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Now and then – Science background of pre-service primary teacher education students.

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Abstract

A comparative analysis of the high school science background of pre-service primary teacher education students in their first year of study was conducted. Using data collected at a 20 year interval, the 1987-1989 intake cohorts are compared to the 2007-2009 intake cohorts.

The analyses revealed that despite major curriculum changes in high school science, a significant proportion of students did not study science beyond Year the 10 level. Additionally, for those who did study science in Years 11/12 the majority selected a biological sciences subject rather than a physical sciences subject.

Finally, analyses of open ended questions on why these students did / did not select a science subject in years 11/12 will be presented. During the presentation, input from participants on their experiences with students from their teacher education courses will be sought.

Introduction

In many Australian primary schools, teaching primary science is often the 'Cinderella' subject. Many teachers avoid teaching science by either passing it off to their substitute teacher or claim that their social science or technology units also cover the content of the science curriculum. The Australian federal government has invested substantial curriculum development efforts into promoting primary (K-6) science through the development of a number of science learning resources over the past 15 years, the most recent of which is the *Primary Connections* set of modular learning materials (Hackling, 2006). Yet the level of teacher uptake of these materials is low.

One of the underlying and explanatory origins for this situation that pervades much of primary science teaching in schools has been the level of content knowledge of pre-service primary teacher education students. Appleton (2002) portrays the situation in Australian schools this way: "Science is often not taught, and when it is, teaching strategies consistent with contemporary science syllabuses are frequently not used." (p. 393). While many reports concur with Appleton's assessment (e.g. Department of Employment, Education & Training (DEET), 1989), little published research identifying the prior level of engagement for primary teacher education students with high school science has been reported. The purpose of this paper is to address this omission and

construct a longitudinal picture of the entry level high school science knowledge for first year students.

Literature

The teaching of science in primary schools in Australia has for many years been seen as problematic (e.g. DEET, 1989; Goodrum, Hackling, & Rennie, 2001; Varley, 1975). Appleton (2003) has suggested that a well-documented difficulty for many primary school teachers is that they have tended to focus on non-science studies in their own schooling and teacher preparation. They consequently lack confidence to teach science, and do have a little or weak content knowledge of the sciences (Appleton, 1995; Skamp, 1989). The DEET report found that one cause for this situation was the inadequate pre-service preparation of teachers in the science disciplines and recommended that the discipline knowledge of primary pre-service teachers should be enhanced by increasing the number of hours of pre-service training that should be allocated to content oriented courses (DEET, 1989).

This phenomenon is not restricted to Australia as Liang & Richardson (2004) described the perplexing trend in the USA for many primary teacher education students to avoid science classes. This trend runs counter to the research of the US National Research Council (2001) which concluded that primary and high school student achievement in science is strongly correlated to both quality teaching strategies and the level of science knowledge of the primary and high school teachers that these students have. Hatton (2008) suggested that science education lecturers working in pre-service primary programs need to understand the level of pre-service teacher knowledge and beliefs about science teaching if these students are to develop into effective classroom teachers of primary science. She found that 33% of her primary science method class students expressed concern about their lack of science content knowledge, especially in the disciplines of chemistry and physics. Watters, Ginns, Enochs, & Asoko (1995) provided earlier and confirmatory support for Liang & Richardson (2004) and Hatton (2008) research on the longevity of this issue when they asserted that the teaching of science in primary schools around the world has been identified as being in crisis for a number of years (Claxton, 1992; DEET, 1989; Tilger, 1990).

Lee Shulman proposed the concept of pedagogical content knowledge (PCK) (Shulman, 1986, 1987), which formed one of seven suggested knowledge bases required for teaching. He suggested PCK was different from content knowledge and knowledge of general pedagogy, rather consisting of representations of subject matter, student conceptions, and understandings of specific learning difficulties (van Driel, Verloop, & de Vos, 1998). Research by Grossman (1990) suggested there were four central components to pedagogical content knowledge: i) knowledge and beliefs about purpose; ii) knowledge of students' conceptions; iii) curricular knowledge; and, iv) knowledge of instructional strategies.

Abell and Roth (1992) argue that "limited content [knowledge] and pedagogical content knowledge may be the biggest constraints for novice teachers in elementary science, especially those who do not begin as science enthusiasts" (p. 592). Gee, Boberg & Gabel

(1996) contend that that "pre-service elementary teachers must have a considerable knowledge base of each of the sciences." (p. 3). Further as Goodrum, Hackling, & Rennie, (2001) have reported, a large number of Australian primary school teachers do not have a strong background in science content that reduces their ability to design and implement appropriate science learning sequences based on a sound foundation of PCK. In contrast to the above portrayal of teachers of primary science, expert teachers have sound content knowledge, pedagogical knowledge and content-specific pedagogical knowledge and apply all three types of knowledge in teaching (Leinhardt, 1990). They also have the confidence borne out of experience to teach science which may be related to attitudinal interests or a dispositional orientation towards science (Dweck & Elliot, 1983).

However, for a primary science teacher to effectively understand and use the four elements of PCK outlined by Grossman (1990), a deep knowledge and understanding of content knowledge in science is also needed. For example, when a teacher is teaching a science concept (e.g. force), it is difficult for the teacher to analyse and diagnose what a student is recounting and explaining about force if the teacher's own understanding of this concept is still pre-Newtonian. This mismatch then flows through to the teacher's ability to develop a learning plan that will assist the student in moving from her incomplete / inaccurate conceptual understanding to the currently accepted scientific explanation of this concept. Here, the work of the *Learning in Science Project (LISP)* from the University of Waikato has made a highly significant contribution to both content knowledge development and pedagogical content knowledge.

Some recent research by Appleton & Kindt, (1999a, 1999b) and Appleton (2002) postulated that primary teachers attempt to resolve this content knowledge / pedagogical content knowledge void by seeking and using "activities that work" as a substitute for, or supplement to their meager science PCK. (Appleton, 2002: 395)

Teachers regarded "activities that work" as having a predictable result and were linked explicitly to curriculum learning goal outcomes. If the activity did not turn out as expected, they therefore felt frustrated that what they had wanted the children to learn was not achieved. Appleton (2002) stated that the teachers' limited science content knowledge "made it difficult for them to diagnose how or why an activity did not perform as expected. Further, since they expect the activity outcome to make some science content knowledge accessible to the children, when an activity has an unexpected outcome, they have no ready means of making it understandable for the children." (pp. 402-403)

In this paper, the literature examined above has highlighted that for many primary teachers prefer not to teach science, often because they have little science content knowledge, and that they often will select science based activities that work as a strategy to resolve this content knowledge void. Additionally, the literature drew attention to the meager information on the entry level science background of first year primary teacher education students. Consequently, this omission reinforces that the need to fully document what the prior high school science experiences and science content knowledge

of pre-service primary teacher education students are as a pre-cursor to considering the form that primary science method subjects should take.

The Research Question

Consequently, this paper seeks to address the research question: What is the science content knowledge that primary teacher education students bring to their first year of study?

Methodology

All first year primary teacher education students enrolled at Charles Sturt University in New South Wales, Australia were administered a questionnaire that sought information on their high school science studies. In total, 424 students provided responses to the questionnaire. The questionnaire was administered within the first two weeks of the start of classes in a first semester, first year science curriculum subject. The data from first year students who commenced their studies in 1987-1989 intake cohorts and in 2007-2009 intake cohorts are reported. The questionnaire was developed initially as part of a review of the Bachelor of Education (Primary) course review process. Many of the same items from this questionnaire were employed with some minor wording changes with the 2007-2009 intake cohorts. The major wording changes were based on changes to the names/types of science courses offered in Years 11 and 12 in the 1987-1989 period compared to the 2007-2009 period. These changes were due to a major science curriculum re-structure that was managed by the Office of the Board of Studies in New South Wales in the 1998-1999 period with implementation commencing in 2000 (www.boardofstudies.nsw.edu.au). Two syllabus changes were: i) in 1987-1989 there was a non-science career course called General Science while in 2007-2009 the equivalent non-science career course was called Senior Science; and ii) Geology was a separate science course offered in the 1987-1989 period while in 2007-2009, a broader course called Earth and Environmental Science had replaced the Geology offering.

The questionnaire consisted of three main parts: i) biographical information about each student; ii) objective item questions on which science subject the students had studied to the end of Year 12; and, iii) open ended items that sought reasons for why the students had or had not selected a science subject after Year 10. A copy of the questionnaire is available from the author. Objective data were analysed using SPSS Version 16.

Results

Selected biographical information for each intake cohorts is presented in Table 1.

Table 1 Biographical information

Intake Year	Cohort Size	Age (Yrs) (mean)	Age Range	Sex			Entry to University			
				Male	Female	Omit	HSC	Mature Age	Special Entry	Omit
1987	60	21.05	18-37	9 15%	51 85%	0 0%	42 70%	15 25%	3 5%	0 0%
1988	60	20.43	18-37	14 23.3%	46 76.7%	0 0%	35 58%	13 22%	12 20%	0 0%

1989	51	21.14	17-50	10 19.6%	41 80.4%	0 0%	33 65%	9 18%	9 18%	0 0%
2007	73	23.41	18-48	13 17.6%	59 79.7%	1 1.4%	37 50.7%	23 31.5%	13 17.7%	0 0%
2008	79	20.73	17-46	8 10.1%	71 89.9%	0 0%	37 46.8%	23 29.1%	6 7.6%	13 16.5%
2009	101	21.03	17-39	24 23.8%	76 75.2%	1 1.0%	47 46.5%	30 29.7%	24 23.8%	0 0%

The data in Table 1 indicate that cohort intake numbers have increased from the 1987-1989 period to the 2007-2009 period. This rise is partially explained by a removal of restricted quotas on intake numbers that the Australian Federal government imposed in the 1980s to the current situation where the University now has flexibility to manage its overall intake and allocate funded spaces where demand is high.

Two consistent trends across both periods of time are: i) the mean age of enrolment in first year (mean = 21.3 years, S.D. = $\pm$ 1.1); and, ii) the high proportion of females studying primary teacher education. On average about 4 in 5 students are female (82.6%) while 1 in 5 is male. The major deviation from this pattern was in 2008 where a large proportion of females started their teacher education course than in any other year.

The mode of entry has undergone a significant change between the two periods. In the 1987-1989 period, the majority of students gained entry to the primary teacher course based on their Year 12 Higher School Certificate examination results. For the 1987-1989 period almost 2 in 3 students (64.3%) gained entry via their HSC results while this mode of entry had dropped to about 1 in 2 students (47.8%) for the 2007-2009 intakes. This drop was balanced by the rise is Special Admissions which is linked to the Principal's Entry Scheme operated at CSU. This scheme allows a student to gain direct entry to a CSU course without necessarily waiting for their HSC results. The student's academic results over both Year 11 and 12 along with the endorsement from their High School Principal are the key determinants of entry.

Science background

All students were asked two questions about their study of science to a) the end of Year 10 (i.e. the compulsory years of schooling), and b) to the end of Year 12 (where they completed the state-wide public examination in that science subject).

In Table 2, the comparative proportions of students who did or did not complete at least one science subject to the end of Year 12 is shown. For those who replied "No" their last encounter with high school science was when they completed the compulsory Years 7-10 science course.

Table 2: Studied Science to end of Year 12

Intake Year	**Study Science to HSC**	
	Yes	**No**

1987	52 (86.7%)	8 (13.3%)
1988	48 (80%)	12 (20%)
1989	35 (71.4%)	14 (28.6%)
2007	41 (56.2%)	32 (43.8%)
2008	35 (44.3%)	44 (55.7%)
2009	60 (59.4%)	41 (40.6%)

Overall, fewer students were studying a science subject through to Year 12 in the 2007-2009 period compared to the three year period twenty years ago. The mean participation rate for the 1987-1989 period was 78.9% compared with the mean participation rate for the 2007-2009 period of 53.6%.

This decline in science studied to Year 12 is mirrored in the NSW state wide figures for students studying a science subject as reported by the Office of the Board of Studies. This statuary body is responsible for syllabus development and assessment especially at the end of Year 10 (the School Certificate) and Year 12 (the Higher School Certificate). Student subject enrolment data from the Board of Studies' website for the most frequently selected senior science subject, Biology, reveal that there has been a significant decrease in student enrolment in Biology over the 20 year period. Part of this decrease may be attributable to the rise in popularity of other subjects including Vocational Education and Training (VET) subjects offered in Years 11/12 but these newer (i.e. post 2001) subjects do not account fully for the reduction in student enrolments in Biology**.** The Biology enrolment numbers for the 1986-1988 and 2006-2008 periods were selected as being indicative of the student numbers in the year immediately prior to when the majority of the pre-service students enrolled in first year of their primary teacher education course. These data are shown in Table 3 with comparative enrolment numbers for the compulsory subject, English.

Table 3: Biology enrolment numbers

Subject	**Year**					
	1986	**1987**	**1988**	**2006**	**2007**	**2008**
Biology	14683	15814	18320	14235	14620	15468
English	37734	40837	46867	66185	67189	64509
Biology as a precent of English	38.91	38.72	39.09	21.51	21.76	23.98

A subsequent question sought to further explore what specific science subject(s) the students had studied during Years 11 and 12. Table 4 identifies the distribution of students across the range of science subjects offered.

Table 4: Specific science subject(s) studied

If Yes Which Ones	**1987**	**1988**	**1989**	**2007**	**2008**	**2009**
Biology	35 58.3%	29 48.3%	25 49.0%	24 32.9%	24 30.4%	40 39.6%

Chemistry	5 8.3%	10 16.7%	5 9.8%	5 6.8%	3 3.8%	6 5.9%
Physics	3 5.0%	6 10.0%	2 3.9%	5 6.8%	3 3.8%	6 5.9%
Geology / Earth and Environmental Science	1 1.7%	1 1.7%	2 3.9%	2 2.7%	3 3.8%	2 2.0%
General Science / Senior Science	12 20.0%	9 15.0%	4 7.8%	10 13.7%	9 11.4%	17 16.8%
Other Science	7 11.7%	3 5.0%	3 5.9%	2 2.7%	1 1.3%	4 4.0%
Totals	***63***	***58***	***41***	***48***	***43***	***75***
Cohort size	***60***	***60***	***51***	***73***	***79***	***101***

The most frequently studied science to the end of Year 12 has been Biology. This was followed by the General Science / Senior Science course. Very few of the primary teacher education students have studied either Chemistry or Physics since completing their Year 7 – 10 Science course in New South Wales schools which included some physical and chemical sciences concepts.

The data presented in Table 4 highlights a discrepancy in individual cohort totals. This discrepancy draws attention to the difference between the total number of students who responded "Yes" (see Table 2) and the total number of specific science courses studied in each intake cohort (e.g. 1987 cohort: 52 said "Yes" but 63 specific science courses studied were reported; 2007 cohort: 41 said "Yes" but 48 specific science courses studied were reported). This discrepancy is due to the fact that in both periods of time all students in NSW were permitted to study 2 Board of Studies science courses. Further, due to changes to the rules governing the HSC in 2001, it was also possible for students in the 2007-2009 cohorts to study 3 Board of Studies science courses. Consequently, a secondary analysis of multiple science subject enrolment by each intake cohort was undertaken. This analysis revealed that some students had studied two science subjects and a very small proportion had studied three science subjects in Years 11 and 12. The findings from this secondary analysis are reported in Table 5.

Table 5: Students studied 2 or 3 science subjects to end of Year 12

Intake year	**2 Sciences subjects**		**3 science subjects**	
	N	%	N	%
1987	7	11.7	1	1.7*
1988	8	13.3	-	-
1989	4	7.7	-	-
2007	5	6.8	1	1.4
2008	7	8.9	1	1.3
2009	10	9.9	2	2.0

* This student completed Year 12 in Victoria where it was permissible to complete 3 science subjects.

For about 1 in 10 students in each intake cohort, they had studied 2 or 3 science subjects over Years 11/12. These students can be classified as "science enthusiasts" (Abell & Roth, 1992: 592) or students with a good science content knowledge and a high level of

interest in science. A breakdown of the combinations of science subject for this small group of students was undertaken. This analysis is described in Table 6.

Table 6: Combination of specific science subjects

Subject Combinations studied to HSC	1987	1988	1989	2007	2008	2009
Two Science Courses						
Biology and Chemistry	2	6	1	1	1	3
Biology and Physics	1	0	0	1	1	0
Biology and Senior Science	-	-	-	0	2	3
Biology and Geology / Earth and Environmental Science (ESS)	0	0	1	0	1	0
Chemistry and Physics	2	1	2	2	1	2
Chemistry and Geology / EES	0	0	0	0	0	0
Biology and other science	2	1	-	0	0	2
Physics and Senior Science	-	-	-	1	0	0
Earth and Environmental Science and Senior Science	-	-	-	0	1	0
Three Science Courses						
Biology, Chemistry and Physics	1	-	-	1	1	0
Biology, Physics and other science	-	-	-	0	0	1
Chemistry, ESS, and Senior Science	-	-	-	0	0	1

The more frequent 2 subject combinations were i) Biology and Chemistry, ii) Chemistry and Physics, and iii) Biology and Senior Science. This later combination was expected as the rules governing the number of science subjects that could be studied post 2001 at the Year 11/12 level were changed and permitted a student to transfer from Biology, Chemistry, Physics or Earth and Environmental Science to Senior Science for their Year 12 study program. Finally, there is a small group of students who study both chemistry and physics in each cohort.

In addition to the formally approved science courses which are developed and assessed by the Board of Studies in New South Wales, there are also a number of other science related courses that students can select. In Table 7 these other science courses are identified.

Table 7: Other science related subjects studied.

Intake year	Other Science Subjects	
	Subject Name	Number
1987	Agriculture Psychology Sheep and Wool Science	2 1 1
1988	Agriculture Botany	1 1
1989	NIL	0
2007	Agriculture Food Technology	1 1
2008	Psychology	1

2009	Agriculture	1
	Marine Studies	1
	Psychology	3

Agriculture, Sheep and Wool Science and Food Technology are all Board of Studies developed and examined subjects but not grouped with the science subjects listed within the Science Key Learning Area. Rather, they are all grouped in the Technology and Applied Studies Key Learning Area. Psychology is a Victorian Year 11 / 12 course which is not available in NSW. Botany and Marine Studies are approved courses but are not externally assessed.

Reasons for studying/not studying science in Years 11/12
In the questionnaire administered to the 2007-2009 cohorts two additional questions were included that were not part of the earlier 1987-1989 survey. These additional questions sought student reasons for either continuing with science into Years 11/12 or dropping science.

In response to the question that asked students why they *continued* studying science in Years 11/12, the four main reasons for their decision were:

- *An interest in science* (45.2% of all responses). Some examples of the comments provided are: 2007 student: "Because I found it interesting"; 2007student: "As I enjoyed learning about living things"; 2008 student: "Wanted to continue because I was interested. I also enjoyed the class"; 2008 student: "I have always loved biology and the bio teacher was fantastic"; 2009 student: "I enjoy science in general terms I find it interesting"; and, 2009 student: "I find science interesting and a good subject to gain further knowledge and interest in and I liked probing things";
- *Perceived relevance to career pathway* (15.3% of all responses). Some examples of the comments provided are: 2007 student: "To cover the area and hope to use it in further study"; 2008 student: "As I found biology interesting and enjoyable and thought it would be useful for teaching"; and, 2009 student: "I enjoyed it and felt it would broaden the future of my studies and help me in Prim Ed";
- *Positive prior science learning experience* (12.7% of all responses). Some examples of the comments provided are: 2008 student: "Because I enjoyed science in previous years and wanted to carry on with it"; and, 2009 student: "Because in year 10 I enjoyed the biological component of the course and I did well in the subject" and,
- *Improve University admission chances* (10.8% of all responses). Some examples of the comments provided are: 2007 student: "Because it would be helpful to get into Uni to do Primary Teaching"; 2008 student: "I enjoyed science in year 10. Also it got my marks up for the HSC"; and, 2009 student: "Because it was going to help my mark in HSC".

Collectively these responses indicated that many students had selected a science course in Years 11/12 based on a personal interest in science phenomena and the relevance of science to their chosen career pathway after completing high school.

The second question sought reasons why students had *not selected* a science course in their Year 11/12 study program. Analyses of the 150 responses identified five main reasons why the students had dropped science in Years11/12. Their reasons were:

- *Lack of interest in science* (30.7% of all comments). Some examples of the comments provided are: 2007 student: "Not comfortable with the subject and was not interested in science"; 2008 student: "Because I don't like science and are not interested in it"; and, 2009 student: "I wasn't interested in any forms of science";
- *Other subjects preferred* (18.7% of all comments). Some examples of the comments provided are: 2007 student: "It wasn't that I didn't like science, I only had limited units and other subjects came first"; 2008 student: "Because science was a hard subject, so I preferred to do hospitality instead"; and, 2009 student: "My interest was in social science (commerce, legal studies)';
- *Lack of science subject confidence* (13.3% of all comments). Some examples of the comments provided are: 2007 student: "Because I wasn't the best at science and I didn't really like it"; 2008 student: "I was not confident and did not enjoy it as much as other subjects offered"; and, 2009 student: "Because I was stronger in the Arts than Science and I would not enjoy struggling, therefore I did all Arts";
- *Not related to career path*way (8.7% of all comments). Some examples of the comments provided are: 2007 student: "At the time it did not relate to what I wanted to do when finished school"; 2008 student: "Wasn't interested in furthering my education in science"; and, 2009 student: "Science wasn't my career path"; and,
- *Subject availability* (7.3% of all comments). Some examples of the comments provided are: 2007 student: "Because I didn't want to focus on one area of science, senior science didn't run"; and, 2009 student: "Biology not offered".

Collectively these responses suggest that for those students who dropped science many of these students did not have an interest in science and chose to study subjects in other areas that they believed were more interesting and relevant.

Conclusion

This paper explored the research question: What is the science content knowledge that primary teacher education students bring to their first year of study? and has identified a significant and long term trend in the level of science content knowledge that Primary Education students bring to the course of studies. The data reported in this paper indicate that fewer students in the 2007-2009 cohorts are studying science beyond Year 10 compared with students in the 1987-1989 cohorts. Secondly in the 2007-2009 cohorts only about half of all students have completed a Year 11/12 science course.

For those students who do study science in Years 11/12, the specific courses that are most frequently studied are Biology and General Science/Senior Science. Very few students study Chemistry, Earth and Environmental Science and Physics subjects. At the other end of the scale, there is a small group of students (about 10% of all students who studied

science) who have significant science content knowledge through studying 2 or 3 science courses in Years 11/12.

In summarizing the literature on primary teacher's preparedness to teach science Appleton (2003: 2) stated: "there is overwhelming evidence that a major contributing factor is the tendency for primary school teachers to have limited science background knowledge, and to lack confidence in teaching science". The findings from this study on the science background of first year primary teacher education students not only confirm Appleton's assertion but provide a quantitative figure to the depth of this issue. The findings emphasise an imperative for teacher education institutions. First year primary teacher education students have limited science content knowledge and often hold memories from their own science studies that are not conducive to engaging substantially with science either in their pre-service course or when a full time teacher.

It was Shulman, (1986, 1987) who suggested that PCK was different from content knowledge and knowledge of general pedagogy. PCK consisted of how the prospective teacher represented subject matter, student understandings and misconceptions, and understandings of specific learning contexts and difficulties (van Driel, Verloop, & de Vos, 1998). As Mellado, Blanco, & Ruiz (1998) suggested it was knowledge of how to teach specific science content in specific classroom contexts - a form of knowledge in action. It is based primarily on the teacher's own science content knowledge. PCK can be developed through the teacher's own experiences, pre-service teacher education experiences, and science teaching practices, as well as the recommendations from colleagues' experiences (Appleton, 2002). The findings from this study raise questions about what science content and PCK should be included in pre-service primary teacher education. It is essential for effective primary science instruction to occur in schools that pre-service teachers develop both forms of knowledge to build their capacity to design and deliver quality science learning experiences to the students.

These data raise questions about the provisions, nature and range of science related experiences that teacher education lecturers should include in their first year science curriculum / method courses. In this presentation, focus discussion questions exploring the following issues will be raised:

- What is the situation in New Zealand tertiary primary teacher education courses in relation to the engagement with science education subjects?
- How does the science background of these NSW students compare with University entrants in New Zealand?
- What should be included in the science curriculum/method subjects for primary teacher education students?

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