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Physics for Teaching High School Physics: Views of Prospective Physics Teachers and Teacher Educators about Undergraduate Physics Study

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Saiqa Azam[1]

Abstract

This paper explores the views of pre-service physics teachers and science teacher educators about the initial teacher education (ITE) programs in two Melbourne universities, focusing on their preparation for teaching high school physics. Using a qualitative interview approach, five pre-service physics teachers and three physics teacher educators were interviewed to generate data to develop an understanding of the role of undergraduate physics study in teaching high school physics, and to determine if science teacher educators' views match with those of future high school physics teachers. Both groups of participants identified a number of issues which impact prospective physics teachers' ability to teach high school physics, and offered suggestions to improve the undergraduate physics study. The findings provided insights into the varied needs of future physics teachers with diverse backgrounds, the inadequacy of their undergraduate physics study, the capacity of some other science courses, and suggestions to improve the preparation of high school physics teachers.

Key Words: Initial teacher education, preparation of physics teachers, pre-service science teachers, science teacher education, subject matter knowledge, undergraduate physics studies

Introduction

The knowledge of subject matter that teachers need to teach has always been considered important preparation for teachers. Scholars in science education have emphasized that effective science teaching requires a thorough understanding of the science content (Abell, 2007; Carlsen, 1991; Lederman, Gess-Newsome, & Latz, 1994; McDermott, 1984; Putnam & Borko, 1997). Peters (1977) suggested, "If anything is to be regarded as specific preparation for teaching, priority must be given to a thorough grounding in something to teach (as cited in Ball & McDiarmid, 1989, p. 151). Ball and McDiarmid (1989) maintained that a "thorough grounding in something to teach" is what should be the focus of preparation for teaching (p. 151). It follows that physics teachers must possess a deeper understanding of the conceptions they need to teach to high school students.

Subject matter knowledge is decisive in physics teachers' curricular and pedagogical choices (Grossman, Wilson, & Shulman, 1989). Understanding what type of sub

[1] Saiqa Azam E-mail:sazam@mu.ca
Faculty of Education, Memorial University of Newfoundland, St. John's NL, A1B 3X8, Canada
ORCID ID: https://orcid.org/0000-0002-8056-0491

ject matter knowledge preparation matters for designing and developing pre-service and in-service teacher education programs is critical (Ball, Thames, & Phelps, 2008; Grossman, 1990, Kennedy, 1998; Shulman, 1987). Thus, what teachers need to know about the subject matter they are supposed to teach is an important issue in teacher preparation, certification, and professional development (Shulman, 1986, 1987). Further, subject matter is a condition for developing the pedagogical content knowledge (PCK) of science teachers, which is the professional knowledge that teachers need to teach a specific content to make it understandable to students (Shulman, 1987) and have a positive impact on student learning (Park, Jang, Chen, & Jung, 2011; Roth et al., 2011). There is consensus on the importance of SMK and PCK as indicators of the quality of science teaching; however, "much less is known about the development of each component as well as the interplay of important aspects of physics teacher preparation in learning physics to teach (Sorge, Kröger, Petersen, & Neumann, 2017, p. 2). This research has focused on one of these important preparations for physics teaching —subject matter knowledge.

Teachers' subject matter preparation begins in their schools and continues throughout their university undergraduate level and teacher education till they begin teaching that subject matter in schools (Feiman-Nemser, 1983). Most subject matter preparation for pre-service physics teachers takes place in science faculties or physics departments, and mainly consists of mastery of factual information; evidence is in the type of assessment used (Anderson & Mitchener, 1994). At the undergraduate level, prospective physics teachers usually take the same standard courses designed for all undergraduate physics students (Anderson & Mitchener, 1994; McDermott, Shaffer, & Constantinou, 2000). There is an enormous criticism of the science course requirements for prospective teachers (see Anderson & Mitchener, 1994), specifically for physics courses (see Yager & Penick, 1990; McDermott et al., 2000). Historically, subject matter preparation is associated with the completion of an undergraduate degree with accumulated course credits within an appropriate discipline. Little is known about what prospective science (physics) teachers learn in science (physics) departments after spending much academic time there (Anderson & Mitchener, 1994). Lillian McDermott studied the type of physics subject matter preparation needed by prospective physics teachers; she observed that university physics courses do not provide the type of preparation that teachers should have (McDermott, 1990). She criticized the lecture format, problem-solving, and type of laboratory work in university physics departments where prospective physics teachers are usually prepared for their subject matter preparation. She claimed that physics courses do not provide the kind of preparation required to serve teaching physics for inquiry (McDermott, Shaffer, & Constantinou, 2000).

For better preparation of physics teachers, McDermott et al. (2000) recommended separate physics courses offered in physics departments for prospective physics teachers. These types of separate courses have gained popularity in many universities in the

USA, for example, such courses have been designed and offered by physics education groups in the USA at the University of Washington (McDermott et al., 2000) and University of Maryland. However, this is not yet the common practice, and moreover, there is no evidence on what kind of impact such separate physics courses have on physics teaching and physics teachers. Therefore, the subject matter preparation of pre-service teachers, where and how it takes place, and its contribution to the attainment of subject matter knowledge for teaching physics has become imperative and needs to be addressed as a central issue in physics teacher preparation. However, physics educators (university physics professors), science teacher educators (university professors from education faculties) and high school physics teachers have disparities in their views about the effectiveness of the physics study of physics graduates and future physics teachers.

Often, university physics professors are not satisfied with high school physics courses for undergraduate physics study, and science teacher educators are dissatisfied with undergraduate physics courses for preparing pre-service science teachers. University physics professors often criticize high school physics courses for not preparing students well for undergraduate physics study (Gibson & Gibson, 1993; Halloun & Hestenes, 1985; Razali & Yager, 1994; Sadler & Tai, 2000; Shumba & Glass, 1994). Contrary to this, many "science teachers view their high school physics courses as valuable preparation for introductory college physics" (Sadler & Tai, 2000, p. 112).

Past reforms to better prepare physics teachers started with science teacher education and ignored the fact that science (physics) teacher preparation is multifaceted; many aspects, explicit and implicit are intertwined, which may pose problems for the better preparation of teachers. Most importantly, pre-service physics teachers' voices are absent from this debate. Therefore, the present study is intended to explore the views and ideas of prospective physics teachers and physics teacher educators about physics studied at the undergraduate level; how this study has prepared them to teach high school physics. The following questions guided the research:

1. What are the perceptions of prospective physics teachers about their undergraduate physics study for preparing them teaching high school physics?
2. What are the perceptions of physics teacher educators about their undergraduate physics study in preparing them to teach high school physics?
3. Do physics teacher educators' views match with the views of pre-service physics teachers about better preparation of prospective physics teachers?

Theoretical Perspectives

This research borrowed theoretical perspectives from constructivism and pedagogical content knowledge to highlight the nature and importance of content knowledge for effective physics teaching (Hausfather, 2002; Richardson, 1997). Hausfather (2002) identified two dilemmas faced by many teacher education programs: (a) a philosophical dilemma of understanding content and process of teaching, specifically how they intertwine in teaching; and (b) a practical dilemma of developing collaboration between education and science faculties, specifically how they help in interweaving content and process in teacher education. Considering constructivism as a useful idea for teacher education, Hausfather (2001) called it "the reigning paradigm in teacher education" (Hausfather, 2001, p. 15); however, very few have a good appreciation and comprehension of the idea (Baines & Stanley, 2000; Hausfather, 2002; Richardson, 1997). Constructivism has been considered as a psychological and philosophical paradigm shifting the fundamental conceptualization of teaching, particularly focusing on the role of content knowledge in teaching. Tobin and Tippins (1993) noted that during teaching, the content and the process of acquiring that content are intertwined, referring to content knowledge as a prerequisite for teaching. Further, clarifying the role of content in constructivist learning and teaching, Hausfather (2002) explained that "the dichotomy between content and process disappears as we take a constructivist approach to knowledge and teaching" (p. 63). From this perspective, effective physics teaching "involves the process of leading learners to understand and use content" (p. 63), which is a goal of constructivist teaching (Hausfather, 2002).

Shulman (1986) introduced a new concept of professional knowledge for teaching, which included "the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations—in a word, the ways of representing and formulating the subject that make it comprehensible to others" (p. 9), and called it pedagogical content knowledge (PCK). Shulman (1987) conceptualized teaching as the integration of content and pedagogy—providing an understanding of the intertwined nature of content and process of teaching. Constructive teaching underpins the idea that content and teaching co-exist in context of effective physics teaching, and that pedagogical content knowledge for teaching physics may provide a means to comprehend their entwined nature.

Both the perspectives described above demand that future teachers should have a conceptual understanding of the content for teaching physics to teach it effectively to high school students. This has serious implications for physics teacher education, especially when content knowledge preparation in science faculties is detached from the preparation for teaching physics in education faculties regarding possible connections between the content and process of teaching physics.

Methodology

The research was conducted in two Australian metropolitan universities. Five prospective physics teachers who were close to finishing their postgraduate teacher education program in secondary science teaching and three physics teacher educators from the same two metropolitan universities in Australia participated in the study. The participants were selected according to their convenient accessibility and willingness to share their experiences. Table 1 presents the educational and teaching backgrounds of the five pre-service physics teachers, and Table 2 presents the educational, teaching, and teacher education backgrounds of the physics teacher educator participants.

Table 1.
Pre-service physics teacher participants

Name	Nature of Undergraduate Degree	Additional Science/Physics Study	Work and Teaching Experience
Margaret	B.Sc. Honors Majors in Physics	Honors in Astrophysics	Tutoring Math (First Year Students at University) - I.5 year
Elvis	B.Sc., Physics as minor	Degree in Computer Sc.	Software Analyst - 4 Years Tutoring IT (First Year Students at University)
Eraline	Degree in Mechanical Engineering	No	Mechanical Engineer - 1 Year Tutoring VCE Students
Ashok	B.Sc. (India)	Masters in Applied Science & Mechanical Eng. PhD in Mechanical Eng. (India) Masters in Computer Sc. (Australia)	Teaching IT at University Level Tutoring VCE Students
Suvik	B.Sc. Honors Majors in Physics (Sri Lanka)	Master in Physics (Australia.)	Teaching Physics at Tertiary Level- 10 Years outside Australia Lab Demonstrator- 4 Years Teaching Physics at University Level - 4 Years

Table 2.
Physics teacher educator participants

Name	Nature of Undergraduate Degree	Additional Science/Physics Study	School Physics Teaching Experiences	Physics Teacher Education Experience
John	B.Sc. Mathematics (Majors) Physics (Minor)	Geophysics Biology Chemistry	High School Teaching - 12 Years	30 Years - science Education including physics teacher education
Rose	B.Sc. Applied Mathematics Physics	Chemistry Biology	High School Teaching - 10 Years	6 Years – Science education including physics teacher education
Tim	B.Sc. Mathematics (Majors) Physics (Majors)	Geology Tissue Culture ICT Environmental Sc.	High School Teaching - 24 Years	5 Years – Physics teacher education

The names used in the study are pseudonyms to protect the privacy of the participants. The selection of the participants was based on convenience. The pre-service teacher participants and physics teacher educator participants were willing to participate and share their opinions and experiences, which according to Creswell (2007) is important for qualitative research. To explore views and ideas of the prospective physics teachers and teacher educators about the undergraduate physics study, a qualitative interview approach was employed. The data were generated through semi-structured interviews as a qualitative research data collection tool (Berg, 1998). The interviews sought the participants' views about their undergraduate physics study and its usefulness for teaching physics during practicum (teaching rounds). In-depth probing was used during the interviews whenever required to clarify and enrich the data.

The data collected through the interviews with prospective physics teachers and physics teacher educators were analyzed using the three-step procedure suggested by Creswell (2007): preparing the data for analysis (transcribing); coding to reduce the data [themes]; and representing the data. All the interviews were transcribed verbatim. To analyze the interview data, the qualitative approach of thematic analysis was used for "identifying, analyzing, and reporting patterns within the data" to yield insightful examination that answers particular research questions (Braun & Clarke, 2006, p. 79). Inductive coding was used, through which the findings were derived by establishing links between the research objectives and the summary findings derived from the raw data (Thomas, 2006).

Findings

In this section, the data from the interviews with the pre-service physics teachers and physics teacher educators are analyzed and presented to voice the concerns of prospective physics teachers about their subject matter knowledge preparation, particularly with regard to their undergraduate physics study. Further, the physics teacher educators' views about the subject matter preparation of prospective physics teachers are described and compared with the views of prospective physics teacher participants to determine if they understand the needs and concerns of prospective physics teachers with regard to their undergraduate physics study and overall preparation for teaching high school physics.

Views of Pre-service High School Physics Teachers

The following sections present the views and ideas of the prospective physics teachers regarding: (1) their undergraduate physics study (2) the helpfulness of their physics study for teaching physics, (3) the utility of other science courses for teaching physics; and (4) suggestions for better preparation of high school physics teachers.

Undergraduate physics study and physics

Prospective high school physics teachers (PTs) expressed diverse views on their respective experiences of undergraduate physics study. Three of these PTs (Margaret, Elvis, and Suvik) who had completed general science degrees found the physics content covered relevant for high school physics teaching, while two (Eralin and Ashok) who completed engineering degrees before entering the teacher education program indicated some concerns about the relevance of their undergraduate physics study and considered it not helpful for teaching high school physics. Despite these diverse views, both groups revealed some issues with their undergraduate physics study, which are described in the following section.

Margaret perceived herself as being "fairly well" prepared to teach high school physics; however, she specified: "I still need to work [on content] for teaching [high school] physics." Later, she acknowledged that most of her understanding about physics was developed during high school.

> I would say . . . that my knowledge [about], what students learn in high school physics, is really good. And, I would be able to explain that fairly well. . . . I had really good physics teachers [in high school]. And I did look up to them as they were fantastic [and] I understood them very well. So I guess there is little bit inspiration [from them].

Suvik who completed his undergraduate degree in Sri Lanka, that was heavily theoretical, covering all areas of physics. He said: "As an Honors degree, it covers all that content [included in high school physics]. So, I think that prepared me well….the content, I mean." However, later he stated that the nature of his physics degree was mainly theoretical, and therefore was not very helpful in understanding or teaching practical applications of physics. Elvis, who completed a B.Sc. with a physics major, felt adequately prepared because he found teaching physics easy as compared to other subjects he taught on Teaching Rounds (field placements).

Eralin, who was a mechanical engineer before coming to physics teaching, was not satisfied with her physics preparations because her engineering degree curriculum did not contain much general physics. She said that she had not studied most of the topics in the high school physics curriculum after her high school study. Therefore, she had a hard time recalling and preparing for teaching physics during the Teaching Rounds. Comparing her degree with pure physics degrees, she pointed out that her physics courses were not relevant to teaching high school physics: She reported her concerns:

> Many people in our Diploma of Education program have done a physics degree, and they have done actual physics and what they did in university was really relevant, what I did, was not. I think maybe two percent of my [undergraduate physics] courses I can use to teach year eleven and twelve

> students. . . .To teach [high school physics], I pretty much have to learn and recollect again, because I never did anything on light, I have never done anything on radioactivity, I have not done Astronomy.

Undergraduate physics study and teaching physics

Specifically, regarding Teaching Rounds (Field Experiences), all five PTs reported not having much help from the physics they studied at the undergraduate level, particularly when teaching difficult physics concepts. They all agreed that they had some background of the content (factual information). However, they revealed that this background knowledge did not include the conceptual understanding of the physics content that is usually required to teach high school physics. In the following section, some of their views are described in detail.

Margaret said that she could not get help from her undergraduate physics study during her practicum, and rather got some help from her high school physics experiences. As described above, Margaret had very good physics teachers in high school, and she appeared to follow them in many ways: "I did find myself looking at my old notes from high school [and] took some of those ideas into the classroom. [For example] some basic definitions and [ideas to] describing things." Similarly, Elvis revealed that he could not use anything particularly from his undergraduate physics study. Instead, he specified that he got help from his physics method classes: "I do not remember explicitly using any of those techniques [experienced during undergraduate physics study. [However] many techniques from the physics methods course I used, which worked."

Eralin, who criticized her mechanical engineering degree, plainly said that she could not get any help from her university physics courses. She also made a comment that whatever she was teaching was pretty basic [foundational], while her undergraduate physics study covered complex physics. Suvik told that he used a few experiment ideas from his undergraduate physics study to teach difficult physics concepts during Teaching Rounds; he said, "These were working during my undergraduate study."

Other science courses and teaching physics

The prospective physics teachers provided substantial evidence that other science courses they studied broadened their knowledge of physics and helped them in teaching different aspects of physics. Four out of five prospective physics teacher discussed examples of linking other science with physics during the Teaching Rounds. They also suggested that there should be better links provided through undergraduate study for physics and other sciences, as these help in teaching physics as well as in a better understanding of our world. For example, Ashok shared experiences of his PhD research about Rheology, which helped him in teaching the concept of Viscosity. Margaret was also able to see and establish many such links:

> Maths was helpful; for example, when you are teaching motion and momentum you calculate the changes in momentum, you can use Maths. [If] you want to look at the relationship between acceleration, displacement, and velocity, you can again use Maths. Chemistry can be used to look at the atomic structure, and how would you look at atomic physics as they have similar models.

Elvis stated that physics could be related to mathematics. Therefore, mathematics helped him teach physics. He discussed examples of problem-solving in physics which according to him obviously needed mathematics. His computer science knowledge also helped him regarding locating resources from the internet and understanding different computer programs and software related to teaching physics or science. The most interesting connection Elvis established was with Ancient History:

> Another subject that I did in my Bachelors was 'Ancient History,' and I found it of help in teaching relativity. A lot of relativity is about the history of the models and how they developed. And I felt that I could be more interested in that and there was a chance for helping the students to find it a little bit more interested.

Suvik found help from "Crystallography" in teaching atomic physics. He had a strong belief that these other sciences have strong links with physics, and that all sciences should be linked in a way to provide a better understanding of things around us.

Suggestions for better preparation of high school physics teachers

All five prospective physics teacher participants suggested that undergraduate physics courses should include deeper conceptual understanding for better preparation to teach physics, and they disapproved of the addition of more physics courses. Ashok said that knowledge is not a static thing, so it is not worth adding more physics areas to undergraduate courses, but it is important to keep students updated with physics knowledge. He suggested using strategies to make students independent learners so that they can keep themselves updated with advancements in the area of physics. Margaret and Elvis both saw first-year physics as very much related to high school physics curriculum, but they thought that from the second year onward it became complicated and not relevant for teaching high school physics. Margaret pointed out that there is an overlap of topics and concepts longitudinally, and she suggested: "Instead of repeating things [physics topics] in subsequent classes, it could be better to discuss [these topics] in more depth at once."

Elvis also suggested more in-depth physics courses as compared to greater breadth: "I think at this stage where I am with my physics knowledge; I think the most valuable thing for me is how to present these concepts rather than more and more concepts." Based on his experience of teaching a new topic - Aerospace in VCE

Physics - Elvis suggested a revision of the curriculum in university physics whenever there is a change in VCE physics. He argued: "I think the real goal of VCE is to select people for year twelve and to give them some background and to help them for future studies." Eralin, who had studied mechanical engineering, did not want any changes in that particular engineering degree because she believed that "it is relevant for what industry demand", and based on her lack of knowledge of the other undergraduate physics degree she said she was unable to compare.

Views of Physics Teachers Educators

The following sections present the views and ideas of the physics teacher educators regarding: (1) issues impeding the subject matter preparation of prospective high school physics teachers; and (2) changes required for better preparation of high school physics teachers.

The issue of undergraduate physics study

All three physics teacher educator (PTE) participants showed serious concerns about the contribution of undergraduate physics study towards prospective physics teachers' understanding of physics and physics teaching. According to Rose, university physics study does not contribute well to the prospective physics teachers' understanding of physics, "because they do not lead to the deeper understanding of those basics." John commented: "They [undergraduate physics programs] are more harm than good or waste regarding preparing to teach." However, he also added that contributions of undergraduate physics towards understanding of physics by prospective physics teachers heavily depends on the university and specific course, so he saw huge variations within and across universities and courses. The physics teacher educators pointed out the following concerns associated with undergraduate physics study in the context of helping prospective physics teachers understand the content.

No emphasis on understanding but mere elaborations. All three PTEs pointed that university physics teaching has a very little emphasis on any understanding of the content. One of the things that concerned John for many years is that "almost always university physics courses do nothing which aims to further develop an understanding of some of the fundamental concepts." John further elaborated his concern and provided possible reasons for this lack of focus on understanding the content knowledge involved by using examples from the area of Electricity and Magnetism, especially fundamental concepts like voltage, current, and potential difference. He maintained that, as these concepts are part of almost every high school curriculum, university teachers assume that students have developed a full understanding and do not bother to further develop understanding. Rose articulated the same issue and said that it is expected from new physics graduates in university that their understanding of all basic concepts (which John strongly recommended be called 'fundamental') is fixed in high school, and that university teachers only elaborate on these assumptions which "is very often only mathematical elaboration and some complex equipment they learn to use." Tim believed that some undergraduate physics preparations have little or no concern about understanding at any point, which is evident from the type of assessments used to evaluate students' physics learning. He said, "The assessment is so predictable that you can basically do forms of rote learning from the past."

Strong emphasis on mathematics. The participant PTEs identified another issue regarding teaching physics in undergraduate university courses that prevents undergraduate students from attaining a deeper understanding of the content knowledge. John and Rose held responsible mathematics as a strong focus on these courses as well as the use of formulae to solve numerical problems. They claimed that the mathematical approach to physics study does not help further in enhancing the understanding of fundamental physics concepts, which according to John, are really sophisticated, complex, partly philosophical, and partly physics concepts.

Lecturing style. All three PTE participants criticized the large classroom lecture style teaching, underpinning the transmission of knowledge as its philosophy. John disapproved of lecture-style teaching, as it does not prepare prospective physics teacher: "All lecturing that is large groups has the potential to be very bad teaching, and I mean even the pedagogy they encounter in the university is a very transmissive style of teaching." John further considered lecturing as "bad teaching" because it ignores the nature of students.

Undergraduate physics curriculum. Two of the three PTEs discussed the undergraduate physics curriculum as a source of the problem in preparing prospective physics teachers. Both John and Rose identified a lack of knowledge about the history and philosophy of science in the university undergraduate curriculum, and recommended that these should be part of any university physics or science curriculum. John reported that this type of curriculum change had already been implemented in his university's physics department.

Gap between undergraduate physics study and physics teacher education programs. While analyzing university undergraduate physics study and physics teacher education programs, two of the three physics teacher educators (tenured faculty members) from two different Melbourne universities identified a gap between education faculties and physics departments regarding focus and teaching philosophies. In education faculties, during a short teacher education program, there is an enormous shift in understanding required for most of the prospective physics teachers. This makes the preparation of physics teachers difficult on the part of education faculties alone. John brought forward the issue that: "for most of them [prospective physics teachers] this [teacher education] is when for the first time they seriously think about understanding."

Importance of other science courses. All three physics teacher educators shared the view that other sciences studied by prospective physics teachers help further develop the understanding of different concepts of physics and help them to teach physics. Both John and Tim believed in the 'wholeness' of science and did not believe in thinking it as compartments like physics, chemistry, biology, etc. Rose said that other science subjects studied at the undergraduate level "can help them in their understanding of physics." She reasoned that anybody who is going to teach science in high school should have a sound grounding in chemistry and biology, and further explained that, "it is wrong [to say] that you can teach science in year seven and not having any background in chemistry or not having any background in physics or not any background in biology."

Suggestions for better preparation of high school physics teachers

During the interviews, the participant physics teacher educators suggested many changes that they believed were needed to improve the subject matter preparation of prospective physics teachers. Their suggestions are reported in the following sections.

Special physics courses for prospective physics teachers. The physics teacher educators had varied opinions on designing separate courses for prospective physics teachers. One of the three participant science teacher educators wanted separate physics/science courses for prospective teachers, while the other two did not want special courses. Instead, they wanted reform in current university undergraduate courses for understanding of physics for all students. Rose, who wanted separate physics courses for prospective teachers, said, "The notion of what physics is needed as a preparation for teachers should be re-thought." However, John and Tim did not want special physics courses for prospective physics teachers on the basis of their strong belief that the issue of teaching physics for understanding in a university is not related only to preparing teachers for teaching physics. John said that this is a much broader issue of teaching physics for understanding for everyone, including prospective teachers, researchers, engineers, and so on because the understanding of physics is important for all students. John said, "Whether you are going to work in the industry, in government, to do research, or teach whatever this is a much more fundamental issue in understanding physics." He provided another important ground for his view not to have any special physics courses for prospective physics teachers alone, based purely on the Australian context. He argued that in the Australian context, people keep on changing careers and they move in and out of teaching at any given time in their life, and that designing special physics courses for teacher preparation may be restricting them to a profession they may not want to be or stay in. So, there is a need to reform university graduate courses for a better understanding of physics and not rote learning.

Changes required to the undergraduate physics curriculum. For better preparation for teaching high school physics, all three PTEs agreed on the importance of a deeper understanding of physics content for prospective physics teachers. John said that he did not want any further additions to physics courses, but reform in the existing physics courses to help in better understanding of physics concepts. John extended his view to include all other professions where physics is to be used, and his broader approach is rooted in some research evidence about the issue which he mentioned during the interview. His argument for the same but better physics for all is context-specific; i.e., it may be that separate physics content preparation is good in other contexts or countries where teaching is a permanent career choice.

Importance of other undergraduate science subjects. All three PTEs showed agreement that other science topics studied by prospective physics teachers helped further develop the understanding of different physics concepts and may help them in teaching physics. Both John and Tim believed in the 'wholeness' of science and did not believe in thinking of it as compartments like physics, chemistry, and biology. John argued that there has been a lot of interdisciplinary research within different areas of science, and that the links between different areas of science with physics were becoming quite important. In the future, prospective physics teachers may have to teach such "interdisciplinary physics", and therefore these areas of science are certainly going to be a great help for them to link physics with other areas of science. Rose believed that studying other science subjects "can help them in their understanding of physics." She also believed that "it is wrong [to say] that you can teach science in year seven and not having any background in chemistry or not have any background in physics or not any background in geology." She supported the idea that anybody who is going to teach science in high school should have a solid grounding in chemistry and biology.

Discussion

To include otherwise missing voices in the debate about the role of physics study in preparing teachers to teach physics, this research explored pre-service science teachers' views about their experiences of undergraduate physics and how this study prepared them to teach high school physics. Further, physics teacher educators' views were explored on the same issue to find out if they were in agreement with the views of the pre-service physics teachers.

The prospective physics teacher participants reported the issue of not gaining direct help from their undergraduate physics study for teaching high school physics. The interpretation of their voices led to three reasons: (i) the content covered was not relevant, (ii) the content was forgotten, and (iii) the teaching methodologies were not helpful. On the other hand, the three physics teacher educator participants presented their views much more strongly. They criticized the undergraduate physics study and discussed that prospective physics teachers have an inadequate understanding of physics, particularly in some areas of physics; for example, Electricity, Mechanics, Energy, and Electronics. They also believed that most undergraduate physics courses focus on elaborations (usually mathematical elaborations), assuming that students have developed a full understanding of the fundamental concepts. The physics teacher educators believed that the predominant lecturing style is not only a hindrance to understanding physics, but also develops traditional views about physics and teaching of physics. Moreover, they criticized the type of assessment of these physics courses, which results in rote memorization of facts at the cost of conceptual understanding. Their voices coincide with the previously established scholarly viewpoint that criticizes traditional undergraduate physics study and notes a lack of emphasis on understanding in undergraduate physics programs (Anderson & Mitchener, 1994; McDermott, 1990; McDermott et al., 2000), and also coincides with the voices of prospective physics teacher participants, especially with regard to lack of lack of emphasis on conceptual understanding.

The participant physics teacher educators also criticized the mathematics focus of undergraduate physics courses, which overlaps with previous research noting that these courses have not taken into consideration the needs of undergraduate students who aspire to become teachers (McDermott et al., 2000). However, the prospective physics teachers did not see this as a problem.

It is important to note that the three prospective physics teachers with pure physics degrees saw the content as more relevant to teaching high school physics compared to the two with engineering degrees from in and out of Australia, who reported not studying many physics areas. These results may be due to differences in motivation to study physics rather than systematic differences in the degrees. Not being able to remember what they studied in university physics courses was common among the student teachers, which may provide some evidence that university physics studies do not develop a deep understanding of physics content. On the other hand, the physics teacher educator participants were completely silent about the issue of content knowledge preparation of diverse physics teacher candidate populations.

The prospective physics teachers did not want any additional areas of physics to be added to university physics courses, arguing that it was not the breadth of the physics courses, but the depth that is helpful in better preparing teachers to teach physics, a well-established narrative in the research on science teacher education, also followed by the physics teacher educator participants. However, the PTEs presented varied opinions on designing separate courses for prospective physics teachers, which has been reported in previous research as a solution to better prepare science teachers (McDermott et al., 2000). Those who did not want separate courses for prospective physics teachers wanted reforms in undergraduate physics courses through promoting conceptual understanding. Moreover, this was the solution suggested by the prospective physics teacher participants. Also, one of them also suggested that the university physics courses should be updated according to changes in school curriculums. Those with engineering degrees thought that their degrees were meant to prepare engineers, not teachers, and were fine with the content for that particular goal. The physics teacher educators also did not want any additional physics courses; however, they wanted more in-depth understanding. They agreed that introducing courses on history and philosophy would help develop an understanding of the nature of science.

Other science courses studied at the undergraduate level were considered helpful for understanding physics and science by the prospective physics teachers. They identified particular links between physics and other sciences and suggested making these more explicit. The physics teacher educators also supported that other science subjects studied during their undergraduate study helped students understand and teach physics better, and stressed explicit interdisciplinary links in order to help students see the wholeness in science and the world around them. The value of studying other science courses was identified by Tamir (1988), who claimed that they were interrelated and help developed a deeper understanding of the phenomenon under study.

Conclusion and Implications

The above analysis of views of pre-service physics teachers and physics teacher educators suggests that physics teacher educators are well aware of the issues with regard to the subject matter preparation of prospective physics teachers, and suggests that a substantial reform in university physics courses can play a key role in preparing physics teachers by focusing on conceptual understandings of physics content. The focus of university undergraduate physics should be 'understanding' and not the 'rote memorization' of facts and algorithmic 'problem-solving.' This reform, to a large extent, needs to focus on the teaching strategies used in undergraduate physics, as well as redirecting curriculums to better portray the nature of physics knowledge.

There is a need for further research into adding future physics teachers' voices to understand the current issues of subject matter preparation faced by diverse teacher candidates, particularly those with shifting careers.

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