Professional Knowledge, Interest and Self-Efficacy: A Pre-Service Science Teacher Education Program Study

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Abstract

Although a broad and complex amalgam of environmental (extrinsic) and personal attribute (intrinsic) factors are known to influence elementary science delivery, the development of the intrinsic factors are of particular importance to pre-service science educators. This research paper, based on quantitative procedures, examines the influence of a variety of science and science pedagogy courses in a Bachelor of Education (Primary) program on the development of teacher candidate personal attribute factors. The study involved the participation of 126 teacher candidates and explored the development and relationships amongst professional science knowledge, science teaching self-efficacy and professional attitude and interest. Results from the study identified that students who had taken a variety of both science content and pedagogy courses, unlike those who had taken only science pedagogy or content courses, held consistently positive correlations between their science background knowledge and self-efficacy. On the basis of the developments and correlations identified in and amongst teacher candidate personal attribute factors, recommendations for this and, potentially, other pre-service science education programs are suggested.

Key Words

science teacher education, self-efficacy,
professional science knowledge, professional attitude

Background to the Study

The problems associated with science education at the elementary level have been referred to as parlous (Mulholland & Wallace, 1996). Although recently applied, this description, referring to the perilously complex nature of the problems influencing science program delivery, is a fitting description of the state of science education in many countries over many decades. As an example, Austin (2001) suggests that despite the best intentions of the inaugural 1878 national primary science curriculum in New Zealand, the teaching of primary science was beset by numerous problems including lack of training in science content and pedagogy for teachers, lack of equipment, lack of time, and pressure of what were considered by teachers more important subjects. Although these problems inhibited the delivery of the primary science curriculum in 1878, historical evidence would suggest similar factors have, to this day, consistently inhibited science program delivery. More recent studies, within the New Zealand (Lewthwaite 1998, 1999a, 1999b, 2000, 2001) and international (Appleton & Kindt, 1999; Mulholland &

Wallace, 1996) context affirm that a broad and complex amalgam of intrinsic (teacher personal attribute) and extrinsic (environmental) factors impact on, and often impede, the delivery of elementary science programs.

The intrinsic factors influencing science program delivery are of particular interest to pre-service science educators and teacher candidates (student teachers) as these are the factors most likely to be developed during teacher pre-service education (Lewthwaite, 2000). A variety of interrelated factors are regarded as being a part of the amalgam of personal attribute factors influencing science teaching. Elementary teachers generally appear reluctant to include science as part of their classroom curriculum (Mulholland & Wallace, 1996). Garden (1996) identifies teacher attitude towards science as a teaching area as a critical factor influencing science curriculum implementation in New Zealand. This reluctance has been attributed to not only a lack of science background amongst science teachers but also a negative attitude toward science as a curriculum area (Hurd, 1982). Professional science teaching motivation and interest are often suggested to be associated with a further intrinsic factor, professional adequacy. Teacher perception of their ability to teach science is a major obstacle to science program delivery at the primary level (Appleton, 1992; Fensham, Navaratnam, Jones, & West, 1991; Franz & Enochs 1982; Hurd, 1982; Jeans & Farnsworth, 1994). Professional adequacy and attitude towards teaching science are implicitly related to a further intrinsic factor, teacher conceptual understanding and knowledge of science (Franz & Enochs, 1982; Tilgner, 1990). Baker (1994) states that feelings of inadequacy and lack of interest are linked to primary science teachers' perceived lack of knowledge, although some studies would suggest that this link is rather tenuous (Skamp, 1989). A lack of background science knowledge of teachers is commonly identified to be a major factor influencing the effectiveness of science program delivery (Baker, 1984; Carre & Bennett, 199 Education Review Office, 2002; Mulholland & Wallace, 1996; Symington, 1974, 1982; Tilgner, 1990).

Understanding the influence of professional science knowledge on professional adequacy and interest is complicated by the fact that the knowledge required for teaching is multidimensional. Shulman (1986, 1987) identifies seven knowledge bases as necessary for effective teaching. These include: (1) content knowledge, (2) general pedagogical knowledge, (3) curriculum knowledge, (4) pedagogical content knowledge, (5) knowledge of learners and their characteristics, (6) knowledge of educational contexts and (7) knowledge of educational ends, purposes and values. New Zealand's Teacher Registration Board (New Zealand Qualification Authority, 2001) similarly recognizes *professional knowledge* as also being a multidimensional aspect incorporating many of the knowledge dimensions identified by Shulman, all of which are expected to be developed during pre-service teacher education. Research that attempts to understand the influence of pre-service science education courses on the development of teacher personal attribute factors is critical in ensuring that teacher education is able to contribute to a "cycle breaking" of the perpetuating malaise and maladies in science education that exist internationally (Mulholland & Wallace, 1996).

Intent of the Study

Although the influence of individual science education courses on teacher knowledge, attitude and professional adequacy have been considered (Appleton, 1991, 1992; Skamp, 1989), the influence of a range of science education courses emphasizing the variety of knowledge bases identified by Shulman (1986, 1987) in a *single* teacher education program on the development of intrinsic dimensions of pre-service teachers has not been explored. In fact, as Skamp (1989) suggests, practical solutions to achieving an improved science background knowledge and more positive attitude and efficacy towards the teaching of science are difficult to prescribe because of the uncertain relationships between the type of science studies taken during pre-service teacher education and their influence on students' attitudes and efficacy. The purpose of this research inquiry is to attempt to address this dilemma by (1) examining the relationships that exist amongst several dimensions of pre-service teacher professional knowledge, in particular subject-matter knowledge, and science teaching self-efficacy as an outcome of the type of science studies taken in a teacher education program; (2) identifying course structures that impact on the development of personal attributes of teacher candidates; and, by so doing, (3) suggesting modifications to an existing pre-service program in order to improve the overall science professional knowledge, attitude and adequacy of the program graduates; and, finally, (4) suggesting critical ingredients for science teacher education programs.

Study Context and Participants

All 126 teacher candidates (student teachers) involved in this study were in their final year of a three-year Bachelor of Education (Teaching – Primary) degree at a New Zealand University College of Education. At the time the research was conducted, the degree structure provided considerable flexibility for students in developing curriculum expertise for teaching Grades 1 to 8 of schooling (Levels 1 to 5 of the *New Zealand National Curriculum Framework*). This was reflected in the courses offered to students within all curricular areas. During the three-year degree program, teacher candidates were required to complete an introductory *Curriculum Inquiry and Practice* course (*Curriculum I*) in each of the seven curriculum areas of the national curriculum framework and further *Curriculum Inquiry and Practice* courses (*Curriculum II* and *III* papers) in curriculum areas of their choice. As well, teacher candidates were required to complete five *Studies in Subjects* courses that develop subject specific knowledge in curriculum areas of their choice. A minimum of three Studies in Subjects courses was required in a teacher candidate's selected area of specialization. The courses offered in science education are outlined in Figure 1 and described in detail in the section that follows.

Science Curriculum I, a compulsory and introductory curriculum teaching and learning course for all teacher candidates enrolled in the Bachelor of Education (Teaching - Primary), explicitly introduced teacher candidates, within a constructivist framework, to the principles and practices of science education relevant to Years 1 to 8 of schooling. The focus was on developing the planning skills and teaching strategies through practical experience necessary to implement a range of science topics relevant to *Science in the New Zealand Curriculum*. Particular emphasis was placed on portraying science as a process of enquiry that leads to an evolving body of knowledge (Ministry of Education, 1993). Although teacher candidates developed some understanding of scientific phenomena during Science Curriculum I, the course was implicitly intended to address the negative preconceptions that teacher candidates commonly have towards science as a teaching and learning area in the national curriculum (Lewthwaite, 2000). In terms of Shulman’s categorization of knowledge structures, Science Curriculum I primarily emphasized the development of curricular and pedagogical knowledge within a reflective orientation (Abell & Bryan, 1997). As well, a strong emphasis was placed on developing the pedagogy for developing student procedural knowledge associated with investigating, a central activity in science (Ministry of Education, 1993). As an example, teacher candidates developed an understanding of the nature of science as a form of inquiry within contexts such as floating and sinking. In this context, emphasis was placed on the investigative process and less so on the development of scientific understanding of flotation. In this study, all 126-teacher candidates had completed this introductory course. For 43 of the 126 teacher candidates, Science Curriculum I was the only science course completed in their degree. These 43 students are identified as *Curriculum I* in this course.

Curriculum Inquiry and Practice Courses		**Studies in Subjects Courses**
Science Curriculum I	⇔	Catchments & Stream Processes
↓		
	⇔	Spaceship Earth
↓		
Science Curriculum II	⇔	New Zealand Bush & Landforms
↓		
	⇔	Natural Resources
↓		
Science Curriculum III	⇔	Environmental Monitoring
		Coastal Processes

Figure 1: Program Structure for Science Education in Bachelor of Education (Primary)

Science Curriculum II, an optional science curriculum and teaching course, further developed aspects of science instruction within a constructivist framework. Within contexts relevant to Years 1 to 8 of schooling, Science Curriculum II emphasized the further development of pedagogical, curricular, procedural, and, especially, subject matter and pedagogical content knowledge specific to Levels 1 to 5 of the national science curriculum. It addressed useful forms of representation, analogies, illustrations, examples, explanations and demonstrations that make selected science phenomena comprehensible to others (Shulman, 1986). Emphasis was placed on developing an understanding of common pre-instructional views held by learners for many of concepts addressed in Levels 1 to 5 of *Science in the New Zealand Curriculum*. As well, teaching strategies were modeled that supported the development of teacher candidate scientific understanding of the phenomena within an investigative context required to be taught within Years 1 to 8 of the national science curriculum. As an example, the concept areas of temporary-permanent changes, physical-chemical changes and dissolving and solubility were explicitly addressed in the course using various forms of physical representation (role play, models, analogies, computer and video simulations) to promote understanding of these phenomena at the particulate level. In this study, 44 students had completed this course in addition to Curriculum I. This group is identified as *Curriculum I & II*.

Within the Bachelor of Education (Teaching-Primary) program teacher candidates were expected to choose a curriculum emphasis and, consequently, completed a minimum of three *Studies in Subjects* papers in one curriculum area. Science Studies in Subjects were optional courses provided by the College of Education to develop teacher candidate subject matter knowledge at the tertiary level in scientific areas within contexts endorsed by the national science curriculum; that is, the New Zealand living, physical, material and technological environments. These courses implicitly assumed that teacher candidates possessed foundational knowledge of scientific phenomena. As an example, in the Studies in Subjects paper *Catchment and Stream Processes*, it was assumed that teacher candidates had a foundational understanding of the particle nature of matter, changes of state, dissolving and solubility from their school experience as foundational knowledge for understanding water chemistry parameters such as dissolved oxygen, total dissolved and total suspended solids and meteorological phenomena such as adiabatic processes, cloud formation and barometric pressure. All of the courses offered as Studies in Subjects for science emphasized field experience and required teacher candidates to conduct a major field-based investigation within the context of study. As an example, in Catchment and Stream Processes, teacher candidates carried out a class investigation examining the changing nature of a New Zealand river from its source in the Ruahine Mountains to its discharge into the Tasman Sea. Teacher candidates also carried out a group investigation on the changing quality of a stream within the Central Districts of New Zealand (Lewthwaite, 2002). A further course, *Spaceship Earth* emphasized, amongst other things, the development of understanding of Earth's place in space relative to the sun, moon and stars through the collection of data through night-sky observation and a computer planetarium program (*Starry Night*™) and verification using an investigating with models approach (MacIntyre, Stableford & Choudry, 2002).

In this study, 27 teacher candidates were completing a Science Studies in Subjects major having also completed Science Curriculum I and II. These teacher candidates are identified as *Science Majors + I + II.* A further 12 teacher candidates, two of whom had been surveyed in Science Curriculum I, were completing a Science Studies in Subjects major having completed only Science Curriculum I. These teacher candidates are identified as *Science Majors +1.* A further course, Science Curriculum III, a pedagogical and curriculum knowledge course for teacher candidates desiring to be science curriculum leaders for Years 1 to 8 of schooling, is also offered to students in their final semester of the three-year degree structure. The sample size associated with Science Curriculum III was very small and, thus, was not examined in this analysis.

Data Collection and Analysis

Teacher candidates were invited to complete a four-section questionnaire at the end of the Curriculum and Inquiry science course (i.e. either Curriculum I or Curriculum II) they were completing. The questionnaire contained 4 sections. Section A pertained to teacher candidate biographical data (age, ethnicity, secondary school science experience, prior science study in degree structure). Section B included a series of Likert scale response questions pertaining to teacher candidate science experience prior to and during their teacher education as well as their future teaching responsibilities. Section C required teacher candidates to respond to their perceived confidence in teaching a series of ten teaching scenarios or vignettes that implicitly addressed a specific knowledge dimension as described by Shulman (1986, 1987) and, more specifically, the New Zealand Teacher Registration Board. As an example, Vignette 10 addressed procedural pedagogical knowledge:

> *"You are asked to teach a unit that promotes student investigative skills, in particular their ability to plan and carry out a fair-test and to record information systematically and analyze recorded information to identify patterns and trends."*

As stated by Bandura (1977), an efficacy expectation is the conviction that one can successfully execute the behavior required to produce outcomes. In the vignette response exercise, teacher candidates identified their perceived level of capability in executing a behavior within a variety of teaching contexts. Thus, the vignettes were regarded as being indicators of teacher candidate expectancy efficacy rather than outcome expectancies (Bandura, 1977) as they addressed teacher candidate beliefs about their perceptions of their ability to successfully implement such behaviors.

Finally, Section D required teacher candidates to respond to a series of ten conceptual understanding questions pertinent to scientific phenomena specifically identified in the four Contextual Strands of Levels 1 to 5 of *Science in the New Zealand Curriculum.* As well, these phenomena were explicitly addressing teacher candidate understanding in conceptual areas they were required to teach in some of the vignettes described in Section C. As an example, question 10 asked teacher candidates to:

> *"Explain the meaning of the terms heat and temperature. Give attention in your explanation to the differences and relationships between heat and temperature."*

Teacher candidate conceptual understanding in this section was ranked from (1) no correct conceptual understanding or no response; (2) some correct conceptual understanding but more incorrect than correct or poorly developed response; (3) equally correct and incorrect or only adequately explained; (4) good scientific response with some aspect omitted or misrepresented and (5) thorough response explaining phenomena fully and accurately. Descriptive and inferential statistics were conducted to analyze responses using Statistical Package for Social Sciences (SPSS).

Results

Teacher Candidate Background

This section begins by presenting some of the biographical data pertaining to teacher candidate formal science education experience and perceptions of this experience prior to and during pre-service education. In each case, teacher candidates were asked to respond to a statements pertaining to their prior science experience on a 1 (Strongly Agree) to 5 (Strongly Disagree) Likert-scale. Means analysis included One-Way ANOVA (Post Hoc Multiple Comparisons – Bonferroni) procedure to determine if differences amongst means were significant.

Prior Science Experience Perceptions	***Curriculum I (n=43) Mean (SD)***	***Curriculum II (n=44) Mean (SD)***	***Science Majors + Curriculum I (n=12) Mean (SD)***	***Science Majors + Curriculum I + II (n=27) Mean (SD)***
I had a positive school Science experience.	2.84 (1.17)	2.61 (0.97)	2.50 (1.34)	2.52 (1.16)
I was a successful Science student.	2.74 (1.03)	2.82 (0.98)	2.67 (1.21)	2.67 (0.96)
I enjoyed my school Science experience.	2.83 (1.01)	2.68 (1.09)	2.46 (0.98)	2.58 (1.24)
I have a strong Science background.	3.37**[1] (0.85)	2.67 (1.21)	2.52**[2] (0.99)	2.50**[2](1.21)

Table 1: Teacher Candidate Perceptions of Prior Science Experience
*Statistically different groups (p<0.01** and p<0.05*) are differentiated as [1] and [2].*

Table 1 presents data related to teacher candidate perceptions of whether their school science experience was positive. The majority of students in this cohort held neutral to slightly positive perceptions of their science experience. This reflects trends in other studies (Appleton & Kindt, 1999; Lewthwaite, 2000; Skamp, 1999) where teacher candidates are identified as having limited positive experience in school science. A one-Way ANOVA analysis determined that no significant difference existed amongst these means. Table 1 also illustrated the majority of students choosing to emphasize science as a teachable area had somewhat higher positive school science experiences. This statistic was not statistically significant. For the purpose of this study, this overall similarity was important as it suggested that the perception of the prior science experience for teacher candidates had been quite similar. Table 1 also indicated that teacher candidates, overall, had quite neutral to slightly positive perceptions of their success as school science students. A one-way ANOVA analysis determined, again, that no significant difference existed amongst means. Similar to international trends (Harlen, Holroyd & Byrne, 1995; Mulholland & Wallace, 1996), the majority of this cohort of teacher candidates perceived they were only moderately successful as school science students. Table 1 also presents data related to teacher candidate perceptions of the strength of their science background. The majority of teacher candidates choosing science as a teachable emphasis regarded their science backgrounds as strong. Teacher candidates who had completed only Curriculum I held a statistically significant lower perception of their strength of science background than both of the Science Major groups (Table 1). This perception of strength of background may have been reflected in teacher candidate science experience prior to or during teacher education confirming Skamp's (1989) findings that attitudes towards strength of science background are associated with exposure to science study.

The data collected from this section of the survey teacher indicated that many teacher candidates enrolled in this teacher education program perceived, and probably quite accurately, their science background was not strong and that they have had limited success in science prior to their enrolment in teacher education. In addition, many of the teacher candidates perceived that their prior science experience was not positive. The majority of teacher candidates choosing to emphasize science as a teachable area had had a more positive, but not statistically significant, school science experience. These same teacher candidates had a statistically significant higher perception of their strength of science background as a likely result of their more extensive pre-service science education experience.

Teacher Candidates Perceptions of Their Development During Pre-Service Education

A summary of teacher candidate responses to a variety of statements related to their pre-service science education are presented and briefly discussed in this section on, again, a 1 (Strongly Agree) to 5 (Strongly Disagree) Likert-scale. Means analysis included one-way ANOVA (Post Hoc Multiple Comparisons – Bonferroni) procedure to determine if differences between means were significant.

Pre-Service Science Education Experiences	***Curriculum I (n=43) Mean (SD)***	***Curriculum II (n=44) Mean (SD)***	***Science Majors + Curriculum I (n=12) Mean (SD)***	***Science Majors + Curriculum I +II (n=12) Mean (SD)***
My attitude towards science and the teaching of science has improved during my teacher education.	2.07 (0.86)	1.80 (0.59)	1.52 (0.58)	1.50 (0.84)
My interest in teaching science has improved as a result of this course.	2.04 (0.90)	1.82 (0.63)	1.48 (0.62)	1.50 (0.84)
I am pleased with the progress I have made in my science teaching knowledge and capability during this course.	2.23 (0.72)	2.09 (0.42)	1.88 (0.59)	1.83 (0.76)
I feel adequately prepared to teach Years 1-8 science.	2.74 (0.88)	2.42 (0.80)	2.35 (0.89)	2.83 (0.75)

Table 2: ***Teacher Candidate Response to Statements Pertaining to Their Teacher Education Science Experience***

Table 2 indicates that the majority of teacher candidates had experienced very positive shifts in their attitudes towards science as a curriculum area and their science teaching knowledge and capability during their pre-service science education experience. Not only do responses give clear indication that most teacher candidates, especially those just completing Curriculum I, had experienced considerable personal and professional development during their courses, they also held positive perceptions of the adequacy of the preparation for the teaching of science. This pattern supports earlier work (Appleton, 1992; Skamp, 1989) that pedagogical courses in science contribute to improved attitude and confidence towards science teaching irrespective of secondary science background and, potentially, science knowledge. No significant differences amongst the groups were identified.

Vignette Responses

Section C of the questionnaire presented teacher candidates with a variety of realistic educational settings, most of which were specific and common to the duties one might expect to encounter in the teaching of Years 1-8 science. In each vignette, candidates were asked to select a response on a 1 (very difficult) – 5 (very easy) scale that best described their level of efficacy in dealing with the situation. Table 3 presents a brief description of each scenario and the range of responses for the four cohorts under consideration. As well, a one-way analysis of variance (ANOVA – Post Hoc Multiple Comparisons – Bonferroni) was completed to compare means and determine if statistical differences existed amongst group means.

Vignette ***Description***	***Curriculum I (n=43) Mean (SD)***	***Curriculum II (n=44) Mean (SD)***	***Science Majors + Curriculum I (n=12) Mean (SD)***	***Science Majors + Curriculum I + II (n=27) Mean (SD)***
Teaching a Year Four Class.	3.74 (0.62)	3.72 (0.63)	4.00 (0.82)	3.67 (0.62)
Motivating and managing a difficult group of students during a science investigation.	2.33 (0.97)	2.27 (0.82)	2.67 (0.52)	2.52 (0.98)
Assisting a class in the planning and implementation of a science investigation.	2.51 (0.88)	2.63 (0.96)	3.00 (0.89)	2.81 (0.93)
Dealing with a class of students that argue and do not work collaboratively.	2.86 (0.80)	3.10 (0.83)	3.17 (0.75)	3.11 (1.01)
Assisting a class in developing data collection and information gathering skills in science investigations.	3.37 (0.87)	3.57 (0.70)	3.00 (0.00)	3.41 (0.94)
Developing students' scientific knowledge within a series of investigative lessons.	3.07 (0.74)	2.61 (0.74)	3.00 (0.64)	2.63 (0.97)
Teaching students' understanding about the changing relationship of the Earth, its moon and sun.	2.48(0.95)	2.28*^{1}(0.98)	2.83*^{2}(0.41)	3.00*^{2} (0.93)
Developing students' understanding about why some objects float and others sink.	4.17**^{1}(0.65)	3.02**^{2}(0.88)	4.00 (0.63)	3.15**^{2}(0.83)
Develop student understanding (at a particle level) of the difference and relationship between heat and temperature	2.58**^{1}(0.94)	3.37**^{2}(0.81)	2.77 (0.75)	3.11 (1.05)

***Table 3**: Teacher Candidate Response to Statements Pertaining to Selected Teaching Settings*
*Statistically different groups ($p<0.01$** and $p<0.05$*) are differentiated as ^{1} and ^{2}.*

One-Way ANOVA determined that no significant difference existed amongst the means for vignettes pertaining to what are regarded as generic teaching tasks. Vignettes pertaining to tasks such as teaching a grade 4 class; motivating and managing a group of students; and dealing with a class of students that argue and do not work collaboratively are educational settings which required non-curricular specific pedagogical knowledge (Table 3). For the purpose of this study, this result was important as it suggested that in regards to their general pedagogical knowledge and capability, teacher candidates had similar perceptions of their capabilities in generic educational settings.

Two of the vignettes, assisting a class in the planning and implementation of a science investigation and assisting a class in developing data collection and information gathering skills in science investigations, specifically addressed settings in which teacher candidate procedural pedagogical knowledge (knowledge of how to teach investigative skills) was explicitly required. Again, one-way ANOVA determined that no significant difference existed amongst these means. These results again suggested that even in regards to a more specialized knowledge and capability that has been identified as a common professional science teaching deficiency (Lewthwaite, 2000), teacher candidates with a range of science teaching capabilities and experiences had similar perceptions of their capabilities. Although this procedural pedagogical knowledge is developed explicitly within Curriculum I, it is further developed in all other Curriculum Inquiry and Practice and Studies in Subjects courses. These data suggest that this further exposure did not significantly influence teacher candidate perceptions of their capabilities.

Three of the vignettes pertained to developing student conceptual understanding in floating and sinking, the Earth's place in space, and the relationship and differences between heat and temperature. These vignettes depicted relatively difficult scenarios requiring specialized teacher pedagogical content knowledge and subject matter knowledge (Lewthwaite, 1999a). One-Way ANOVA determined that significant differences exist amongst these means. In comparing these four groups in these teaching contexts, the Curriculum II group had significantly lower perceptions of their ability to teach towards student understanding of the Earth's place in space than the Science Majors + I + II group. The Curriculum I group had significantly lower perceptions than the Curriculum II group of their ability to teach towards conceptual understanding of the relationship and differences between heat and temperature. In both of these cases the groups with the higher perceptions of capability had explicitly addressed these phenomena in either a Curriculum II or Studies in Subjects course. Paradoxically, the

Curriculum I group had significantly higher perceptions of their teaching efficacy than the Curriculum II and Science Majors + I groups in developing student understanding of what causes floating and sinking. The topic of floating and sinking was used as a context to develop teacher candidate understanding of the nature of science and the role of investigating in science in Curriculum I. It is suggested that because all Curriculum I students completing this survey would have recently worked within the context of floating and sinking, this exposure had strongly influenced their perception of their capability in teaching students towards understanding of what causes some objects to sink while others float.

The data collected from the vignette section of this survey suggested that in generic teaching situations where non-specific curricular, pedagogical knowledge is required (e.g. management and motivation of students) teacher candidates with a range of science teaching attitudes, capabilities and experiences had similar perceptions of their capabilities. For the intent of this study this was important as it suggested that the professional capabilities and knowledge developed in science education courses were limited in self-efficacy influence to contexts in which these capabilities would be specifically employed. That is, these aspects of science professional knowledge and capability did not influence general pedagogical capability, but, instead, influenced specialized professional capability within specific science contexts. Overall, teacher candidate responses to this limited series of vignettes indicated that the formal experience and specific professional knowledge provided in teacher education courses influenced professional self-efficacy in dealing with teaching requirements in related areas, especially when the teaching requirement explicitly was supported by subject matter and pedagogical content knowledge. One might expect that formal learning experiences in teacher education, or the lack thereof, would directly influence strength of efficacy in related professional contexts. There is evidence in this series of vignettes that strength of efficacy in particular contexts was likely be directly related to the learning experiences teacher candidates have had pertaining to these concepts.

Subject Matter Knowledge: Conceptual Understanding

The table and discussion that follow pertain to teacher candidate understanding of scientific phenomena specific to selected achievement objectives from Levels 1 to 4 (approximately Years 1-8) of *Science in the New Zealand Curriculum.* These conceptual areas addressed only selected fundamental conceptual areas of the Years 1-8 science curriculum that are addressed within Curriculum II or Studies In Subjects courses. and means and standard deviations were calculated. As well, a one-way analysis of variance (ANOVA – Post Hoc – Bonferroni) was completed to compare means and determine if differences exist amongst means.

Conceptual Understanding of Selected Science Phenomena	***Curriculum I (n=43) Mean (SD)***	***Curriculum II (n=44) Mean (SD)***	***Science Majors + Curriculum I (n=12) Mean (SD)***	***Science Majors + Curriculum I + II (n=27) Mean (SD)***
Difference(s) between living and nonliving things.	2.82*[1](1.21)	3.15 (1.04)	3.20 (1.30)	3.67*[2](1.21)
Difference(s) between plants and animals.	2.03**[1](1.08)	2.45 (0.89)	3.20**[2](1.48)	2.90**[2](1.09)
Observable changes in the moon.	2.18**[1](1.45)	2.87 (1.31)	3.28**[2](1.30)	3.29**[2](1.45)
Cause of day and night.	2.18**[1](1.52)	2.92 (1.34)	3.20**[2](1.29)	3.29**[2](1.21)
Description at the particle level of what is happening when something is evaporating.	1.85**[1](1.15)	3.13**[2](1.07)	2.00 (1.00)	3.14**[2](1.20)
Reason(s) for objects floating and sinking.	2.06 (1.18)	2.24 (0.96)	1.80 (0.45)	2.64 (1.00)
Reason(s) for clouds commonly forming over mountain ranges.	1.71**[1](1.21)	1.69**[1](1.00)	3.20**[2](1.79)	2.30 (1.43)
Description of what is happening at the particle level when something is dissolving in water	1.90**[1](1.15)	3.58**[2](1.14)	1.80**[1](0.84)	3.55**[2](1.14)
Difference and relationship between heat and temperature	1.90*[1](1.03)	2.67*[2](1.14)	1.83*[1](0.76)	2.69*[2](1.12)

***Table 4**: Teacher Candidate Conceptual Understanding of Selected Science Phenomena*
*Statistically different groups ($p<0.01$** and $p<0.05$*) are differentiated as [1] and [2].*
Responses were categorized on a 1 (No scientific understanding/wrong answer) – 5 (Full scientific understanding),

Standard deviation results indicated a wide range of conceptual understanding within each group for most phenomena (Table 4). One-Way ANOVA determined that significant differences existed amongst these means in most conceptual areas. As well, The differences between living and nonliving and plant and animal identified as a Grade 1-2 (Level One) Living World phenomenon were explicitly addressed in some

Curriculum II and selected Studies in Subjects science courses offered to Science Majors. Correspondingly, teacher candidates that had taken these courses had a better understanding of these phenomena than those that have only completed Curriculum I (Table 4). Similarly, an understanding of the reasons for the observable changes in the moon and the cause of night and day were developed in Spaceship Earth, a Studies in Subjects course. Science Major teacher candidates that were likely to have completed this course had a statistically significant higher understanding of this phenomenon in comparison to those that had completed Curriculum I only (Table 4). An understanding of the cause of the common occurrence of cloud formation over mountain ranges was similarly developed in several Studies in Subjects courses. Again, Science Major teacher candidates held statistically significant higher conceptual understanding of this phenomenon than those that have only completed Curriculum I. One-Way ANOVA determined that a significant difference existed amongst these means for the phenomena of evaporation, heat and temperature, and dissolving (Table 4). Teacher candidates that had completed Science Curriculum II had a significantly higher conceptual understanding of the phenomena. This topic of study was explicitly addressed in this science course. The development of conceptual understanding pertaining to flotation was not explicitly addressed in any course within the degree structure.

The data collected from the conceptual understanding section of the questionnaire indicated that teacher candidate conceptual understanding in the areas examined was consistently linked to courses completed during their teacher education. Although some variation existed in this tendency, trends in teacher candidate understandings paralleled the subject matter content of the courses they had completed. That is, where teacher candidates held significantly higher understanding in a concept area, this was consistently related to the subject matter covered in corresponding Curriculum II or Studies in Subjects courses that teacher candidates may have studied. Teacher candidates that were in the Science Majors + I + II group generally held the highest conceptual understanding of the phenomena selected for analysis. Although the Curriculum I group had the most limited pre-service science education experience and often showed the lowest level of conceptual understanding of these selected phenomena, those teacher candidates that were designated as Science Majors + I held the lowest conceptual understanding means for several of the phenomena under analysis. This suggests that although this group had likely developed an understanding of more complex scientific phenomena and processes during their Studies in Subjects courses, their understanding of some basic science phenomena pertinent to Grades 1 to 8 of the national science curriculum, as represented by some of the concepts in this section of the survey, was quite limited.

Correlating Self-Efficacy with Conceptual Knowledge

The final analysis in this research exercise was conducted to determine if correlations (Spearman) exist amongst teacher candidate professional self-efficacy and professional science knowledge structures. The vignettes had been developed to address (a) particular knowledge structure(s) including subject matter knowledge. As well, some of the conceptual understanding questions were based on subject matter knowledge of phenomena explicitly addressed in the vignettes. Thus, the strength of efficacy in teaching a phenomenon could be correlated to conceptual understanding of this phenomenon.

The first correlation was completed between the vignette

You are required on Teaching Experience to teach a very bright Year 8 class about the relationship and difference between heat and temperature (at a particle level) with an emphasis on developing their knowledge in this area. How difficult would this be for you?

and the following conceptual understanding question:

Fully explain the relationship and differences between heat and temperature.

In this correlation analysis, a weak negative correlation ($r = -0.12$) existed between self-efficacy and conceptual understanding for Science Majors + I, suggesting that the Science Major group that had completed only Curriculum I had a strong perception of their capability to teach their students' about the relationship and difference between heat and temperature, yet did not possess this understanding themselves. In contrast, a positive correlation existed between Science Majors + I + II (r = 0.56) and Curriculum II (r = 0.49) teacher candidates and their conceptual understanding of the phenomena. Again, an understanding of this conceptual area was only explicitly addressed in Curriculum II.

A further correlation was conducted between the vignette

During Teaching Experience, you are required to teach an accelerated group of Year 6 students a series of linked lessons related to the relationship of the sun, the Earth and moon and observable changes in the position and appearance of the sun and moon in our sky. How difficult would this be for you?

and the following conceptual understanding question:

If you observed the moons "behavior" (appearance, movement, shape, etc.) over a month, what would you expect to see? As well, explain what causes this "behavior".

In this correlation analysis, there was a positive correlation (r = 0.29 & 0.32) between self-efficacy and conceptual understanding for both Science Major + I and Science Major + I + II groups respectively. This indicates that those groups that had a strong perception of their capability to teach this area similarly possessed an understanding of this phenomenon. Again, this conceptual area was only explicitly addressed in the Studies in Subjects course, Spaceship Earth.

A final correlation was conducted between the vignettes

During Teaching Experience you are required to teach a 4-lesson sequence on the topic of floating and sinking where you assist children in developing an understanding of what causes some things to float and others to sink. How difficult would this be for you?

and the following conceptual understanding question:

Fully explain why some objects float in water while other objects sink.

In this correlation analysis, a strong negative correlation existed between science teaching self-efficacy and scientific conceptual understanding for both the Curriculum I (r = -0.67) and Science Majors + I (r=-0.78) groups, suggesting that the Science Major group that had completed only Curriculum I and the group of teacher candidates that had only completed Curriculum I during their teacher education had a very strong perception of their capability to teach their students' towards an understanding of floating and sinking, yet did not possess this understanding themselves. In contrast, a positive correlation existed between Science Majors + I + II (r=0.32) and Curriculum II (r=0.29) teacher candidate self-efficacy and conceptual understanding of the phenomena even though an understanding of this phenomenon was not developed explicitly in Curriculum II.

In addition to these correlations, further correlations were determined for strength of science teaching efficacy, conceptual understanding and teacher candidate perceptions of their level of strength of science background and preparation by comparing selected items within the questionnaire. Science Majors + I and Science Majors + I + II teacher candidates showed positive correlations ($r = 0.67$ and $r=0.84$ respectively) between their perceived strength of science background and strength of professional teaching efficacy. Despite this positive correlation, the Science Major + I and, less commonly, the Curriculum I, teacher candidates showed negative correlations ($r = -0.35$ and $r = -0.22$ respectively) between general science teaching efficacy and overall conceptual understanding scores in the basic conceptual areas addressed in the conceptual understanding questions. This suggests that Science Majors + I teacher candidates commonly held a more positive perception of their ability to teach science, as represented by the surveyed vignettes, than their conceptual understanding of basic phenomena indicated. Conversely, teacher candidates that had enrolled in Curriculum II (both majors and non-majors) showed a tendency for positive correlations between their conceptual understanding and self-efficacy ($r=0.32$).

Since the vignettes implicitly are underpinned by specific knowledge structures, it is worthy to note the relationship between specific knowledge structures and self-efficacy. As stated in the introduction to this paper, although the subject matter knowledge of science teachers is believed to play an important role in teachers' science teaching efficacy beliefs (Baker, 1994; Education Review Office, 2002), this research exercise would suggest, similar to previous findings (Appleton, 1992; Skamp, 1989) that these links are likely to be, at best, rather tenuous. There is no consistent correlation between subject matter knowledge in selected conceptual areas and science teaching self-efficacy in these areas. This suggests, similar to Appleton's (1992) findings that the development of science teaching professional efficacy in teaching situations requiring teacher candidates to foster student conceptual understanding is, potentially, as much a product of experience and exposure to conceptual areas as it is based on teacher candidate conceptual understanding.

Implications of this Study

The data collected from this study affirm Skamp's (1989) assertion that those teacher candidates who have had a greater exposure or 'immersion' in science during their pre-service education have a higher science teaching expectation efficacy despite how well-developed their foundational scientific understanding might be. As well, quite paradoxically, these same teacher candidates had a more reserved perception of the adequacy of their preparation as a teacher of science. Despite this reservation, those teacher candidates that had chosen science as an area of teaching specialization held consistently high perceptions of their expectation efficacy as teachers of science in most conceptual areas addressed by the vignettes. Although this high expectation efficacy positively correlated to their content knowledge of some of the conceptual areas they are required to teach, in other situations, these same teacher candidates' teaching self-efficacy was negatively correlated to their understanding of the phenomenon. Similarly, teacher candidates in the Curriculum I group had comparatively, in some situations, very strong expectation efficacy of teaching in selected conceptual areas but possessed very poor understanding of these same and most phenomena. Similar to Appleton's findings (1992), this study suggests a tenuous link amongst subject matter knowledge and confidence and attitude to the teaching of science.

It is apparent from this study that those teacher candidates that have had more science experience through *both* a variety of Studies in Subjects (emphasizing subject matter and pedagogical content knowledge) and Curriculum Inquiry and Practice (emphasizing curricular, pedagogical and pedagogical content knowledge) courses hold consistently (1) higher perceptions of their capabilities as teachers of science; (2) higher conceptual understanding of foundational science phenomena and (3) more positive attitudes towards the teaching of science as future educators in comparison to those that have only completed a foundation Curriculum and Inquiry course. The data from this analysis also suggest that Science Major teacher candidates that have completed only the foundational Curriculum and Inquiry course, although having a strong perception of capability and subject matter knowledge of more advanced science phenomena, have limited understanding of some foundational science phenomena.

The data collected from this survey have been valuable in informing recent modifications to the course structure of the BEd (Teaching-Primary) program in which this study was conducted. The trends in the data identified the influence that Studies in Subjects courses had on teacher candidate self-efficacy and advanced knowledge structures largely unaddressed by this study and supported the retention of these courses in the program. The data had also identified the poorly developed foundational subject matter knowledge base of both groups of teacher candidates in the BEd program that had completed Curriculum I only, whether they had selected science as a curriculum area of specialization or not. For this reason, all teacher candidates in the program are now required to complete a further Curriculum Inquiry and Practice course in science education. Finally, the data provided clear indication that teacher education programs that provide their teacher candidates (whether science specialists or not) with only a foundation course in science education lacking in foundational subject matter and pedagogical content knowledge are unlikely to contribute sufficiently to the development of the professional science knowledge, interest and efficacy necessary for entry-level teachers.

Summary

As both the national and international science education community continue to consider the parlous nature of elementary science education, pre-service science education must continue to be given serious attention as a critical agent in affecting professional attribute change in teachers of science (Skamp, 1989, Education Review Office, 2002). In response to this challenge, this study addresses Skamp's (1989) concern in attempting to understand the uncertain relationships between the type of science studies taken during pre-service teacher education and their influence on students' attitudes and efficacy. The study identifies the influence of course structures within a pre-service program on teacher candidate science professional knowledge and perceptions of professional science teaching attitude and efficacy. As Appleton (2003) states, bringing about personal attribute change is not just about increasing the amount of science subject matter content in pre-service programs. On the basis of this study, it is suggested that all science education programs must contain substantial course elements that provide for learning experiences to foster development in science teaching self-efficacy and attitude, as well as the multidimensional nature of the professional knowledge structures foundational to the elementary science curriculum. Finally, despite the contribution of this study in understanding the influence of particular courses on science teacher professional attributes, it does not provide a concise answer as to what constitutes a good science education program in regards to promoting professional science teaching attributes for its' teacher candidates. Instead, for the College of Education in which this research is conducted, these data instead have provided the potential foundation for further decision-making amongst its science educators and the College of Education as a whole for an improvement to courses and an overall course structure for purposeful science teacher education.

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