perception-based data obtained in stage one. Creswell (2007) observed that the use of multiple data sources and cross comparisons to gain understanding of a phenomenon ensured trustworthiness and credibility of interpretation of data. Also, using mixed methods has the advantage of helping the researcher to gain a deeper understanding of certain issues pertaining to the problem under investigation (Best & Kahn, 2005; Cohen, Manion, & Morrison, 2007; Taylor, 2004).

Sample and Sampling Technique

The sample population for the study comprised senior high school physics teachers and other stakeholders in physics education, including initial teacher educators. Secondary school physics teachers were invited to complete an online questionnaire. No accurate information about the total number of physics teachers in New Zealand was available.

The participating teachers had a wide variety of educational backgrounds and experiences. Their educational qualifications ranged from a bachelor of science degree to a PhD. All teachers had a diploma in teaching and learning or a post graduate diploma in education, a requirement to teach in New Zealand. The age of the teachers ranged from 21 – 50+ years, with teaching experience averaging from 17 – 30 years. About 70% of all the teachers were less than 50 years of age.

Three state high schools in Christchurch, New Zealand were purposefully sampled as a convenience sample for on-going observation (Creswell, 2007) and used in the case studies. Reasons for selecting these schools included accessibility and a willingness by school leaders and staff to engage with the researchers. Physics teachers at these schools were interviewed and observed while teaching physics. Also, one private (fully independent) co-educational school, was purposefully selected as an additional and alternative case study. The physics teacher at this school was a biologist who had taught biology for many years but later changed to teaching physics.

Three teacher educators, from three universities, were also interviewed to gain their perceptions about what was currently provided in initial teacher education qualifications and what they thought the needs of physics teachers were. This information served to triangulate the information provided in the teacher interviews and from the national survey data.

Procedure

The online survey questionnaire was developed and distributed using the Qualtrics survey platform. The link to the online questionnaire was posted on three local websites commonly accessed by New Zealand physics teachers. In addition, the national physics teacher association mailing list was used to send an email message to secondary school physics teachers, inviting them to participate in the study.

The participants based in Christchurch were interviewed at a face-to-face meeting and the video communication application Skype was used to interview participants based further afield. All the interviews were conducted at dates and times convenient to the participants.

Data Analysis

Data from the survey questionnaire were analysed using descriptive statistical methods (including percentages, means, standard deviations and graphs where appropriate). Qualitative data gathered during interviews were used to substantiate findings from the survey data. Audio recordings from the interviews were transcribed and coded into nodes which provided easy retrieval of the themes that emerged. Where quotes are used within the findings, they were chosen because they were representative of the statements of most of the respondents. The production of accurate and verbatim transcripts was integral to establishing the credibility and trustworthiness of the data.

Findings

Teacher Characteristics

A total of 138 physics teachers started the online survey, with 104 completing it, a 75.4% completion rate. Incomplete responses were discarded from the analysis. The majority of the physics teachers who participated in the study were males (67.3%). Approximately 60% were above 40 years of age and about 57% of the teachers had been teaching physics for more than ten years. About three-quarters of the teachers were qualified in Physics and it was their first-choice of teaching subject. The remaining one-fourth were qualified in another subject and had switched over to physics in the course of their teaching career. Their reasons for doing so were job availability and a lack of physics teachers.

Areas of professional learning

The study sought to look at pertinent areas of professional learning that physics teachers would like to engage in to support their teaching practice. In the online questionnaire, the teachers were asked to indicate how important they thought professional learning was in a number of areas: the use of technology in physics instruction; the use of inquiry/investigation-oriented teaching strategies; understanding student thinking in physics; how to assess student learning in physics; deepening the teacher's own content knowledge; and knowledge of *The New Zealand Curriculum*.

On a five-point Likert scale from 1 (not important) to 5 (very important), the teachers reported a substantial need for professional development in all of the areas. As can be seen in Figure 1, the areas of highest perceived need for professional development were understanding student thinking in physics (95.2%) and deepening their own content knowledge (93.3%).

Professional development about assessing student learning, the use of inquiry/investigation-oriented teaching strategies, professional learning regarding the use of technology in physics instruction and knowledge of *The New Zealand Curriculum* all ranked highly.

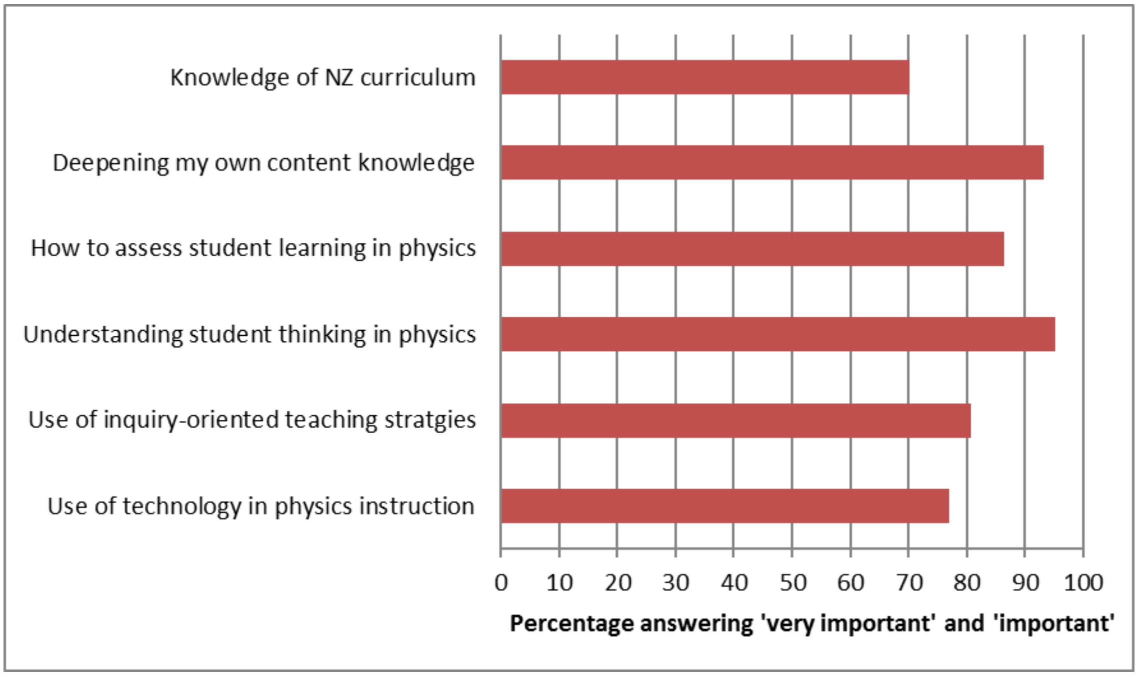

Figure1: Percentage of teachers rating "very important" and "important" for areas of professional learning

Similar perceived needs were recorded in the areas of professional development for teachers whose first choice teaching subject was physics and those who changed to physics. Figure 2 shows the distribution of percentage scores for both groups answering 'very important' and 'important'. Almost all the teachers in these groups perceived that they needed moderate or substantial professional development in all of the areas. Both groups of teachers reported a significant need for professional learning in the areas related to understanding student thinking in the subject and deepening their own content knowledge.

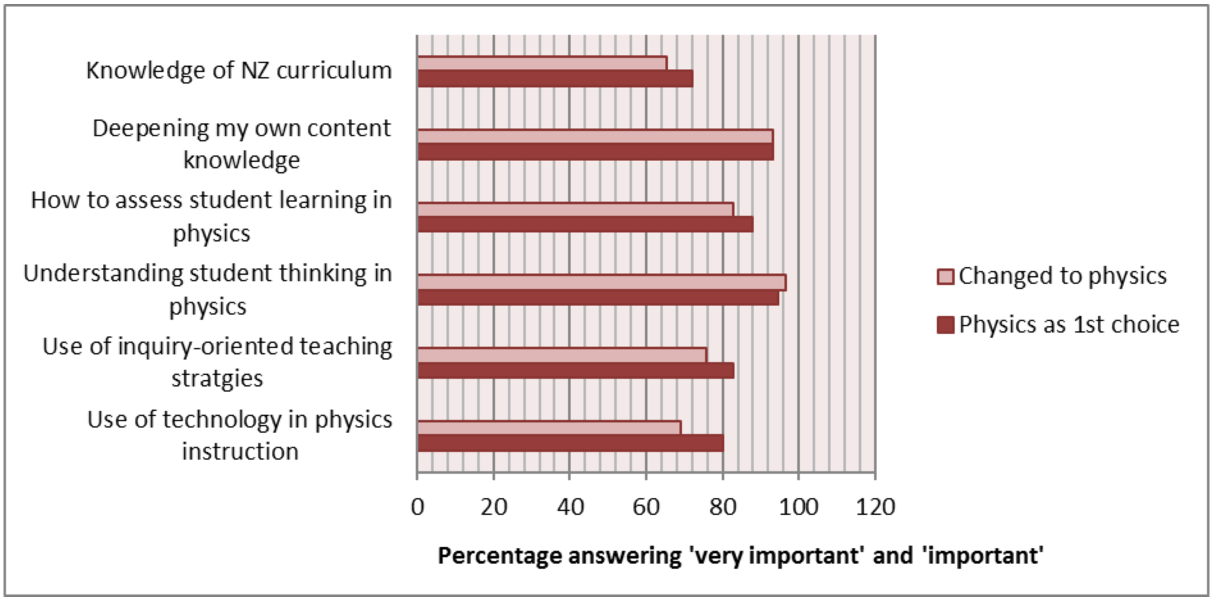

Figure 2: Comparison of teachers rating "very important" and "important" to areas of professional learning

The types of professional development activities that teachers had previously engaged in are shown in Table 1. Meeting with a local group of physics teachers on a regular basis to discuss issues about physics teaching was the most common form of professional development for qualified physics teachers, and for those teachers who had switched to physics, it was engaging in independent self-study to deepen their subject matter content knowledge.

Table 1: Types of Professional Development Activities Teachers have undertaken

Professional development activities	Percentage responses: Physics as 1st choice teaching subject (N=75)		Percentage responses: Teachers who switched to physics (N=29)	
	Yes	No	Yes	No
Learning how to use technology in physics instruction	43.2	56.8	34.5	65.5
Learning how to use inquiry/investigation-oriented teaching strategies	74.7	25.3	72.4	27.6
Understanding student thinking in physics	48.0	52.0	24.1	75.9
Learning how to assess student learning in physics	64.0	36.0	58.6	41.4
Deepening my own physics content knowledge	77.3	22.7	79.3	20.7
Observed other teachers teaching physics as part of teacher's professional development (formal or informal)	53.3	46.7	58.6	41.4
Met with a local group of physics teachers on a regular basis to study/discuss issues about physics teaching	78.7	21.3	69.0	31.0
Collaborated on physics teaching with a group of physics teachers at a distance	49.3	50.7	44.8	55.2
Served as a mentor and/or peer coach in physics teaching, as part of a formal arrangement that is recognized or supported by the school	42.7	57.3	10.3	89.7

The Case Study Teachers

The purpose of the case studies was to gain further insight into the professional learning experiences of the physics teachers. Four exemplary physics teachers (three males and one female) voluntarily participated in the study. Information about the teachers and their schools is presented using pseudonyms.

Background and Experience

Philip was a physics teacher in co-educational School A. He was aged 50+ years and had 30 years of teaching experience. He had a degree in physics and a graduate diploma in education. Philip was the assistant head of science and the teacher in charge of senior physics and electrotechnology, taught as separate subjects in the last three years of schooling. He retired from teaching soon after participating in this study.

Nick was a physics teacher in an all boy's state School B. He was aged between 41 – 50 years. He had a PhD in physics and a graduate diploma in teaching and learning. He had been teaching physics and science for about 12 years and was head of physics. At the time of the study, Nick was teaching 20 hours per week, although his normal teaching load was 17 hours per week.

Vicky was a physics teacher at School C, an integrated Catholic girls' school. She was aged between 31 – 40 years and had been teaching for ten years. She had an honours degree in physics, a Diploma of Teaching and was the assistant head of science. Vicky was the only physics teacher at School C and was employed on a part-time basis.

Bernard was a physics teacher in a co-educational private School D. He was aged 50+ years and had over 30 years of teaching experience. He was both head of science and head of physics. Bernard was purposefully selected as a teacher who had switched science disciplines. He had a bachelor's degree in biology, a master's degree in marine biology and a Diploma in Teaching and Learning. He had taught biology for almost ten years before switching to physics, which he had taught for 25 years.

Professional Learning Experiences

Philip highlighted the need for more professional learning opportunities for teachers. He had participated in several professional development experiences within the last five years. He said:

In physics, I've only had one professional development opportunity in the last twelve months, and it was on literacy in senior physics and I've got to say that I didn't find it particularly useful. I did not find it useful at all, and I was quite disappointed. But in the last twelve months I've had lots of professional development here at school but it's mostly about Junior Science. No (external) professional development, apart from that one on physics. (Philip).

Philip considered professional learning that he had initiated himself, to be valuable. He had undertaken self-study using inquiry-based reflection to understand his own teaching practices, analysing tests, exams and experiments to find better ways to help students with their learning.

I do my own professional development. I'm always looking at different experiments, different ways to present material, and I'm always analysing tests, exams to see if there's a better way to get the ideas across. I'm doing that constantly, and all the time. For example, at the moment I'm looking at a way, a better way to measure Planck's Constant using LED's because in the past we've done it with the photoelectric effect. Though it gives a good result, there is another way that I've discovered with LED's. (Philip)

Philip believed that this form of professional learning was far more effective than other types of professional development. He indicated a preference to spend more time doing this rather than attending short-term facilitated workshops, which seemed to focus predominantly on assessment issues and which he perceived as having little value.

Nick indicated that at his school there was a professional learning initiative focussing on pedagogy. Most of Nick's professional development in physics had been through personal reading and attending conferences. He explained that he used Facebook as a reader and had subscribed to New Scientist, Scientific American, and Physics Today. This material helped him to focus on things that he was either personally interested in or that he could use to promote student interest. He described how effective this had been in the following statement:

So, this year for example, while I was teaching Nuclear Physics, there was a paper in New Scientist about measuring the mass of a proton and the two different ways of measuring it gave two different values where the uncertainties didn't overlap. And I was teaching uncertainties to my Year 13 students at that time, and what we used them for. Why, if you want two *numbers to agree, the uncertainties have to overlap. And so, this was good timely professional development for me, to know this was what was going on and be able to use that with my students. To say well this is why we're learning how to do uncertainties, because without them, you're just guessing. (Nick)*

Vicky, expressed concern about the lack of professional development available to physics teachers. She had attended meetings for in-service teachers organised by the local university and described these as "really good". At these meetings, which she stated were held infrequently, teachers shared resources and discussed teaching strategies that they had found to be effective in promoting learning. Vicky had also attended several professional development workshops run by the government crown entity responsible for overseeing qualifications and was disappointed that these focussed entirely on assessment.

Vicky had occasionally inquired into her own teaching practice by personal reflection. She had been trying to improve her subject knowledge and to better understand the teaching approaches she used in her classroom. She did this by giving herself challenging questions to answer and by using contextual scenarios with her students that encouraged them to ask deep, searching questions. She viewed this "minds on" approach as a way to promote critical thinking.

Bernard, the biologist who switched to teaching physics, considered that professional development had played a vital role in progressing his career. Much of the professional development he had engaged in had been workshop-based and was organised by his school. This focussed on pedagogy, enhancing student literacy and the effective use of ICT. Bernard emphasised that engaging in inquiry by personal reflection was an essential part of his teaching practice. He considered that this form of professional learning had greatly enhanced the effectiveness of his teaching, and by sharing his findings with colleagues, their effectiveness as teachers. Bernard strived to stay current with literature related to education and to his teaching subjects and when he was able to, he attended education and physics conferences. He remarked:

I try to go to those as much as I can, and I find they're very valuable. I find they're invigorating, you get some good ideas, you get to network with other physics teachers and they've been great. (Bernard)

There was one particular conference Bernard had attended that had a profound effect on his practice. It had been about cognitive overload and he subsequently referred to it as his "thinking conference". The experience had changed his ideas about what is important in physics teaching and how physics should be taught. He had embedded these ideas into his practice and claimed they had yielded very positive results.

Overall, Bernard described the professional learning courses he had attended as "valuable" and he felt lucky he was employed by a school that valued professional development. He stated:

> *I've got the advantage that our school values professional development. I think that it's kept me enthusiastic, it's kept me wanting to improve, it's kept me wanting to do better, it's kept me questioning my own technique in the classroom, more than just the straight teaching of physics. (Bernard)*

Initial Physics Teacher Education

Three initial teacher educators responsible for preparing physics teachers were interviewed as part of this study. All were university-based academics who had considerable past experience teaching in high schools.

The teacher educators were at three different universities and each delivered their physics course as part of a one-year full time teacher preparation programme. The physics course focussed primarily on developing pedagogical content knowledge for physics and had been designed to comply with the requirements of the Education Council of New Zealand/ Matatu Aotearoa for initial teacher preparation. The teacher educators had little time in their courses to cover subject content knowledge and they relied heavily on the non-education or first degree that students undertook to provide this requirement. They stated that students who enrolled in their physics courses were often weak in some areas of physics content knowledge. If time constraints permitted it, the teacher educators would try to address these deficiencies. The teacher educator at University B stated:

> *The students that come to the physics course are often quite rusty in terms of content knowledge, and that's a concern and the comment has been made in the past by associate teachers in schools that the students need to better know their physics. They don't come to our physics course with the intention of learning physics, we want to teach them to be physics teachers. But we*

invariably end up spending some time looking at content. (Teacher Educator, University B)

The teacher educator at University C stated:

Where there are gaps in their own knowledge we give them time and resources and they interact with each other to try and fill those gaps. But there's not an emphasis on trying to actually remedy any changes in their subject content knowledge. (Teacher Educator, University C)

Asked about the provision of professional learning programmes for in-service high school physics teachers, the three teacher educators responded that they played little role in this and to do more would be challenging. Their primary responsibility was the preparation of new teachers and all considered they had heavy academic and administrative workloads. To become more involved in providing in-service teacher professional development would compromise the effectiveness of their existing teaching.

Discussion and Implications

An important strategy for improving the quality of science instruction and student outcomes is for teachers to engage in professional development (Banilower et al., 2007). To inform this process, it is essential for stakeholders to investigate what kind of professional learning teachers require. This study has provided important information about the kind of professional development the participant physics teachers currently access, what they view as important and find most valuable to enhance their teaching.

The teachers in this study indicated there was a lack of regular and readily accessible organised professional development in physics. Centralised government-funded professional development was viewed by the survey and case-study teachers as being largely ineffective. It was evaluated as being infrequent and largely focussed on assessment.

The teachers perceived that their most beneficial professional development experience was critically reflecting on their own practice through personal inquiry and reflection. This activity has been promoted by Timperley (2011) and found to be effective by other New Zealnd science teachers (Conner, 2015).

In the teacher survey, the teachers reported (Figures 1 and 2) a need for professional learning in a number of areas. These were: deepening their own content knowledge; understanding student thinking in physics; the use of inquiry/investigation-oriented teaching strategies, the use of technology in physics teaching and knowledge of *The NZ Curriculum*. This list is not intended to be comprehensive and the importance of professional development in shaping teacher conceptions and beliefs should not be ignored.

New Zealand schools have considerable autonomy and teachers in each school develop their own planning and units of work. The national curriculum statement requires schools to develop and deliver their own curriculum to address the needs of their learners as well as the requirements of a national standards-based assessment system. Teachers need to be aware of and use a wide range of teaching approaches and resources for the students they teach. Teaching practice is generally very student-centred and teachers deliver content that is relevant to their students' learning needs. This requires teachers to identify what individual student needs are and how these might best be addressed. This is in contrast to previous notions of teaching whereby the same content was taught in the same way to all students. This change of focus is in line with the OECD (2014) reporting that teachers now need to be prepared for a much broader range of tasks and approaches to enable learning at all levels. The teachers in the survey and the case study teachers all identified the need to be supported better to further their skills and practices for the betterment of their students.

Physics teachers' meetings were the main source of collaborative professional learning that the teachers engaged in, except for Bernard who also attended physics conferences as an external source of inspiration for his teaching. The meetings were organised and resourced by the local university or by the physics teachers themselves.

Physics teacher educators are responsible for preparing physics teachers entering the teaching profession and some university-based physics teacher educators were interviewed in this study. They all belonged to and supported physics teacher or science teacher associations and supported in-service teachers as much as they were able. But the physics teacher educators were not responsible for in-service teacher career development as in New Zealand, this is mostly developed through independent contracts with the Ministry of Education. Within the requirements of their academic roles, they did not have the workload capacity nor the funding resources to provide in-service development for physics teachers in a regular professional learning community model. However, there was scope to consider how working with teachers on a range of improvements to teaching physics, could lead to potential collaborative research opportunities which would then help the teacher educators to meet their university academic requirements.

Findings from the national survey and the teacher and teacher educator interviews revealed that the provision of professional development in teacher content and pedagogical knowledge for teaching physics needed to improve in New Zealand. Professional learning programmes should support teachers to deepen their technological pedagogical content knowledge (TPACK) to make learning for their students interesting and relevant (Owusu, Conner & Astall, 2015). TPACK is about teachers selecting pedagogy that is appropriate for specific content including useful forms of presentation using multi-modal technologies, analogies, illustrations, examples, explanations and demonstrations that make the learning of specific topics more accessible for learners. In other words, appropriating pedagogy to content. That is, in-depth knowledge about integrating content and pedagogy are crucial for teachers to be able effect and enhance learning.

Comments from the case study teachers showed that continuous professional development can sustain teacher improvement and development, thereby enhancing student learning. Continuous self-study or teaching as inquiry (Conner, 2015; Timperley, 2011), had impacted significantly on the case study teachers – e.g. Philip, Nick, Vicky and Bernard. Bernard's attributed much of his success to his self-study and participation in professional development opportunities, where he networked with other physics teachers who he could contact for support and ideas. Philip, in his reflective inquiry to understand his own teaching practices, had analysed tests, exams and experiments to find better ways to help his students with their learning.

Physics teachers need to be supported through induction, mentoring, and opportunities for collaboration so they have the capability to effectively deliver the best possible physics instruction. Futernick (2007) and Hodapp, Hehn, and Hein (2009) reported that in the United States, strong collegial support had a significant influence on physics teachers who decided to continue teaching. As a form of support for teachers, the PhysTEC institutions in the United States have been providing induction and mentoring services to graduate teachers through the use of experienced teachers and/or teachers-in-residence (TIR) programmes (Hodapp et al., 2009).

Perhaps there is scope for physics departments and physics teacher educators in New Zealand universities, the New Zealand Institute of Physics, and others with physics expertise to collaborate more effectively to create a physics learning community supporting physics teachers. Many institutions and organisations in the United States have collaborated in this way and have achieved excellent results (Etkina, 2010; Hodapp et al., 2009).

Cochran-Smith and Lytle (1999) identified three types of knowledge needed by teachers: knowledge-for-practice; knowledge-in-practice and knowledge-of practice. The third type of knowledge, knowledge-of-practice, results when teachers learn from their teaching experiences, issues concerning learning, knowledge, and theories leading to the development of local knowledge of practice. As a result, teachers produce their own knowledge which works in their classroom situations and may not necessarily be generalized to other situations. Teachers may not be able to generate this knowledge by themselves and therefore need to collaborate with others as part of the inquiry process (Conner, 2015). In view of this, it is suggested that any professional development organized for teachers should enable them to take ownership of the learning process through reflecting on their practices, identifying their own needs and connecting their practices with relevant theories, as well as connecting together in professional learning groups – as exemplified by the collaborative meetings, which the participants in this study found particularly useful. As Conner (2015) reported, when teachers find professional learning is directly relevant to their practices, there was more chance of transfer of their learning to their instructional practices and ultimately translation of their teaching approaches to successful students' learning outcomes.

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