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Chapter 8

Professional Development and Physics Teachers' Ongoing Learning Needs

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.78711

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, analysed and used to triangulate and add depth to the survey data. Findings indicated that physics teachers were dissatisfied with the lack of formal physics-focussed professional development opportunities available to support their professional growth. Instead, teachers tended to rely 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.

Keywords: professional development, content knowledge, teacher learning, teaching as inquiry, physics teaching

1. Introduction

It is irrefutable that to maintain excellence in their practice, teachers need to continually develop their knowledge and skills through professional development (PD). However, teacher PD may seldom live up to expectations or provide the knowledge and skills teachers are seeking. In response, there has been a call for a shift from professional development to professional learning and development (PLD), which is capable of promoting ongoing teacher and student engagement, learning and well-being (Timperley, [1]). This process examines teachers' practices and allows them to take control of their own professional learning through reflection on evidence of how changes to teaching have influenced students' outcomes [1].

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A national study investigating the main reasons why teachers left the profession in the United States [2] found that teachers thought teaching was too complex. This study showed that about one-third of teachers left the profession within the first three years and about 40-50% left within 5 years. Mizell [3] also found that teachers were challenged by subject content knowledge, new instructional methods, advances in technology, and increasing student learning needs. PLD has the potential to support teachers to build their knowledge and capabilities for creating changes necessary to comply with changes in standards and/or curriculum requirements.

The results of the 2013 Teaching and Learning International Survey (TALIS) also highlighted that teachers' roles are changing and that their existing knowledge and skills may not match new needs and expectations. The 2014 Organisation for Economic and Cooperative Development (OECD) report [4] emphasised 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 highlighted the importance of collaborative professional learning for teachers, as those participating in such activities, reported being significantly more confident in their teaching [4]. Since teachers are expected to prepare students to become lifelong learners, they also need to learn and participate in continuous improvement throughout their career.

In the present study, part of a larger project [5], PLD was viewed as the body of systematic activities to prepare teachers for their job [6], including initial teacher education, induction, in-service activities, and ongoing professional learning. 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.

2. Literature review

Probably, the most important way for teachers to excel and improve is through professional development. For example, Mizell [3] argued that the acquisition of new knowledge and new ways of improving performance is often attributable to participation in PLD. Borko [7] also suggested that ongoing PLD opportunities are vital to enhance and augment teachers' understanding and appreciation of the subject matter. According to Mizell [3], university and college curricula do not adequately equip pre-service teachers to gain sufficient confidence to be effective teachers. Mizell [3] viewed teacher learning as ongoing and a process in which they learn through experience and reflection/action cycles—as well as through more traditional course work or activities led by an expert.

The need for revising what kind of PLD teachers have access to has been extensively reported in the literature. In the USA for example, reports from the 2000 National Survey of Science and Mathematics Education revealed that the majority of Science teachers were not adequately equipped to be adaptive to their students' needs by adopting and shaping classroom activities appropriately [8]. The authors found that about 60% of elementary

and middle school teachers indicated their need for professional learning that focussed on inquiry-oriented teaching and learning approaches. Among middle school teachers, 67% reported a need to deepen their own Science content knowledge, and 71% reported a need to deepen their understanding about integrating technology into Science learning experiences. Despite these indications, many of the projects funded by the National Science Foundation (NSF) and the US Department of Education focussed on improving teachers' knowledge and skills [9] rather than on inquiry approaches or the integration of technology.

So, what should PLD focus on? Reporting on what makes PLD effective, Garet et al. [10] 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. [9] commented that professional development programmes that focused on subject-matter knowledge as well as identifying student learning within that subject were more likely to improve student learning. Further, they found that providing teachers with opportunities to deepen their content and pedagogical knowledge when simultaneously accompanied by high-quality instructional materials, improved teaching. Other authors have also stressed that PLD that equipped teachers with the pedagogical skills to teach particular types of content, positively influenced practice and student learning and achievement [11–14]. In a review of 25 PLD programmes for Science and Mathematics teachers across the USA, Blank et al. [12] found that 22 of the programmes focused on content knowledge, but they were also positively rated by teachers for also providing useful pedagogical content knowledge.

2.1. Professional development for teachers

In multiple studies, PLD that focused on teacher subject-matter knowledge and pedagogical skills was shown to have a positive impact on student learning and achievement [9, 10, 12, 13]. Research has linked the amount of PLD teachers receive positively to an improvement in student learning outcomes [15]. Short-term workshops or one-off events do not necessarily produce the intended changes in the teachers' practices and results for students' achievement [9, 10, 16]. These researchers found that PLD activities that spanned a longer time period with a greater number of contact hours (an average of 8–14), and that required ongoing reflection were more likely to bring a positive and more enduring change. In view of this, Darling-Hammond and Richardson [13] advised that schools should devise a coherent PLD strategy rather than that of the "traditional one-shot workshop" (p. 48). They added 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, resources or assessment. So, to avoid this situation, professional learning opportunities must be linked with the current curriculum, assessment and standards.

Physics is one of the subjects in which students have to master complex knowledge, 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 Physics learning environments for their students. Timperley et al. [17] outlined the effective contexts for promoting PLD opportunities

and their impact on a range of student outcomes; more generally, these ideas can be applied to PLD for Physics teachers as well. For example, the authors identified that there was a need for a paradigm shift—to move the focus from facts, procedures, and memorization to a process of developing pedagogy that supported student inquiry and the development of students' conceptual understanding. They provided examples of how there was a link between teachers perceptions of their roles in being an effective teacher and how students learned most effectively in Mathematics and Science. Teachers' conceptions about their role in teaching and learning often needed to be challenged before they could shift their focus from what they teach to how they teach, and especially on how these changes in teaching approaches might lead to enhancing student outcomes [18].

2.2. Do Physics teachers need professional development?

Professional development is viewed in this study from the point of view of [6] 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 for teaching specific content (PCK) [6, 19, 20].

Krauss et al. [20] defined three main components of PCK: knowledge of tasks, knowledge of students' prior knowledge and knowledge of instructional methods. These authors measured PCK by an assessment centre approach, where teachers rated real-life teaching scenarios in Mathematics classes. Their results gave a basis for the hypothesis that teachers with more pedagogical content knowledge displayed a broader repertoire of teaching strategies for creating cognitively stimulating learning situations. Another interesting outcome was that PCK was highly correlated with subject matter mastery, thus suggesting that deep knowledge of the subject matter is indeed the critical precondition for PCK. Even though the study was conducted in Mathematics, the findings are by no means limited to that discipline alone.

But which professional activities can improve teachers' practice effectively and which teacher learning needs should be addressed? The literature has indicated that keeping up to date (collecting new knowledge and information), experimentation, reflective practice (giving and asking for feedback), knowledge sharing and innovation are all very important PLD activities [6, 19–22]. Teacher collaboration aimed at improving instruction and education was also shown to matter [23]. 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 [24]. Furthermore, teachers' participation in decision-making, where they are more argentic in decision-making about what and how they teach, can have positive effects on teachers' motivation and commitment to change [19, 25].

http://dx.doi.org/10.5772/intechopen.78711

3. Methods

3.1. Design

This study employed a two-stage convergent parallel mixed methods design [26] 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 using a series of case studies. The purpose was to move beyond the perception-based data obtained in stage one and gain more in-depth insights into the reasons why teachers felt the way they did. Creswell [27] indicated that the use of multiple data sources and cross comparisons to gain an understanding of a phenomenon ensured trustworthiness and credibility of the interpretation of data. Also, triangulating methods have the advantage of potentially gaining deeper understanding of the issues under investigation [28–30]. Thus, a mixed-methods approach was used in this study.

3.2. Sample and sampling technique

Senior high-school Physics teachers and other stakeholders in Physics education, including initial teacher educators were the participants for this study. All secondary school Physics teachers in New Zealand who were affiliated to two teacher associations were invited to complete an online questionnaire. No accurate information about the total number of Physics teachers in New Zealand was available. However, in New Zealand, the majority of teachers do belong to teacher associations, so they were deemed a good source for recruiting participants.

The participating teachers had a wide variety of educational backgrounds and experiences. Their educational qualifications ranged from Bachelor of Science degrees to PhDs. All teachers had a diploma in teaching and learning or a postgraduate diploma in education, since this is a requirement to teach in New Zealand. The age of the teachers ranged from 21 to 50 years and above, with teaching experience, averaging between 17 and 30 years.

Three state high schools in Christchurch, New Zealand were purposefully sampled as a convenience sample for ongoing observation [27] and used in the case studies. These schools were included due to accessibility and willingness by the 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. He was selected as a case to provide some insight as to why multiple teachers have done this in NZ and what their specific issues for professional learning might be.

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. The time

scale of when teachers undertook their teacher education qualification was taken into account when comparing current with previous initial teacher education provision.

3.3. 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. All participants volunteered to be part of the study. The anonymity of participants was assured, and the research ethics approval obtained from the University of Canterbury was adhered to.

3.4. 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 the 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. Quotations were chosen according to how well 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.

4. Findings

4.1. 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 10 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 in New Zealand.

4.2. Areas of professional learning

The study sought information about pertinent areas of professional learning that Physics teachers currently engaged in and what they would like to engage in to support their teaching.

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; assessing student learning in Physics; their 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 the highest perceived need for professional development were as follows: understanding students' 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.

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.

The types of professional development activities that teachers had previously engaged in are presented in **Table 1**. The most common form of professional development for qualified Physics teachers was meeting with a local group of Physics teachers on a regular basis to discuss issues about Physics teaching. For teachers who had switched to Physics after being a teacher in another subject, the most common PLD was engaging in self-study to deepen their subject matter content knowledge. This was not surprising given Physics was not the subject they had chosen to start their teaching careers.

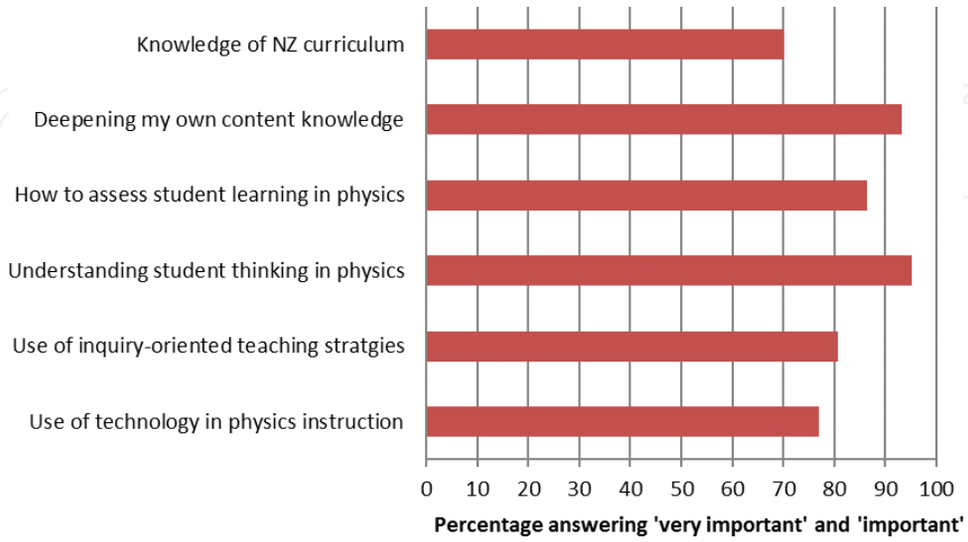


Figure 1. Percentage of teachers rating "very important" and "important" for areas of professional learning.

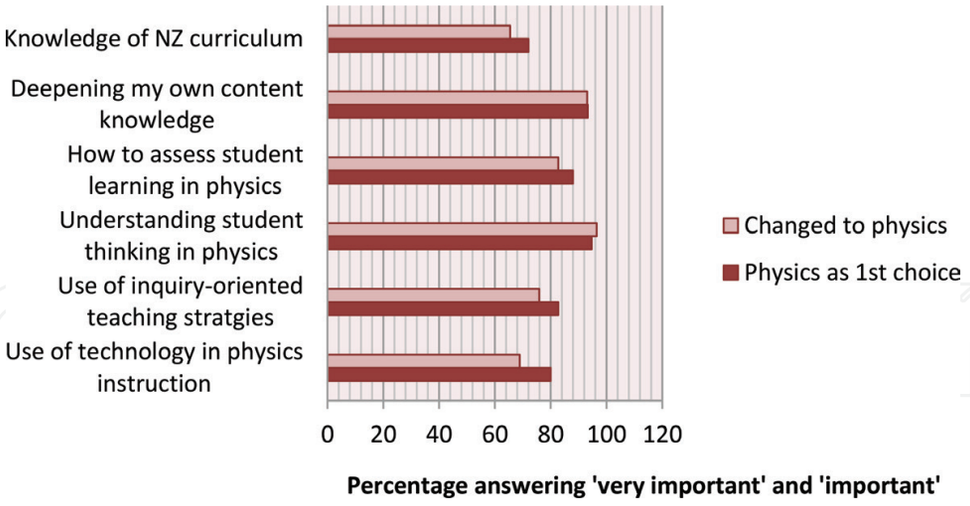


Figure 2. Comparison of teachers' rating "very important" and "important" with areas of professional learning.

Professional development activities	Percentage responses			
	Physics as 1st choice teaching subject (N = 75)		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 students' 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 recognised or supported by the school	42.7	57.3	10.3	89.7

Table 1. Types of professional development activities teachers have undertaken.

5. The case study teachers

The case studies provided further insights into the professional learning experiences of the Physics teachers.

http://dx.doi.org/10.5772/intechopen.78711

5.1. Background and experience

Philip was a Physics teacher in co-educational School A. He was above 50 years of age 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 3 years of schooling. He retired from teaching soon after participating in this study.

Nick was a Physics teacher in all boys' state School B. He was aged between 41 and 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 h per week, although his normal teaching load was 17 h per week.

Vicky was a Physics teacher at School C, an integrated Catholic girls' school. She was aged between 31 and 40 years and had been teaching for 10 years. She had an honours degree in Physics and 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 above 50 years of age 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 10 years before switching to Physics, which he had taught for 25 years.

5.2. 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 5 years. He said:

> *In physics, I have only had one professional development opportunity in the last twelve months, and it was on literacy in senior physics and I have got to say that I did not find it particularly useful. I did not find it useful at all, and I was quite disappointed. But in the last twelve months I have 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 am always looking at different experiments, different ways to present material, and I am always analysing tests, exams to see if there's a better way to get the ideas across. I am doing that constantly, and all the time. For example, at the moment I am looking at a way, a better way to measure Planck's Constant using LED's because in the past we have done it with the photoelectric effect. Though it gives a good result, there is another way that I have discovered with LED's. (Philip)*

Philip believed that this form of PLD was far more effective than other types of PLD. 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.

Most of Nick's PLD in Physics had been through personal reading and attending conferences. He used Facebook and subscribed to New Scientist, Scientific American, and Physics Today. This material helped him to focus on content and innovations 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 did not 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 are learning how to do uncertainties, because without them, you are just guessing. (Nick)*

Vicky expressed concern about the lack of PLD 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 PLD 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 through personal reflection. She had been trying to improve her Physics knowledge and to better understand potential teaching approaches she could use. 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, who began his teaching as a biologist and switched to teaching Physics, considered that PLD had played a vital role in progressing his career. Much of the PLD 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 through personal reflection was an essential part of his teaching practice. He considered that this form of PLD had enhanced the effectiveness of his teaching greatly. He often shared his findings with colleagues, which he thought, supported their thinking about their effectiveness as teachers as well. Bernard strived to stay current with the literature related to education and to his teaching subjects. 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 are very valuable. I find they are invigorating, you get some good ideas, you get to network with other physics teachers and they have been great. (Bernard)*

He remembered one particular conference that had a profound effect on his teaching. It had been about managing cognitive load for students 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 led to very positive results.

Overall, Bernard described the PLD he had experienced as "valuable" and he felt lucky he was employed by a school that valued PLD. He stated:

> *I have 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)*

6. Initial physics teacher education

Three initial teacher educators responsible for preparing Physics teachers undertaking a teaching qualification 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 teaching qualification programme. The Physics course focussed primarily on developing PCK for Physics and had been designed to comply with the requirements of the Education Council of New Zealand/Matatu Aotearoa for initial teacher education qualifications. The teacher educators had little time in their courses to cover subject content knowledge in their postgraduate teaching qualification courses and they relied heavily on the first degree that students undertook, to provide this subject-specific knowledge. 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 while they undertook the pedagogical instruction. As an example, 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 do not 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 a minor role in this and to do more would be challenging, given the academic requirements of their universities

for teaching and research. 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. However, all of them were connected to subject teacher associations, and often attended conferences designed for teachers.

7. Discussion and implications

We are not disputing that PLD is very important for teachers. What was surprising in these results was the information provided by teachers about the kind of professional development the participant Physics teachers currently access, what they view as important and what they find most valuable to enhance their teaching and student learning outcomes.

The teachers in this study indicated there was a lack of regular and readily accessible organised PLD in Physics. Centralised government-funded professional development was viewed by the participants in the survey and case study teachers as being largely ineffective. It was evaluated as being infrequent and largely focussed on assessment. This is likely due to the focus in secondary schooling on a standards-based assessment system that had been introduced and revised over the last 12 years.

The teachers perceived that their most beneficial PLD was when they critically reflected on their own practice through personal inquiry. This activity has been promoted for all teachers generally by Timperley [1] and found to be effective by other New Zealand Science teachers [18].

In the survey, teachers reported (**Figures 1** and **2**) a need for PLD in a number of areas. These were as follows: 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*.

Schools in New Zealand 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 meeting 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 where 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 [4] 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 develop their skills and practices for the betterment of their students.

Among the case study participants, Physics teachers' meetings were the main source of collaborative PLD that they engaged in, except for Bernard who also attended Physics conferences as an external source of inspiration for his teaching. The meetings were usually organised and resourced by the local university or by the Physics teachers themselves.

Physics teacher educators indicated that they were responsible for preparing Physics teachers entering the teaching profession. 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 neither 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 PLD for content and pedagogical knowledge for teaching Physics, needed to improve. In a previous study in New Zealand, Science teachers believed that PLD should support teachers to deepen their technological pedagogical content knowledge (TPACK) to make learning for their students interesting and relevant [31]. 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. That is, appropriating pedagogy to content. Owusu et al. [31] indicated that in-depth knowledge about integrating content and pedagogy were crucial for teachers to be able to effect and enhance learning.

Comments from the case study teachers emphasised that they valued continuous PLD to sustain their ongoing improvement and development, thereby enhancing student learning. Continuous self-study or teaching as inquiry [1, 18] had impacted significantly on the case study teachers—for example, Philip, Nick, Vicky and Bernard. Bernard attributed much of his success to his self-study and participation in PLD opportunities, where he networked with other Physics teachers who he could contact for support and ideas. Perhaps because he realised he lacked background in Physics, he actively sought interesting Physics content and interesting ways to teach for understanding Physics, since he was grappling with understanding it as well. 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 indicated that they needed to be supported through induction, mentoring, and opportunities for collaboration so they had the capability to effectively deliver the best possible Physics instruction. Futernick [32] and Hodapp et al. [33] 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 [33]. This idea could be picked up and developed in the New Zealand Physics teaching context.

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 to support Physics teachers' ongoing learning. Many institutions and organisations in the United States have collaborated in this way and have achieved excellent results [33, 34].

Cochran-Smith and Lytle [35] 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 generalised 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 [18]. In view of this, it is suggested that any professional development organised for teachers in the future, 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. This was exemplified by the collaborative meetings, which the participants in this study found particularly useful. As Conner [18] reported, when teachers find professional learning is directly relevant to their practices, there were more chances 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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