Australian Journal of Teacher Education

Volume 41 | Issue 7 Article 3

2016

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Recommended Citation

Buabeng, I., Conner, L., & Winter, D. (2016). Physics Teachers’ Views on their Initial Teacher Education. *Australian Journal of Teacher Education, 41*(7).
http://dx.doi.org/10.14221/ajte.2016v41n7.3

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Physics Teachers' Views on their Initial Teacher Education

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Abstract: This paper explores New Zealand (NZ) physics teachers' and physics educators' views about Initial Teacher Education (ITE). Perspectives of physics teachers nationally indicated that in general, teachers considered themselves not well-prepared in some content areas including electronics, modern physics, and atomic and nuclear physics. This may be because in NZ, physics teachers have usually gained their content knowledge from an undergraduate science degree where they may have only taken one or two courses in physics. One year postgraduate teacher education programmes do not have sufficient time to cover the physics content taught in the final three years of schooling. The implications for ITE of physics teachers are discussed in terms of the shifts needed to help them to identify the gaps in their content knowledge and to develop their conceptual understanding of physics.

Keyword: Initial teacher education, content knowledge, physics teachers, physics educators, classroom practices

Introduction

The focus of this study was to ascertain whether NZ physics teachers perceived their ITE prepared them well for teaching physics at senior levels in high schools. The study also focused on the course content, course structure and programme requirements of ITE programmes for aspiring physics teachers in NZ. Initial teacher educators assume a daunting responsibility when preparing students to become effective and pedagogically competent classroom practitioners. From a social justice perspective (Darling-Hammond & Baratz-Snowden, 2005; Nilsson & Loughran, 2012), ITE programmes must enable pre-service teachers to acquire professional knowledge from multiple dimensions, including subject and context knowledge, general and pedagogical content knowledge, and knowledge of learners and learning. We report here on our attempts to measure NZ physics teachers' perceptions of their ITE experience.

In many respects, physics is the most basic and fundamental natural science - it involves universal laws and the study of the behaviour and relationships among a wide range of important physical phenomena (Cutnell & Johnson, 2007). It encompasses the study of the universe from the largest galaxies to the smallest subatomic particles. Moreover, it is the basis of many other sciences, including chemistry, oceanography, seismology, and astronomy, and physicists may work in many fields including the health services, communications, education, and meteorology among many others (American Physics Society, 2008; Gibbs, 2003). The physics learning experiences in schools provided by physics teachers are therefore very important.

For some time now, the physics learning experiences in schools, particularly those provided in the senior secondary school by specialist physics teachers, have been a major concern of many physics education researchers. McDermott and Shaffer (2000) advocated that a well-prepared physics teacher should have a strong command of the subject matter content knowledge and an understanding about the difficulties this content presents to students. Lederman and Gess-Newsome (2001) mentioned that understanding the content matter is vital for beginning teachers to teach in a conceptually rich and accurate manner. Darling-Hammond and Baratz-Snowden (2005) also emphasised that in order to organise the curriculum to suit both students' needs and school's learning objectives, beginning teachers must know and understand the subject matter they will teach. The National Research Council's science education standards recommended that teachers of science and mathematics should have a strong knowledge of science and mathematics concepts to enable them to guide students to explore these concepts (Coffey, Black, & Atkin, 2001; Loucks-Horsley, & Olson, 2000). Research findings, however, show that it is difficult to measure the extent to which a large national sample of teachers understand these concepts they are teaching, hence proxy measures such as 'major' or 'number of courses taken' in one's field are usually used (Weiss, Banilower, McMahon, & Smith, 2001). Teachers who have acquired sufficient academic preparation – usually subject matter content and pedagogical skills, are generally regarded as effective in classrooms (Darling-Hammond, 2000; Hendriks, Luyten, Scheerens, Sleegers, & Steen, 2010; Orleans, 2007; Scheerens, 2009).

The importance of context in science teaching and learning and successes of science education in NZ have been reported (Bull, Gilbert, Barwick, Hipkins, & Baker, 2010; Coll, Dahsah, & Faikhamta, 2010; Cowie, Jones, & Otrel-Cass, 2011; Stewart, 2011). Even though the practice of science education research in NZ has changed over the last century, "there is little evidence on how science is taught in schools" (Bull et al., 2010, p. 31). A number of reports on students' performance and classroom practices in NZ have identified some areas of concern including little time for science, few hands-on activities, teachers with insufficient knowledge of subject matter and confidence in science instruction and students with less interest for science (Bull et al., 2010; Cooper, Cowie, & Jones, 2010; Hipkins & Bolstad, 2005; Hipkins, Roberts, Bolstad, & Ferral, 2006; Vannier, 2012).

The Role of Content Knowledge

Initial teacher education plays a key role in supporting the development of effective teachers. Lederman and Gess-Newsome (2001) found that, despite the fairly high level of confidence pre-service teachers have in their subject matter knowledge and the attainment of a bachelor's degree in the academic area, most do not understand the content that they are to teach in a conceptually rich or accurate manner. In discussing how the nature of science content affects learning and teaching, Fensham, Gunstone, and White (1994) indicated that content, learning and teaching are interrelated. To them, the extent to which teachers will go about a particular task in the classroom is greatly influenced by the subject matter content they know. Advancing on this, Gunstone (1994) suggested that content knowledge is important for "metacognition purposes" (p. 145). He argued that, understanding the science subject matter content, for physics in particular, is most important for pre-service teachers, in the sense that it promotes self-reflection amongst them about their learning and how and what others have learned.

Conner and Gunstone (2004) noted that learning outcomes are maximised when content knowledge is promoted together with strategic learning approaches. In 1986/7, Shulman introduced the term Pedagogical Content Knowledge (PCK) and asserted that PCK represented “the blending of content and pedagogy into an understanding of how particular topics, problems or issues are organized, represented and adapted to the diverse interests and abilities of learners, and presented for instruction’’ (Shulman, 1987, p. 8). Shulman’s (1987) work indicated the importance for teachers to develop PCK so they can apply appropriate pedagogies to content knowledge. However, pedagogy can only be applied to content knowledge when there is an understanding of the conceptual knowledge to be taught. All these have implications for ITE in that ITE programmes need to model how to identify and learn content knowledge for pre-service teachers so they will gain confidence to teach the fundamental aspects of physics. ITE providers are responsible for the training and development of effective teachers. Commenting on the role that science teachers can play in facilitating high school students’ learning, Wellington and Osborne (2001) indicated that “as teachers of science … our primary skills lie not in our ability to do science, but in our ability to interpret and convey a complex and fascinating subject” (p. 138).). Therefore it is important for teacher educators to consider how beginning teachers are enabled to interpret and connect ideas and make these explicit in their teaching.

As evidenced by a survey of about 1355 participants, McDermott (2001) and McDermott, and Shaffer (2000) found that in the USA, a science degree programme majoring in physics does not provide adequate preparation for teaching in high schools. McDermott emphasized that the scope of topics and the laboratory courses offered by most physics departments rarely address the needs of student teachers. Likewise, using both quantitative and qualitative methods Mohd Zaki (2008) found that in Malaysia, about 113 pre-service teachers had a weak conceptual understanding of Newtonian concepts and had difficulty understanding kinematics graphs. Similar observations have been made by other researchers (Cochran-Smith, 2005; Darling-Hammond, Chung, & Frelow, 2002; Fensham, 2004; Korthagen, Loughran, & Russell, 2006). This has led to various attempts to reorganise teacher education programs. Korthagen et al. (2006), for example, after analysing effective features of teacher education programs in Australia, Canada and Netherlands, outlined how to guide the development of teacher education programs that are responsive to the expectations, needs and practices of student teachers. Also, Fensham (2004) argued that in developing appropriate pedagogies, the problematic nature of the content itself should not be ignored. This means that when educating physics teachers, we need approaches that are specific to the content domain of physics (Mohd Zaki, 2008).

The Shortfalls – Figuring Out What Works and What Doesn’t Work

McDermott and Shaffer (2000) argued that a well-prepared teacher of physics or physical science should have, in addition to a strong command of the subject matter, knowledge of the difficulties it presents to students. The authors, through a series of classroom observations and interviews with pre-service and in-service teachers, found that traditional courses in physics did not provide the kind of preparation that teachers needed to teach physics at secondary school level. They indicated that teachers tended to teach as they were taught – “if they were taught through lectures, they are likely to lecture, even if this type of instruction is inappropriate for their students” (p. 72). McDermott and Shaffer (2000) argued further that, although the content of the high school physics curriculum is closely matched to the introductory university course, the latter does not provide adequate preparation for teaching the same material in high schools. The authors emphasized that the breadth of topics covered and the laboratory courses offered by most physics departments, did not address the needs of students, in that most of the time the equipment used in universities was not available in high schools, and no provision was made for showing teachers how to plan laboratory experiences that utilize simple apparatus. In discussing the implications of the study, the authors noted that in ITE programmes there was often separation of instruction in science (which takes place in science courses) from instruction in methodology (which takes place in education courses) and that this decreased the value of both for the teachers. They emphasized that effective use of a particular instructional strategy was often content specific, hence if teaching methods were not studied in the context in which they were to be implemented, teachers may be unable to identify the elements that were critical. Thus they may not be able to adapt an instructional strategy that has been presented in general terms to specific subject matter or to new situations. In NZ, prospective secondary physics specialists undertake a science degree including physics, before their specialist one year teacher education programme. Therefore, they are learning content knowledge separated from knowledge about how to teach that content knowledge.

Among many other things, McDermott and Shaffer (2000) recommended that teachers should study each topic in a way that is consistent with how they are expected to teach that material, so they experience effective models for learning that particular content. In addition, they stressed, teachers also needed to be given the opportunity to confront and resolve their conceptual and reasoning difficulties, not only to improve their own learning but to become aware of the difficulties that their students might have.

Through a survey of about 3000 beginning teachers (from both teacher education programmes and alternative teacher preparation programmes), Darling-Hammond et al. (2002) examined the teachers' perceptions of their preparedness and their sense of teaching efficacy. The variables that were found to correlate with student's achievement were overall preparedness, sense of teaching efficacy and teacher effectiveness. Findings from these studies showed that teachers' overall preparedness to teach related significantly to their sense of self-efficacy about whether they are able to make a difference to student learning. The results indicated that teachers who felt better prepared were significantly more likely to believe they could reach all of their students, handle problems in the classroom, teach all students to high levels, and make a difference in the lives of their students. However, those who felt underprepared were significantly more likely to feel uncertain about how to teach some of their students and more likely to believe that students' peers and home environments influence learning more than teachers do (Darling-Hammond et al., 2002.). In discussing the findings, the authors noted that the teachers' feelings of preparedness were also significantly related to their confidence about their ability to achieve teaching goals. They concluded that measures must be put in place to improve teacher education programmes. They cited quality control standards by the National Council for Accreditation of Teacher Education (NCATE) as one of those measures that can be used to improve initial teacher education programmes.

The professional learning of student teachers has been attributed to three major sources of influence, namely pre-training education experiences, teacher education coursework, and fieldwork in the teacher education programme (Cheng, Cheng, & Tang, 2010; Kagan, 1992; Levin & He, 2008). These authors assert that the practicum experience and the variability of this experience influence teaching preparation. In NZ most secondary teachers complete a one-year graduate diploma in teaching, which includes supervised practicum experience in local high schools. Most of these teachers complete their first degree in their respective subject specialisms. The subject specific degree is deemed to provide most of the content knowledge required for at least one specialist-teaching area. Thus, usually the ITE physics course is primarily about acquiring pedagogical content knowledge (PCK). Findings from the Teaching and Learning International Survey (TALIS) 2013 results indicated that teachers whose initial education included content, pedagogy and practice elements specifically for the subjects they taught, reported feeling better prepared for their work than their colleagues without this kind of training (OECD, 2014). Though the NZ education system has been reported to be attending well to developing understandings of the teaching and learning processes, teacher educators continue to have divided opinions over the subject matter knowledge that should be included in teacher education qualifications (McGee, Cowie, & Cooper, 2010). The recent shift to Masters qualifications for ITE in NZ provides an opportunity to review what subject matter content knowledge is included.

Recent international studies about effective approaches to teaching and learning, such as findings from the OECD Innovative Learning Environments (ILE) Project (OECD, 2013) mean that adjustments to initial teacher education are required to accommodate the needs of current day learners and what we know makes a difference to learning. Recently, Conner and Sliwka (2014) indicated the implications of the ILE work (OECD, 2013) for initial teacher education internationally. The authors argued that initial teacher education programmes should include ways to help student teachers self-identify what they know and what they need to work on, that is, take a more student-centred or customised approach to ITE, if prospective teachers are to be effective in the learning environments in which they will be expected to teach. Thus, significant changes are imminent in the initial teacher education programmes in NZ. Further reviews are presented in the discussion session.

This paper acknowledges that in NZ teacher education providers have the freedom to design their own courses and programmes to meet the needs of their students, providing they can demonstrate that graduates meet the Registered Teacher Criteria (New Zealand Teachers Council, 2010). That is, there is no national teacher education curriculum as occurs in some countries. Therefore, different teacher education providers have prepared current teachers differently. It is not the intention of this paper to highlight such differences by institution, but rather to discern whether the preparation that current physics teachers have received was appropriate for what they perceived they needed. Given that prospective teachers enter initial teacher education programmes with different backgrounds, experience and knowledge, this means that beginning teachers will have varying degrees of need to prepare them to be effective teachers. Our study used mixed methods to answer the following questions:

1. What is the perception of physics teachers about their tertiary preparedness to teach high school physics?
2. Is there any significant difference between teachers from overseas and those educated in NZ in their perception of preparedness?
3. What is emphasised in the initial teacher education of high school physics teachers in NZ and why?

The Importance of Teaching Quality

There has been much written about the links between student achievement and teaching quality. Therefore, it seems important that ITE providers take note of this research. To improve the quality of teaching, Darling-Hammond and Baratz-Snowden (2005) outlined three general intersecting areas of knowledge that beginning teachers must acquire that have implications for what is included in initial teacher education programmes. Firstly, knowledge of learners and how they learn and develop within a social context; secondly, understanding the subject matter and curriculum goals (skill to be taught) in light of the social purposes of education; and thirdly, understanding the teaching in light of the content and learners to be taught, as informed by assessment and supported by a productive classroom environment (Darling-Hammond & Baratz-Snowden, 2005, p. 5). The authors argued that for beginning teachers to be effective in “managing the classroom, selecting appropriate tasks, guiding the learning process and maintaining children’s motivation to learn” (ibid, pp. 9-10), they needed to be equipped with subject matter content knowledge, knowledge of teaching and knowledge of learners and their development. This idea has also been applied to initial teacher education, i.e. that initial teacher education programmes should model this by assessing individual student teacher’s needs in terms of content and modelling processes (Conner & Sliwka, 2014).

The study reported here was guided by ideas from the understanding teaching and learning model (Darling-Hammond & Baratz-Snowden, 2005) which outlined the three general intersecting areas of knowledge. The general areas are summarised in Figure 1 below.

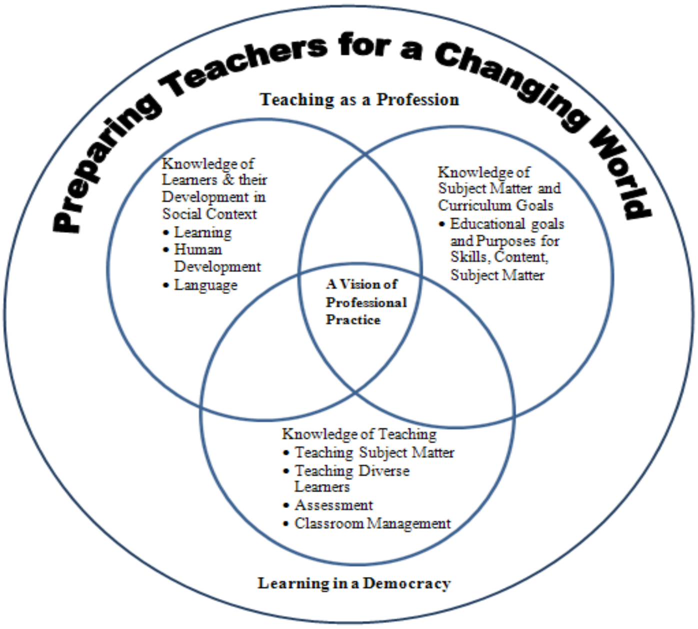

Figure 1. Framework for understanding teaching and learning (Darling-Hammond & Baratz-Snowden 2005, p. 6)

Design and Procedure

The study followed a mixed method design using both survey and case study techniques. Specifically, the convergent parallel design (Creswell & Clark, 2011) was employed for this study. The parallel quantitative/qualitative design included a national survey of 104 physics teachers throughout NZ, and interviews with three teacher educators from three different universities who were involved in physics teachers education programmes. An online survey (close and open-ended questionnaire) was developed and made available to high school physics teachers throughout NZ. The questionnaire was adapted from existing surveys (Darling-Hammond & Baratz-Snowden, 2005; Weiss et al., 2001) for evaluating secondary schools science and mathematics classrooms. The items selected were modified to suit the purpose and context of this study, with attention given to ensuring that items constructed were unambiguous, unbiased, unloaded and relevant (Fraenkel, Wallen, & Hyun, 2012; May, 2001; Sarantakos, 2005), and also appropriate for the culture and context of NZ.

The survey questionnaire was pre-tested with 23 physics teachers in Christchurch. The teachers were selected with the help of science advisors at UC Education Plus who provide professional development courses for local teachers. The teachers had approximately four weeks to complete the survey, which was activated on July 30 and ended on August 31, 2013. The survey was multidimensional in nature in that it consisted of three primary scales – knowledge of learners and their development; knowledge of subject matter; and knowledge of teaching. The reliability of each scale was determined to find out the internal consistency of the scales, that is, the extent to which the items that constitute the scale "hang together" (Pallant, 2007, p. 85), using the Cronbach alpha reliability coefficient. A coefficient alpha value of 0.737 was obtained for knowledge of learners and their development professional learning areas. Subject matter knowledge and knowledge of teaching had coefficient alpha values of 0.747 and 0.840 respectively. Reliability coefficients were measured by using a scale from 0.00 (very unreliable) to 1.00 (perfectly reliable) (Gray, 2009). Henderson, Fisher, and Fraser (1998) indicated that alpha coefficient values ranging from 0.62 to 0.77, exceeding the threshold of 0.60, are acceptable reliabilities for research purposes. The scales generated for the surveys in this study were therefore considered reliable.

A link to the main survey was posted on the New Zealand Institute of Physics (NZIP) 2013 conference website and websites for two professional teacher organisations – the New Zealand Association of Science Educators (NZASE) and the Canterbury Science Teachers Association (CSTA). Teachers completed the survey over a three month period and typically took 20 minutes to respond to 25 questions, with a five-point or four-point scale with extreme alternatives of 'strongly agree-strongly disagree'; 'very important-not important' and 'very well prepared-not sure'. A total of 138 physics teachers started the survey and the completion rate was 75.4%. Incomplete responses were excluded from the analysis.

Purposeful sampling was also employed to select three teacher educators of physics who participated in the study. The reason for selecting these physics teacher educators was mainly due to their interest in the study and their willingness to participate. Two forms of interviews, face-to-face and using Skype, were conducted with the respondents involved in physics teacher education programmes. The Skype interviews were organised for the physics teacher educators who were outside Christchurch. The Skype platform was used because it was cost beneficial and because interviews were conducted more quickly (Gray, 2009; Sarantakos, 2005). All the interviews were conducted at dates and times convenient to the respondents.

Data Analysis

The data generated from the survey were analysed using frequency tables and inferential statistics including t-test and MANOVA. Audio recordings from the interviews were transcribed. Nvivo 10 for Windows (QSR International Pty Ltd. Version 10, 2012) was used to organize the materials by coding them into nodes which provided easy retrieval of the themes that emerged. The production of accurate and verbatim transcripts was integral to establishing the credibility and trustworthiness of the data. The themes were cross-checked between the authors and some items were shifted on reconsideration of alignment with the themes. The comments collated under each node in NVIVO were analysed and sample quotations were selected for inclusion in this paper.

Findings

Teacher Characteristics and Course Background

The majority of the physics teachers who participated in the survey were males (67.3%). Approximately 60% of all respondents were above 40 years of age and 57% had been teaching physics for more than 10 years. About 26% of the teachers had earned a qualification beyond the Bachelor's degree. The majority (73.1%) had obtained a Bachelor's degree in science and had also completed a one-year Graduate Diploma in Teaching in a Faculty of Education at a university and/or had participated in a conjoint degree and diploma programme (e.g. Bachelor of Teaching and Graduate Diploma Teaching). The teachers who participated in the survey completed ITE between 1965 and 2012. The majority (72.1%) received their ITE in NZ with the balance being educated as teachers overseas. All respondents were teaching in a school. The characteristics of the teachers who participated by completing the survey are presented in Table 1.

Characteristic		**Freq.**	**%**
Gender	Male	70	67.3
	Female	34	32.7
Age (in years)	21-30	11	10.6
	31-40	32	30.8
	41-50	31	29.8
	51+	30	28.8
Teaching experience	< 1 year	3	2.9
	1-2 years	9	8.7
	3-5 years	17	16.3
	6-10 years	16	15.4
	11-15 years	20	19.2
	16+	39	37.5
Educational attainment	PhD	5	4.8
	Masters	22	21.2
	1st Degree	76	73.1
	Others	1	1.0
Type of school	Co-educational	77	74.0
	Girls only	19	18.3
	Boys only	8	7.7
Completing year of ITE	1965-1987	27	26.0
	1988-2000	27	26.0
	2001-2007	24	23.1
	2008+	26	25.0

Table 1: Characteristics of Physics Teachers Who Completed the Survey (N = 104)

Physics was a first-choice teaching subject for about three quarters of the teachers. The remainder had changed to teaching physics in the course of their teaching career and their reasons for doing were mainly lack of subject specialist and job availability. The physics teachers whose first-choice teaching subject was not physics, provided information about their content background in physics in relation to recommended college/university physics content courses. Electronics was an area where the majority (69.0%) had not undertaken any formal study. Over half of the respondents had also not pursued formal study related to atomic and nuclear physics (51.7%) and modern physics (51.7%).

Teachers' Perceptions of their Preparedness

The teachers indicated the extent to which their ITE prepared them for teaching various physics topics currently taught in NZ high schools. Their responses were coded and ranked using a scale of 1 (not sure) to 4 (very well prepared). The mean scores, as can be seen in Table 2, show that the physics teachers felt more qualified and/or prepared to teach Mechanics (3.06), Electricity and Magnetism (3.02), and Waves (3.00) but considered themselves weak in Atomic and Nuclear physics (2.88), Investigations (2.81), Modern Physics (2.69), Applications (2.54), and Electronics (2.40). For all the content areas, only a few teachers indicated that they were unsure whether their initial teacher preparation programme made them suitably qualified to teach those areas.

Content areas	**Frequency (and percentage) of responses**				**Mean**	**SD**
	Very well prepared	**Adequately Prepared**	**Not well prepared**	**Not sure**		
Mechanics	29 (27.9)	55 (52.9	17 (16.3)	3 (2.9)	3.06	0.75
Waves	28 (26.9)	51 (49.0)	22 (21.2)	3 (2.9)	3.00	0.78
Electricity and Magnetism	30 (28.8)	49 (47.1)	22 (21.2)	3 (2.9)	3.02	0.79
Electronics	9 (8.7)	31 (29.8	57 (54.8)	7 (6.7)	2.40	0.74
Atomic & Nuclear physics	24 (23.1)	47 (45.2)	30 (28.8)	3 (2.9)	2.88	0.79
Modern physics	19 (18.3)	37 (35.6)	45 (43.3)	3 (2.9)	2.69	0.80
Investigations	19 (18.3)	48 (46.2)	35 (33.7)	2 (1.9)	2.81	0.75
Applications	13 (12.5)	35 (33.7)	51 (49.0)	5 (4.8)	2.54	0.77

Table 2:Teachers' Perceptions of their Level of Preparedness to Teach Various Physics Content Areas

Differences in Teachers' Perceived Preparedness

An inferential statistical analysis was conducted to find out if any significant difference existed between teachers who received their ITE in NZ and those who trained overseas on their views about their levels of preparedness to teach physics topics. As shown in Figure 2, a box plot of the pattern of scores for the two groups of the teachers showed a difference in the mean scores between the groups. This recorded difference was further investigated with an independent-samples t-test (Table 3).

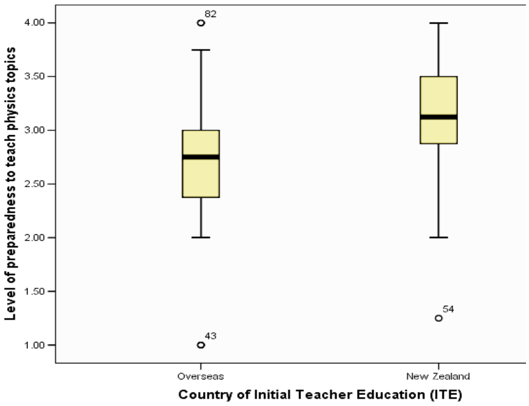

Figure 2: Boxplot showing the distribution pattern of preparedness to teach physics topics

An independent-samples t-test (Table 3) showed a statistically significant difference, t (102) = 2.05, p = 0.04, between teachers educated in NZ and overseas. That is, on average, teachers educated in NZ felt they were more prepared to teach the various physics topics (M = 3.00, SD = 0.60) than those teachers trained overseas (M = 2.72, SD = 0.65). In NZ the assessment system for physics values recall of content knowledge and we propose that teachers trained in NZ are perhaps more familiar with the assessment standards than those trained overseas. This might have accounted for the difference observed in their perceived training. Effect size statistics (r), also called eta squared, showed that the magnitude of the difference observed was small (r = 0.20). That is, only 4% of the variance in teacher preparedness to teach various physics topics was explained by the country they received their ITE. The threshold values for interpreting effect size are given as follows: r = 0.10 for small effect; r = 0.30 medium or moderate effect; and r = 0.50 large effect (Cobern, 1998; Field, 2009; Pallant, 2007).

Variable	**Group**	**N**	**Mean (M)**	**Std. Dev. (SD)**	**t**	**p-value**
Teachers preparedness to teach various physics topics	Teachers trained in NZ	75	3.00	0.60	2.05	0.04*
	Teachers trained Overseas	29	2.72	0.65		

*Significant, $p < 0.05$

Table 3:Independent Samples T-Test on Differences about Teachers Preparedness to Teach Various Physics Topics

As presented in Table 4, the majority of the teachers were of the view that their ITE experience equipped them with knowledge of learners and their development. More than 90% (SA+A) of the teachers indicated that their ITE provided background knowledge on how learners develop and learn. About 75% also believed that they were equipped with the skills of observation, monitoring and diagnosing learners to gain accurate feedback on their learning and development. Far fewer responded that their ITE provided neither information on skills of observation and monitoring and assessing to gain feedback on learners and their development. On the other hand, about 64% indicated that their ITE did not equip them with adequate subject matter knowledge. Almost 50% said their training did not enable them to understand, interpret and use both the state and school curricula. There was a negative response on the use of ICT in the teaching of physics. This may be a reflection on when they undertook their ITE.

The teachers responded to a number of points on how their ITE prepared them on other interdependent classroom variables. In particular, knowledge of learners and their development, knowledge of subject matter and curriculum goals, and knowledge of teaching which constitute the framework of the UTL model (Darling-Hammond & Baratz-Snowden, 2005). Table 5 shows the teachers' ratings on their preparedness on these constructs (knowledge of learners and their development, knowledge of subject matter, and knowledge of teaching).

On knowledge of teaching, the mean scores, as seen in Table 4, show that the teachers were not definite about being equipped with the appropriate knowledge of teaching from their ITE. However, most of the teachers held the view that they were equipped with knowledge about teaching diverse students (3.66). More than a quarter (29.8%) thought that their training did not focus on the use of inquiry and problem-based approaches, though more than half (58.0%) believed that their initial training focused on the use of inquiry and problem-based approaches. Also, a good number of the teachers (about 38%) disagreed that their initial training provided information on assessing students' learning. Surprisingly, 22% were also not sure of this claim. About 40% indicated that they had knowledge on students' assessment and learning.

My initial teacher education …	Percentage responses					Response Mean	SD
	SA	A	NS	D	SD		
Knowledge of learner dev. & learning							
Provided background on how children develop and learn	23.1	67.3	4.8	3.8	1.0	4.08	0.72
Equipped me with skills to observe, monitor, and assess students to gain accurate feedback about their learning and development	14.4	60.6	13.5	7.7	3.8	3.74	0.94
Provided background about how children acquire and use language	7.7	41.3	17.3	26.0	7.7	3.13	1.13
Knowledge of subject matter							
Provided knowledge of curriculum goals	20.2	65.4	3.8	9.6	1.0	3.94	0.85
Equipped me with adequate subject matter knowledge	11.5	15.4	9.1	46.7	17.3	2.74	0.89
Enabled me to understand, interpret and implement the national and school curricula	17.0	30.8	11.7	28.7	20.9	2.63	0.93
Incorporated the use of ICT into teaching and learning of physics	9.6	36.5	8.7	28.8	16.3	2.54	1.31
Knowledge of teaching							
Enabled me to teach diverse student population	14.4	55.8	12.5	16.3	1.0	3.66	0.95
Provided background about how to observe an individual student with different tasks and other students to diagnose his/her need	8.7	31.7	22.1	33.7	3.8	3.08	1.08
Focused on the use of inquiry and problem-based learning approaches	5.8	51.9	12.5	26.9	2.9	3.31	1.03

SA=Strongly agree A=Agree NS=Not sure D=Disagree SD=Strongly disagree

Table 4: Teachers' Perception of their Preparedness on the UTL framework (N = 104)

One-way analysis between groups’ multivariate analysis of variance (MANOVA) indicated differences among the ITE groups in relation to the year (clustered) they completed their ITE on the three constructs (framework) of UTL - knowledge of learners and their development; knowledge of subject matter; and knowledge of teaching (Darling-Hammond & Baratz-Snowden, 2005). Preliminary assumptions testing was performed to check for univariate and multivariate normality, linearity, equality of variance, homogeneity of covariance matrices, and multicollinearity (Field, 2009; Pallant, 2007; Tabachnick & Fidell, 2007) with no violations noted. The main results of the MANOVA are shown Table 5.

Grouping variable	Effect statistics	Value	F	df	Error df	p-value	Partial eta squared
Completing year of ITE	Pillai’s Trace	0.206	2.459	9.00	300.00	0.010	0.069
	Wilk’s Lambda	0.802	2.517	9.00	238.66	0.009*	0.071
	Hotelling’s Trace	0.237	2.545	9.00	290.00	0.008	0.073
	Roy’s Largest Root	0.183	6.088	3.00	100.00	0.001	0.154

*Significant, $p < 0.05$

Table 5: Multivariate Tests of Significance for Combined UTL

As seen in Table 5, there are several test statistics to choose from; however, Tabachnick and Fidell (2007) recommend Wilk's Lambda for general use if assumptions are not violated. Using Wilk's Lambda statistics, there was a statistically significant difference among the year groups on the combined three constructs of UTL: F (9, 238.7) = 2.52, p = 0.01; partial eta squared = 0.071. When the results of the test (dependent variables) were considered separately, tests of between-subject effects, as shown in Table 6, revealed that the only difference to reach a statistical significance was knowledge of subject matter with a p-value of 0.001 and an eta squared value of 0.149.

Grouping variable	**Dependent variables**	**Type III sum of squares**	**F**	**df**	**Mean squares**	**p-value**	**Partial eta squared**
Completing year of ITE	Knowledge of learners dev. and learning	3.781	2.527	3	1.260	0.062	0.070
	Knowledge of subject matter	7.814	5.814	3	2.605	0.001*	0.149
	Knowledge of teaching	3.245	2.028	3	1.082	0.115	0.057

*Significant, $p < 0.05$

Table 6: Tests of Between-Subject Effects for UTL Sub-scales

A post hoc test, using the Bonferroni correction and Games-Howell (Field, 2009) procedure, revealed that a difference in subject matter knowledge existed between teachers who completed ITE in the year 1965-1987 and those who completed in 2001-2007 (p-value = 0.05) and 2008 or later (p-value = 0.001). There was no significant difference between those who completed in 1965-1987 and 1988-2000. An examination of the estimated marginal mean scores (Table 7) indicated that teachers who completed in 2001-2007 (M = 3.69, SD = 0.54) and 2008+ (M = 3.94, SD = 0.61) reported a higher level of knowledge of subject matter than their counterparts who completed in 1965-1987 (M = 3.19, SD = 0.81).

	Year group	**Mean**	**Std. dev.**
Knowledge of subject matter	1965-1987	3.185	0.808
	1988-2000	3.630	0.675
	2001-2007	3.694	0.538
	2008+	3.936	0.611

Table 7: Estimated Marginal Mean Scores for the ITE Completion Year Groups

Structure and Components of ITE Physics Programme

This section is focused on the main findings relating to the course content, course structure and programme requirements of ITE programmes for aspiring physics teachers in NZ. The section reports on the main similarities and differences of the ITE programmes offered to prospective physics teachers at three universities in NZ. For the purpose of anonymity, the three institutions were given pseudonyms as University A, University B and University C respectively.

The ITE physics programme offered by the three universities is a one-year full-time programme which runs from February to November. The course structure and programme requirements for physics ITE programmes are generic across the three institutions. The course was one semester in length with two-seven week periods of teaching practice (practicum). The course structures in all universities had been set up to meet the requirements of the NZ Teachers Council for initial teacher preparation for secondary teachers. The programme requirements to teach physics, and therefore entry into the course, were third year BSc physics papers and other science papers that would support teaching junior science at high schools. During the interview, the teacher educators explained that, with regards to programme entry requirements for engineering students and foreign students, they looked at the applicant academic transcripts to decide whether the applicant had a sufficiently strong physics background to pursue the physics course. The teacher educator at University A stated that he did not admit people with only Stage Three Electronics papers but looked for papers with a stronger core component of physics, such as Stage Three Mechanics or Civil Engineering as preparation for entry into secondary teaching.

The components and nature of the programmes, varied considerably across the three universities. Analysis of the interviews revealed that the teacher educators, who were also the coordinators for the physics teachers' ITE programme solely determined the component content to be included in the physics teacher education qualification. There was no national teacher education curriculum to follow in terms of subject matter content knowledge or pedagogical content knowledge (PCK) to be included in the qualification. Each teacher educator had designed his/her own course work for the programme which they reviewed as and when necessary. The physics educator at University A, for example, commented that he was reviewing the course to include a session that would take into account the interest and special needs of ethnic groups with special interest in Māori students. He explained below:

> *Each year I review the course, and at the moment I'm wanting to include a bit more relation or thinking about students from various ethnic groupings such as Māori, so that when students complete assignments they take into account the interests and special needs of, in this case Māori students, being our Tangata Whenua of New Zealand. (Physics Educator, University A)*

The teacher educators at University B and University C indicated that they regularly contacted local physics teachers in schools to keep themselves abreast of issues relevant to their courses and made changes when required.

It is not the intention of this study to highlight what each teacher educator was doing but rather to discern whether the preparation that pre-service physics teachers received was sufficient and appropriate for today's classrooms. The pre-service physics teacher educators were clear that their ITE physics courses were primarily about PCK, and that the non-education or first degree that students undertook, was assumed to provide most of the subject knowledge required. The physics educators stated that some of the students who enrolled in the physics courses were weak in some areas of physics content knowledge, but there was little time available to address this because the courses were not intended to teach the students physics content but rather to equip them with pedagogical knowledge to teach physics. The physics educator at University B mentioned that he occasionally spent some time developing content knowledge. He 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. (Physics Educator, University B)*

The physics educator at University C stated:

> *We spend time looking at the curriculum statements and NZQA requirements for the NCEA levels, particularly Levels 2 and 3, so they become very familiar with the material that's supposed to be taught. 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. (Physics Educator, University C)*

The physics educators emphasized that students came into the physics courses (and other science courses) with fairly specialist degrees which are supposed to provide the content knowledge required and there may be big gaps in content knowledge across science areas more generally. But what they seemed to be doing was mainly focussing on the content that was assessed through the National Certificate of Educational Achievement (NCEA) standards and different pedagogical approaches to teaching this content. Responsibility for learning content was mainly given to the aspiring student teachers to remedy any gaps in their subject matter content knowledge.

Discussion

Prospective teachers enter initial teacher education programmes with different backgrounds, experience and knowledge. This means that beginning teachers will have varying degrees of need to prepare them to be effective for their professional career. The physics teachers in this study indicated the extent to which their ITE prepared them to become effective teachers, i.e. how to reflect on approaches to teaching the various physics topics currently taught in NZ high schools. The findings suggest that most NZ physics teachers in this survey specialised in physics and therefore completed traditional undergraduate physics courses through a Bachelor of Science prior to entering a teaching programme. Also, more than a quarter of the physics teachers had a subject major other than physics in their initial science degree and therefore undertook initial teacher education in a different subject area. Their change in subject once they had been teaching for some time, was either due to a shortage of physics specialists or because an opportunity arose to teach physics.

The tertiary-level educational background of teachers provided useful information about their preparation for their chosen career. Also of importance were teachers' perceptions of their preparation, i.e. how well teachers felt they were prepared to teach the various content areas. The findings show that the majority of the teachers specialised in physics within their science degree and this gave an indication that the teachers were likely to understand most physics concepts. Table 2 provided more detailed information on physics teachers' perceptions of their preparedness to teach each of the content areas in the curriculum. Though the majority of the teachers completed the traditional undergraduate physics courses, the physics teachers considered themselves not well-prepared in some content areas, including electronics, modern physics and nuclear and atomic physics. Similarly, tests of between-subject effects, presented in Table 6, showed that the only construct of the UTL model to reach statistical significance was that for subject matter knowledge. The content areas investigated in the survey were largely based on *The New Zealand Curriculum* (*NZC*) (Ministry of Education, 2007). However, some of the teachers completed ITE some years ago, when concepts which are now core parts of the curriculum may not have been emphasised in either their undergraduate physics degrees nor covered in teacher education programmes. This may explain the respondents' weaknesses in other content areas, as presented in Table 2.

On the other constructs of the UTL, especially knowledge of teaching, a large proportion of the teachers indicated that their ITE did not incorporate the use of technology into physics teaching and more than a quarter of the teachers thought that their pre-service education did not focus on the use of inquiry and problem-based approaches nor information on assessing students' learning progress. These aspects of physics teaching were, in the past, not considered as important as they are now and this may explain these findings. The estimated marginal mean score of 3.94 recorded by the 2008+ (Table 7) completing year group revealed that current ITE programmes in NZ have provided better development in this respect.

The physics teacher educators who participated in the study thoroughly discussed the course structure, content components and what was emphasised in their physics education courses. The components and nature of the physics education courses varied across the universities in NZ, but all focussed primarily on the development of pedagogical content knowledge and the practical aspects of teaching physics. They did not emphasize subject matter content knowledge. The entry qualification to the physics education courses is a physics degree or successful completion of one or more third year physics courses. At least part of a traditional undergraduate physics course within a science degree has to be completed to meet this requirement. The traditional physics course in NZ at undergraduate level comprises a blend of theory (e.g. mechanics, waves, optics, heat, electricity and electromagnetism, nuclear physics) and laboratory work, similar to what is reported internationally (Korthagen et al., 2006; McDermott, 2001; McDermott & Shaffer, 2000; Weiss et al., 2001). The content knowledge physics teachers gained arose mainly from their participation and learning in this undergraduate programme.

The traditional approach to teacher education (generally, not just for physics) has been criticised for its limited relationship to student teachers' needs (see for example Cochran-Smith, 2005; Darling-Hammond et al., 2002; Korthagen et al., 2006; McDermott, 2001; McDermott & Shaffer, 2000). After analysing the effective features of teacher education programs in Australia, Canada and Netherlands, Korthagen et al. (2006), for example, outlined how to guide the development of teacher education programs to be responsive to the expectations, needs and practices of pre-service teachers. The authors recommended seven principles called "principles of practice" (p. 1039) to those teacher educators willing to accept the challenge of reconstructing teacher education from within.

Also, Etkina (2010) and Hodapp, Hehn, and Hein (2009) have outlined the features of a successfully implemented new model of teacher preparation and recruitment. At the University of North Carolina, Chapel Hill, the model (programme) requires a student to complete a science major within a teaching qualification in four years (Hodapp et al., 2009). At Rutgers University, Etkina (2010) reports that the model centres on three aspects of teacher preparation – content knowledge of physics, knowledge of pedagogy and knowledge of how to teach physics (pedagogical content knowledge). Among other things, students in these programmes learn physics through the pedagogy that pre-service teachers need to use when they become teachers. They learn how the processes of scientific inquiry work and how to use this inquiry in a high school classroom for specific physics topics. They also learn what students bring into a physics classroom and how to identify their strengths and weaknesses, as well as engage in scaffolded teaching before starting independent teaching or forming a learning community (Etkina, 2010, pp. 21-22). Findings from the Teaching and Learning International Survey (TALIS) 2013 results indicated that teachers whose initial education included content, pedagogy and practice elements specifically for the subjects they teach, reported feeling better prepared for their work than their colleagues without this kind of training (OECD, 2014). The philosophy and coursework for this model can be adapted by stakeholders who are committed to physics teacher preparation.

The finding that NZ physics teacher educators in their respective colleges decide what content to include in their physics education courses aligns with the assertion by McGee, et al., (2010) that teacher educators in NZ generally continue to have divided opinions over how much subject matter knowledge should be included in teacher education qualifications. That is, there is no national teacher education curriculum, which means that different teacher education providers can prepare teachers differently. It is likely that content knowledge is somewhat assumed, since secondary teaching in NZ for science teachers is mostly a postgraduate qualification. The time or teaching the physics components within these one year add-on qualifications (Graduate Diplomas and Masters) may not have sufficient time to cover all the content that is needed for the final three years of schooling. There is, however, oversight of the ITE process by the New Zealand Teachers Council and there are generic Graduating Teacher Standards (New Zealand Teachers Council, 2010) that need to be met by new teachers graduating from teacher education programmes.

Conclusion and Implications

Findings from the study provide insight about physics teachers' preparation and indicate that the physics education programmes for would-be physics teachers generally do not cover all of the content knowledge for the final three years of schooling. That is, the physics teacher education programmes are primarily about PCK rather than content *per se*. It was evident from this study that the physics teachers considered themselves not adequately qualified or prepared to teach some of the content areas in the curriculum. In part, this may have been due to the science degrees which provided the teachers with most of their physics content knowledge. The findings suggested that the content knowledge gained from the science degree was inadequate and did not address the needs of the teachers. As discussed in the previous session, ITE programmes need to be aware of this and respond appropriately (OECD, 2014). Among other things, Etkina (2010, pp. 21-22) recommends that physics teacher preparation should enable pre-service teachers to learn physics through the pedagogy that pre-service teachers use when they become teachers, to learn how the processes of scientific inquiry works and how to use this inquiry in a high school classroom for specific physics topics, and to find out about their students' strengths and weaknesses both for content and processes of learning.

This study has reported on high school physics teachers' perceptions of the adequacy of their preparation to teach their subject. More than a quarter of the respondents were physics teachers who had changed subjects due to a shortage of physics specialists or because an opportunity arose to teach physics. Teachers who completed their initial teacher education between 1965 and 1987 reported a lower level of knowledge of content and curriculum goals than teachers who had graduated more recently. In addition, the teachers in the survey reported feeling not well-prepared to teach content areas such as electronics, modern physics and nuclear physics. Teachers prepared outside of NZ, were less prepared than those that undertook their initial teacher education programme in NZ. The overall implication is that teachers needed more content preparation or help to find ways to develop their content competencies for themselves. As indicated by the respondents, continuing professional development and learning must also be more responsive to the needs of teachers from other science disciplines because they may choose or be required to teach physics due to the shortage of physics teachers worldwide.

Findings from this study also suggested that in the past, the use of ICT and inquiry were not necessarily emphasised in teacher education programmes as much as they are now. This implies that teachers may need on-going professional learning opportunities to develop these skills. The challenge for teacher educators is to ensure that today's teacher preparation programmes are responsive to the needs of physics graduates who aspire to be effective teachers. As Conner and Sliwka (2014) have suggested, as ITE programmes are revised and renewed, they need to build in processes for student teachers to self-identify what content areas they need to work on through diagnostic testing, and to accommodate the different needs that students have due to their diverse backgrounds and different levels of content and pedagogical knowledge. This would go some way to addressing the diverse backgrounds amongst candidates entering ITE institutions. Given that ITE programmes in NZ are currently exploring shifting to Masters level, it is timely to reconsider what subject matter content knowledge and pedagogical knowledge is included in physics teacher preparation.

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