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Changing Science Teaching Practice in Early Career Secondary Teaching Graduates

Rex Bartholomew, Azra Moeed, and Dayle Anderson
Victoria University of Wellington, Wellington, NEW ZEALAND

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Initial teacher education (ITE) is being challenged internationally to prepare teachers with the understandings needed to teach an increasingly diverse student population. Science teachers need to prepare students with both conceptual and procedural understanding. The challenge is to prioritise a balance in ITE courses between theoretical perspectives, curriculum requirements, and pedagogical approaches. This paper presents results of a three-year longitudinal study from pre-service through two years of in-service teacher development, and provides an insight into how pre-service and early carrier teachers gain confidence in their subject matter and pedagogical content knowledge and the teaching strategies they implement.

Keywords: Initial Teacher Education, Subject Matter Knowledge, Teaching Strategies

INTRODUCTION

Initial teacher education programmes face multiple challenges. Tensions exist in ensuring sufficient coverage: effective implementation of the curriculum; subject matter knowledge; pedagogical content knowledge, multiple strategies to engage the students in wanting to learn and learning; and, the requirements of assessment, particularly in senior secondary school. McGee, Cowie and Cooper (2010) suggest that student teachers should be engaged in learning experiences that will get them started in teaching and develop expertise so that in future they can have a positive influence on their students' learning. Critics of teacher education programmes suggest there is a mismatch between what the student teachers have learnt and can apply in the classroom (Cameron, 2007). Conversely, there is evidence that supports the view that new teachers have a positive impact on their students' learning when student teachers implement the practices they have learnt during initial teacher education (ITE) programmes (McGee et al., 2010).

Faced with these tensions and critique of the structure and content of secondary science teacher education we undertook this research to gauge the effectiveness of our teacher education programmes. We investigated not just how prepared the student teachers felt when they completed our science methods courses, but also how they perceived themselves as teachers of science in the first two years of their secondary teaching careers.

Theoretical perspectives and connection to literature

How new teachers perceive science teaching and learning is influenced by their own experiences (Finson, Pedersen, & Thomas, 2006). A key element of our ITE programme was to provide opportunities and learning experiences for the student teachers. The study takes the perspective that teacher confidence and knowledge influence classroom practice. Teacher confidence can determine whether or not, and how, science education occurs in the classroom (Anderson, Bartholomew, Moeed & Kinsella, 2009; Appleton, 2006; Grossman,

Correspondence to: Rex Bartholomew, Senior Lecturer Science Education, School of Education Policy and Implementation, Victoria University of Wellington, PO Box 17 310, Karori, Wellington, NEW ZEALAND
E-mail: rex.bartholomew@vuw.ac.nz

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State of the literature

- Critics of teacher education programmes suggest there is a mismatch between what the student teachers have learnt and can apply in the classroom.
- Conversely, there is evidence that supports the view that new teachers have a positive impact on their students' learning when student teachers implement the practices they have learnt during initial teacher education (ITE) programmes.
- It is suggested that ITE programmes need to teach subject matter knowledge, general pedagogical theory, and pedagogical content knowledge.

Contribution of this paper to the literature

- This study takes the perspective that teacher confidence and knowledge influence classroom practice.
- We undertook to gauge the effectiveness of a teacher education course that focused on subject matter knowledge and pedagogical content knowledge.
- We investigated how teacher graduates perceived themselves as teachers of science in the first two years of their secondary teaching.
- All participants reported being well prepared by their pre-service science course.

Wilson, & Shulman, 1989; Jarret, 1999). Amongst the sets of knowledge that teachers bring to teaching are subject matter knowledge (SMK) and pedagogical content knowledge (PCK) (Shulman 1986, 1987). The nature and breadth of the former can be problematic and ways of building this knowledge need to be addressed given the evidence that possession of sound SMK has a positive impact on teacher effectiveness (Kind, 2009). SMK includes both syntactic and substantive elements (Shulman, 1987). In terms of syntactic knowledge, the perspective of the nature of science promoted in the ITE courses in the programme examined in this study is one in which theories about how the world works are developed by people and that these ideas change over time as new evidence is presented, discussed and critiqued by the scientific community (Lederman, 1999). This view of science is developed in lectures and reinforced in tutorials as pre-service teachers explore different aspects of science. A social-constructivist approach (Bell & Gilbert, 1996) to science learning is encouraged which is in congruence with the approach promoted by *Science in the New Zealand Curriculum* (*SiNZC*) (Ministry of Education, 1993), and the *New Zealand Curriculum* (Ministry of Education, 2007).

According to Appleton (1995), factors other than exposure to more science content in ITE courses may influence beginning teachers' confidence. Pedagogical content knowledge (PCK) is about "how to teach particular content in particular ways in order to lead to enhanced student understanding" (Loughran, Berry, & Mulhall, 2006. p. 9). According to Bell and Gilbert, 1996) teaching science requires more than knowing content and how to teach. It requires an understanding of how to teach the content, that is, PCK. PCK development includes learning about strategies and approaches, and begins during pre-service education – including during practica – and continues with classroom experience. Science education places an emphasis on conceptual learning through a variety of approaches, including practical investigations and group learning using teaching strategies typically underpinned by either cognitive or social constructivist views of learning. Hipkins et al. (2002), in their extensive review of science education literature, posit that a significant factor in what happens in the classroom is "the teacher's familiarity and confidence with a variety of different types of strategies and their experiences of success in using these" (p. 238). Further evidence suggests that "intense SMK preparation helps in transformation to PCK" in case of pre-service teachers teaching outside their area of expertise within science (Kind, 2009, p. 1548). If initial teacher programmes promote new approaches in teacher education courses, then these approaches need to be part of their own teacher development (Ackay, & Yager, 2010). The same concern was the motivation for this study.

Objectives

In order to improve the efficacy of initial teacher education programmes, we investigated three aspects of pre-service secondary school teachers' perceptions:

- ✓ *confidence in their ability to teach science*
- ✓ *ability to access and update subject content knowledge together with factors that influence the development of SMK*
- ✓ *application of science teaching strategies and approaches [PCK] (aspects of pre-service science education courses that were regarded as useful were identified).*

The above perceptions were monitored as the teachers moved from pre-service into the first two years of their career

Research questions

- ✓ *How does pre-service teachers' confidence in teaching science develop in the first two years of teaching?*
- ✓ *How do pre-service teachers and early career science teachers develop their subject matter knowledge?*

- ✓ *How does teachers' selection of teaching strategies change from initial teacher education through the first two years of teacher practice?*

METHODOLOGY

This research investigated the case of early career science teacher development. Our interest was in understanding how pre-service science teachers at the completion of their ITE course continue to develop in their first years in the classroom. The case was investigated through an initial teacher survey, teacher interviews during the first two years, and a survey and interview at the end of their second year in the classroom.

The ITE Secondary Course 2006

The Diploma of Teaching (Secondary) science education course involves 30 two-hour workshops and additional time allocation of 20 hours to complete an online course in students' senior specialist science subjects. There are no lectures in this course. The course focused on teaching science, teaching about science (Nature of Science) and doing science (investigations) (Hodson, 1998; Monk, 2006). Workshops provided students with the opportunity to explore science concepts through practical activities and discussion, become familiar with teaching and assessment strategies, participate in practical activities and investigations, and to discuss the reasons for teaching in particular ways. Each workshop culminates in a structured reflective way by unpacking the session both in terms of learning and management. The courses are supported by comprehensive and up-to-date books of readings. The senior online courses require students to become familiar with *Science in the New Zealand Curriculum* (Ministry of Education, 1993), the then current curriculum document as well as the senior subject curriculum documents for biology, physics and chemistry. They also covered examination requirements and other assessment processes followed for qualifications.

Participants

The research was conducted among participants from secondary school teacher education courses. The participants comprised all those who agreed to participate from the then current cohort of pre-service teachers undertaking the Graduate Diploma in Teaching secondary science courses who were likely to teach general science to junior secondary school students and physics, chemistry or biology to senior secondary school students. The entry requirement for teaching at this level is a tertiary degree in a science discipline. Twelve (out of 16) secondary school pre-service teachers participated in the research. The pre-service teachers were both males and females between the ages of 21 and 50 with a mixture of ethnicities including New Zealand European, Māori, Pacific Nations, and Asian.

Data collection and analysis

Questionnaires were used to gather data from participants at the end of their ITE programme and after two years in the classroom. The questionnaires comprised a mixture of Likert-scale, selected and ranked responses, and open-ended questions. The questionnaires were piloted to ensure common understandings of the questions. Participants were interviewed at the end of heir first and second year as practising science teachers and completed a sequel questionnaire at the end of their second year in the classroom.

Questionnaires and interviews explored teacher confidence, their SMK at the completion of the ITE courses and how they continued to access and develop it. Data were also collected regarding participants' use of teaching approaches and strategies as well as their perception of the usefulness of the ITE science course. All researchers collaborated in coding and processing the responses to reduce bias. Responses for qualitative data were sorted as themes emerged.

RESULTS

The results are reported beginning with teacher confidence, followed by SMK, teaching strategies and approaches, and the perceived usefulness of this ITE course.

Teacher confidence

Participants expressed a positive shift in their attitude toward science teaching during ITE. Changes in teaching practice related more to their pedagogical approach than to their SMK and led to increased confidence in their own ability to teach science. Several teachers commented on the importance of science in understanding environmental issues.

Confidence in the classroom

Following two years of teaching practice, confidence in student teachers' ability to teach science increased from a mode of 4, on the six point Likert scale, to 5 (see Table). All participants also reported being well prepared by their pre-service science course. They mostly (9/12) indicated that they were confident or very confident about their ability to teach science. All (12/12) credited their pre-service science education course as a reason for this. A smaller number credited

their experiences in the classroom or their associate teachers.

There was a slight improvement in reported ease of teaching science over the first two years of professional practice (see Table 2). This was reflective of the increased confidence, though none found it very easy to teach the subject. Some illustrative examples of interview comments that confirm this are: "I am not always confident before I teach a new concept, but I do a lot of background learning and teaching, it then improves my confidence (Female teacher, 2008); and "Improved from first year, and teaching with more confidence. Need to have more time in practising experiments before teaching them. Haven't taught all the units in Y10" (Male teacher, 2008).

Subject matter knowledge (SMK)

Pre-service teachers indicated that their ability to access SMK had developed as a result of their ITE courses (11/12). When participants were asked which aspects of the ITE course supported their ability to access new SMK, they referred to teaching resources distributed by lecturers (5), experiments/class activities (5), ideas presented in tutorials, websites, and sharing ideas with peers (2 each). Teachers were asked not to include SMK derived from previous academic study. Following two years of practice, confidence in their own SMK rose from a mode of 4 with no teachers reporting 6 (very confident), to a mode of 5.5 with 40% reporting 6 on the Likert scale (see Table 3).

Teachers reported being more confident in the biological sciences than the physical. One teacher reported that:

- ✓ *My confidence in teaching Science stems from teaching in a supportive environment where it is OK for me to admit that I do not have the content knowledge of a Google search. I readily admit that I don't know everything and this has made it far easier to relate to my students and the science content. I do a lot of background research when I'm not confident in a topic, and I like learning along side my students. (Female teacher, 2008)*

As the student teachers had identified gaps in their SMK as an enduring issue during their ITE course, they were asked how confident they were at accessing SMK. In 2006 more than half of the participants were very confident; however, by the end of their second year all reported being very confident at accessing SMK (see Table 4). Key sources for updating SMK were identified as text books, colleagues, and school resources.

Teaching strategies and approaches

As part of the questionnaire, participants were provided with a list of teaching strategies derived from those covered in the courses, and those commonly used in science classrooms. They were asked to indicate on the list those they had used and the degree of success that they experienced in using them. Immediately following ITE, participants reported commonly using worksheets, formative assessment (assessment of

Table 1. Reported confidence at teaching science

Likert scale	Very difficult ①	②	③	④	⑤	Very easy ⑥
2006		1	2	8	1	
2008				1	6	3

Table 2. Reported ease of teaching science

Likert scale	Very difficult ①	②	③	④	⑤	Very easy ⑥
2006		1		5	1	
2008			1	4	5	

Table 3. Reported confidence in their own science subject matter knowledge

Likert Scale	Not at all confident ①	②	③	④	⑤	Very confident ⑥
2006			2	7	2	
2008			1	1	4	4

Table 1. Reported confidence at accessing subject matter knowledge

Likert Scale	Not at all confident ①	②	③	④	⑤	Very confident ⑥
2006				3	4	4
2008						7

learning during learning) (Bell & Cowie, 1999), analogies, and teacher-led discussion. Following two years of practice they reported continuing to use most of these; however, teacher-led discussion was used less often and group discussion increased slightly. There was a marked increase in the use of video and internet resources, games, use of the Predict Explain Observe Explain (PEOE) teaching strategy, and field trips. There was also a slight increase in the use of investigations, experiments and demonstrations (see Table 2).

When asked what their common sources of science activities were, participants reported: YouTube clips, Internet searches for student activities, recommended activities in the textbook, recommended activities from colleagues, and student suggestions.

Table 2. Reported successful use of teaching strategies – combining all "used successfully" Likert categories

Teaching strategies and activities	2006	2008
Worksheets	11	10
Formative assessment	11	8
Analogies	10	8
Teacher led discussion	10	7
Investigations	9	10
Experiments	9	10
Demonstrations	9	10
Text books	9	8
Copying notes from board	9	8
Models	9	7
Summative assessment	8	9
Cooperative group work	8	6
Diagnostic assessment	8	6
Group discussion	7	9
Teaching in context	6	2
Use of video	5	10
Use of internet	5	10
Games	5	9
Student generated questions	5	7
Making notes from book	5	4
Stories	5	1
PEOE's	4	10
Fieldtrips	3	9
Culturally relevant activities	3	6
Integrated approach	2	3
Other	0	0
N	*11*	*10*

Investigative approaches

Participants reported feeling slightly more confident with using investigative approaches immediately following their ITE than they did after two years of practice. The dilution of confidence is within the same range on the Likert scale, but is less aggregated at the higher confident levels (see Table 6).

All types of investigation were reported as being used more often after two years of practice, except pattern seeking investigations which declined, and developing systems which remained low (see Table 7).

In response to being asked what factors influenced their choice of strategies, participants reported their own content knowledge and experience of using the strategies in their ITE or subsequent teaching as most helpful, especially at the beginning of their career. Available time was identified as the greatest limiting factor when deciding the choice of investigative strategies. By 2008 fewer participants found student behaviour a hindrance, recourses and equipment had become important limiting factors and time had become a bigger hindrance, together with student behaviour (see Table 8).

Perceived value of ITE course

In response to the question "How well do you feel your pre-service science education course has prepared you for teaching science...", there little change from a mode of 4 to a mode of 5 on the 6-point scale; 6 on the scale equated to "extremely well" (see Table 9).

- ✓ *I think the nature of teaching is that a lot of it has to be learned as you go. A longer course would have provided better preparation, but as I completed a one-year diploma there wasn't a lot of time available for the amount of learning that a teacher needs to go through. (Female participant, 2008)*

Influences on teaching practice over the three years

During the interviews participants reflected upon changes in their teaching approaches and identified a number of influences that led to these changes. Although not requested by the researchers, participants volunteered further information related to the reasons for any changes. Two such examples were:

- ✓ *I do more book-based work than I did to start with. I was very motivated to do hands-on, kinaesthetic/ visual learning, but my classes struggled to put their ideas into words. Now I integrate the two more. Assessment results were not in keeping with my expectations. Students showed good understanding in class discussion, but their exam literacy was low. I have had to take this into consideration in planning and include more written notes and literacy strategies in my teaching. (Female teacher, 2008)*

- ✓ *How teaching in a SCHOOL is different to my ideals of teaching. Other influences that effect what you can and can't do in a classroom, like HODs, curriculum selection, health and safety, cost, senior management view on how a classroom should be run. Negative experiences with HODs senior management, and a school / department are much more focused on grade averages, than engendering a love of science or of learning. (Male teacher, 2008)*

Teachers identified enjoyable and not so enjoyable aspects of their teaching. They reported as enjoyable student interaction, experiments and group learning, EOTC sessions, and students asking questions and wanting to learn more about a topic. Marking, over assessment, repeated teaching of the same topic, poor student behaviour, insufficient preparation time, and cleaning up after students were reported as being less enjoyable.

When asked "how do you think you have grown in your ability to teach science?" participants reported:

- ✓ *I'm starting to accept some of my limitations. That is probably a good thing. (Female teacher, 2008)*
- ✓ *Much better content knowledge and understanding, thus enabling use of models and analogies as well as being able to use other kinds of experiential learning ☺ (Male teacher, 2008)*
- ✓ *Improved knowledge, and learning to target more specific areas for the students to learn. More evaluating of my own lessons, and self-reflection. Developing my own practical experiments/activities which the students might enjoy. (Male teacher, 2008)*

Table 6. Reported confidence at using an investigative approach

Likert Scale	Not at all confident ①	②	③	④	⑤	Very confident ⑥
2006			3	1	8	1
2008			1	3	4	2

Table 7. Summary of reported types of science investigation used

	2006	**2008**
Pattern seeking	8	4
Fair testing	7	10
Investigating models	7	10
Exploring	6	9
Classifying & identifying	5	8
Making things	5	8
Developing systems	2	2

Table8. Reported factors that affected teacher choice of investigative strategy

	2006			**2008**		
Factor	**Helped**	**Hindered**	**Neutral**	**Helped**	**Hindered**	**Neutral**
1. Your knowledge of the content	10	0	1	6	2	2
2. Your experience of these approaches in pre-service science education courses	9	0	1	7	2	1
3. Your past experience of using these approaches in your teaching	8	2	1	9	0	1
4. Nature of the conceptual content of the science topic	6	2	3	7	1	2
5. Your ability to manage students	6	3	2	6	3	1
6. Associate	6	3	2	2	0	4
7. Resources	6	3	2	3	7	1
8. Equipment	4	5	2	1	8	1
9. Student behaviour	3	6	2	1	5	4
10. Time available	3	7	1	0	9	1
11. Classroom organisation	2	3	6	3	4	3
12. Safety issues	1	4	6	0	3	7

Table 3. Reported usefulness of ITE in teaching practice

	Not useful					Very useful
Likert scale	①	②	③	④	⑤	⑥
2006					4	5
2008				2	6	2

In response to being asked *to what do you attribute this growth?,* teachers reported:

- ✓ *Better understanding of my students. The knowledge that I can present them with choices and I can make those choices as varied and interesting as I possibly can, but in the end the choice is theirs to make. When they make it, I can help them, but I cannot make their choices for them. (Female teacher, 2008)*
- ✓ *Experience and research. (Male teacher, 2008)*
- ✓ *Improving content knowledge, better communication and feedback with peers, Self-reflection (Male teacher, 2008)*

Asked about their vision for science education, teachers responded:

- ✓ *Everyone should do it. It should be a living thing. There should be no dust on the resources.*
- ✓ *Secondary education occurs during the last great growth-spurt of the human brain. Science education should be about building the synaptic connections between logic, creativity, enquiry, and communication that will enhance whichever field our students enter in their adult lives. (Female teacher, 2008)*
- ✓ *That it should pique students interest, teach them how to learn and how to discover and hypothesise so that they can take their own learning forward without a teacher. (Male teacher, 2008)*
- ✓ *To develop more enquiring minds, and self-reflection in the students. To develop their initiative. (Male teacher, 2008)*

DISCUSSION AND CONCLUSIONS

Confidence in their ability to teach science remained high and increased slightly between completion of ITE and during the first two years of teaching. Initially, participants were somewhat confident and attributed this confidence to their initial teacher education. This information was useful for informing the course content as it is teacher confidence that determines the actual content they teach and how they teach it (Anderson et al., 2009; Grossman et al., 1989; Jarret, 1999). Secondary school teachers graduating from the ITE course reported finding it fairly easy to teach, and following two years of practice the same teachers reported improvement in both the ease of teaching science and their self confidence. When starting on their teaching journey, teachers' initial confidence came from having tried out various teaching approaches during ITE. However, it is only possible to provide limited opportunities for practical work in the time allocated in the ITE course. It appears that the illustrative examples used in the course contributed towards the initial confidence in teaching. The early career teachers at the end of the first two years found it critical to try out the practical they would like to use in class which is in congruence with findings of Kind (2009) in the United Kingdom. Anderson et al. (2009) found that according to pre-service teachers, confidence comes from trying out beforehand what they want their students to do. These indicators of successful practice are likely to be linked to the building of experience in using a wide range of teaching strategies, the successful use of investigative approaches, their increasing confidence in their own SMK, and how to develop that further.

There was considerable improvement in pre-service teachers' confidence in their SMK and their ability to access it between 2006 and 2008. As SMK anchors the teaching approach early career teachers apply in their teaching, this finding is significant. Additionally, sound SMK is almost a pre-requisite to the development of PCK and has a positive effect on teacher effectiveness (Kind, 2009).

As teachers become confident in SMK and develop ways of accessing it they appear to try out a variety of pedagogical approaches. At the end of their ITE, pre-service teachers reported using: worksheets; formative assessment; teacher-led discussion; and investigations, experiments and demonstrations. The use of these strategies remained high in 2008, two years later, although teacher-led discussion was replaced by group discussion. There was a considerable increase in using PEOEs and fieldtrips. There was a decline in the use of text books and copying notes. Teachers' use of teacher-led discussion, worksheets and written work is in congruence with Loughran, Mulhall and Berry's (2008) findings that when student teachers are faced with topics they have not taught before and for which they do not have depth of content knowledge, they turn to a more transmissive approach to delivering the content even though they are dissatisfied with doing so. This shift from a more teacher-led approach may be an indication that there was a willingness to give the students some responsibility for their learning.

Although there was a slight decrease in using an investigative approach, it may be that such an approach was used in a structured way for assessment purposes in senior school and the teachers perhaps wanted to use it less with their junior science classes. Teachers continued to use different types of investigations in which there was a noteworthy increase in the use of fair testing and investigating models and a decrease in a pattern-seeking type of investigation. In terms of factors that influenced the choice of teaching strategy, having SMK was crucial. However, SMK was a more important factor at the end of ITE and less so for early career teachers at the end of their first two years of teaching. Given the importance of SMK as a condition of effective teaching (Kind, 2009), the improvement in teacher confidence in this area is encouraging. That the teachers unanimously reported being very confident at accessing SMK by the end of their second year of practice is in sharp contrast with the qualms of incoming student teachers. Participants revealed an increasing awareness of the role

of experience in developing PCK, and a more pragmatic, less idealistic approach to teaching.

Early career teachers believed lack of time, poor student behaviour, safety issues related to taking an investigative approach, and the lack of availability of equipment in good working order to be barriers to taking an investigative approach. These factors were also reported as barriers to taking an investigative approach by New Zealand science teachers during the curriculum stocktake (McGee et al., 2003). In the current study time, safety issues and student behaviour were perceived as less of a hindrance as teachers gained experience and the resources and equipment were perceived as more of a hindrance.

More generally, Magnusson, Krajcik and Borko (1999) posit that a teacher's knowledge and beliefs about the purposes and goals for teaching science are related to the teaching approaches they take. A more didactic orientation is associated with the goal of transmitting the facts of science where the teaching approaches include the teacher conveying information, and students being expected to learn facts. Magnusson et al. provide research evidence showing how such orientations may influence the development of PCK accordingly. In the same vein, Henze, van Driel and Verloop (2008) hypothesise that secondary teachers' development of PCK is related to teachers' general pedagogical knowledge and their beliefs about the nature and purpose of science education. A greater influence on teaching strategies used by the secondary teachers may be associated with the focus on assessment, especially in the senior school, and the need to 'cover' the content (Hume & Coll, 2008). That most of the strategies encouraged on the ITE course were reported as being used successfully was pleasing, as was the subtle shift from teacher-led approaches toward student-led. The reported increase in use of internet resources, particularly video-clips from sites such as YouTube, is a recognisable trend in this group of early career science teachers. The increase in the use of field trips is most likely related to having opportunities to be able to organise them as they said there were relatively few when they were student-teachers on practicum placements.

Given the changes underway in New Zealand ITE programmes that are resulting in reduced student contact time, the findings of this study are relevant for science course development. A follow-up study on graduates from the current modified course is planned, which will allow direct comparison of recent graduate teacher perceptions of the two ITE strategies.

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