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Primary Connections: Simulating the Classroom in Initial Teacher Education

Anne Christine Hume

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Abstract The challenge of preparing novice primary teachers for teaching in an educational environment, where science education has low status and many teachers have limited science content knowledge and lack the confidence to teach science, is great. This paper reports on an innovation involving a sustained simulation in an undergraduate science education course as a mediational tool to connect two communities of practice—initial teacher education and expert primary science teaching. The course lecturer and student teachers role-played the expert classroom teacher and primary students (Years 7/8) respectively in an attempt to gain insights into teaching and learning through authentic activity that models good practice in primary science teaching and learning. Activity theory was used to help frame and analyse the data. Findings from the first trial indicate that the simulation was very effective in initiating science pedagogical content knowledge (PCK) development of primary student teachers.

Keywords Primary science teacher education · PCK · Activity theory · Simulation as a meditational tool

Introduction

Worldwide disquiet about the low status of science education in primary schools has been long-standing (Kenny 2010). Research indicates that the poor showing of science relative to other curriculum areas in primary school programmes relates closely to many primary teachers' lack of confidence in teaching science. For many primary teachers, their low self efficacy is a direct consequence of their limited science content knowledge (e.g., Hipkins and Bolstad 2008; Lloyd et al. 1998; Nilsson and van Driel 2010; Rice 2005), and may even lead some to 'avoidance' of science in their classroom (Tytler et al. 2008). Further compounding the issue is the raised profile of literacy and numeracy in recent national curricula, which is placing even greater pressure on science education as schools predictably relegate science to a lower priority level (Kenny 2010; The Royal Society 2010).

A. C. Hume (✉)
School of Education, University of Waikato, Private Bag 3105, Hamilton, New Zealand
e-mail: annehume@waikato.ac.nz

The low status of science education inevitably impacts upon the nature and quality of primary science education as research findings into students' attitudes to science, especially in their early years of schooling, are showing. It appears many students are disengaging from science at a time when their inherent curiosity about the physical world should be to the fore, and capitalised upon and promoted in teaching and learning programmes. The Royal Society highlights this worrying decline in student interest in their 'State of the Nation' report (2010) into mathematics and science teaching in Britain. "Children are innately curious about the natural world. But, year after year, large proportions are 'turned off' science and mathematics by the time they reach secondary school, with little prospect of that interest being rekindled" (p. vii). Similar observations are reflected in recent studies in Australia (Tytler et al. 2008), and in New Zealand where attitudinal data collected during the National Educational Monitoring Project (NEMP) across four sample rounds (1995, 1999, 2003, 2007) also indicated a trend to a decline in engagement from middle primary (Year 4) to upper primary (Year 8) (Hipkins and Bolstad 2008).

The causes of student disengagement from science are complex, but central to their active involvement and participation in science learning at school is enjoyment of the classroom experience. Despite the proven success of strategies like discussion, working in groups, and using an inquiry-based approach to learning in real life contexts, many students are being 'bored to death' by whole-class teaching and uninspiring practical work that does not reflect the true nature of science (The Royal Society 2010). The issue of what inhibits teachers from using the most effective strategies needs further research, but certainly the professional knowledge of many teachers is known to be weak, i.e., science content knowledge and pedagogical content knowledge [PCK] (Shulman 1987), and this weakness must be a significant underlying cause of teaching that does not connect with the learner. Teachers who completely avoid teaching science may further exacerbate students' disengagement from science (Tytler et al. 2008).

In a professional community like primary teaching, where most practitioners are generalists, the task of deepening the science content knowledge and the associated pedagogies is massive (The Royal Society 2010). Raising the entry requirements to the profession is one option but runs the risk of reducing the already small pool of people wishing to enter primary teaching. Training teachers as specialists in science is another possibility, however redeployment requirements may cause flexibility issues. Continuing professional development could be another answer to the problem if costs, availability of teacher cover, and high stakes assessment issues can be addressed.

Clearly in this environment the task of science teacher educators preparing primary student teachers for their future career is going to be challenging! How does one equip these novice teachers in teacher education programmes with the knowledge and skills that will raise the status of science education in primary schools and engage students in long-term science learning? To answer such a question first requires consideration of what knowledge and skills a teacher capable of achieving such goals might possess. Shulman (1987) gives a valuable lead in this regard. He maintains that effective teaching (of any subject) is a skilled and purposeful activity involving complex processes of pedagogical reasoning and action in order to facilitate sound student learning. Moreover, this pedagogical reasoning and action are underpinned by a complex knowledge base that these teachers who are expert in their field draw upon and progressively develop from the time they first enter the teaching profession. Shulman has proposed a number of domains or categories to deal with the complexity of the knowledge base good teachers draw upon. These categories include: content knowledge; general pedagogical knowledge; curriculum knowledge; pedagogical content knowledge, "that special amalgam of content and pedagogy that is uniquely the province of teachers, their special form of professional understanding” (p. 8); knowledge of learners and their characteristics; knowledge of educational contexts; and knowledge of educational ends, purposes, and values. This knowledge is sourced from scholarship in the content discipline (in this instance science), educational materials and structures, science education research and the wisdom of practice.

Developing a Pedagogy for Primary Science Teacher Education

Novice teachers come to teaching with wide and varied prior experiences and beliefs about the profession and what teaching involves. The in-depth professional knowledge and capabilities possessed by an expert and experienced primary science teacher obviously cannot be built solely in a pre-service training course but rather, it evolves and accumulates over time and with practice and experience in the classroom (Nilsson 2008). What science teacher educators can do is help novice teachers begin to build the foundations they need to start a successful teaching career, especially in the domains of science content knowledge and pedagogical content knowledge (PCK), and equip them with the capabilities and capacity for ongoing professional learning throughout their careers.

The research interest in PCK since its introduction by Shulman (1987) as an academic construct to facilitate the elucidation of a largely tacit form of teacher knowledge has generated many findings with the potential to inform teacher education. For example, Magnusson et al. (1999), building on the work of others such as Grossman (1990), proposed five components of an experienced teacher’s PCK:

- orientations towards science teaching (since teachers’ knowledge and beliefs related to their teaching goals and approaches will influence their classroom practice);
- knowledge of curriculum;
- knowledge of assessment (since what is to be assessed, how and why, also influences a teacher’s practice);
- knowledge of students’ understanding of science;
- knowledge of instructional strategies.

These PCK components offer direction for the content of a pedagogical approach that promotes the acquisition of an accurate portrayal of the nature of science and its key ideas by student teachers and pedagogies that will both excite their future students in science and facilitate deep and meaningful learning.

Obviously to develop such a pedagogical approach for primary science teacher education requires exploration and understanding of how such professional learning could be initiated and sustained. For example, if a constructivist perspective on learning was taken, the process of helping student teachers to begin building this professional knowledge base for teaching science could be approached through the notion of ‘mental structures’ (i.e., an individual’s concepts, schema or mental models) and ‘conceptual change’ (Leach and Scott 2003). In the constructivist view, individual learners come to given situations with pre-existing understandings and beliefs and attempt to make sense of experience by making links with their prior knowledge. This process may involve little/no change to existing mental structures while in other instances individuals are motivated to change their existing structures and construct different structures to make sense of new information. In other words, they have constructed their own new knowledge.

Expanding this approach to include sociocultural perspectives of learning utilises the concept of situated cognition where cognition is inextricably linked with context. In a process involving legitimate peripheral participation in authentic settings (Brown et al. 1980; Lave and Wenger 1991; Resnick 1987) the apprentice (the learner) is progressively inducted into a community of practice by an expert (the teacher). The learning that results exists as ‘knowing’ rather than accumulated knowledge i.e., the ability to think and participate within a given community. In teacher education this induction process ideally sees the student teacher spending significant portions of their learning time having practical teaching experiences in classrooms (school-based practicum) working alongside an expert teacher. Here the novice teacher initially observes the actions of an expert teacher operating in a classroom and over time is “scaffolded into increasingly more central professional activities’ (Girod and Girod 2006, p. 483) through teaching opportunities provided by the experienced teacher. Unfortunately the apprenticeship model can fail to live up to expectations during the school-based practicum if the pedagogy of the classroom teacher does not embody the teaching and learning approaches promoted by the teacher education programme (Putnam and Borko 2000), or if that teacher simply lacks teaching expertise and confidence. In the context of primary science education the limited science knowledge of many primary teachers and their resultant lack of confidence in teaching science makes the apprenticeship model particularly problematic for student teacher education (Kenny 2010).

Work done by Lloyd et al. (1998) into primary science teaching led them to suggest some approaches for course design of pre-service primary science programmes. They found that while science content knowledge is a necessary pre-requisite for effective science teaching, there was not a simple correlation between the science content knowledge of a teacher and their ability to teach that knowledge. They observed that while primary teachers need a secure understanding of the underlying science, they also need general pedagogical knowledge and PCK to teach the concepts confidently and effectively. To develop student teachers’ pedagogy and PCK, Lloyd et al. suggest that in their teaching lecturers model how subject knowledge and pedagogical knowledge can be amalgamated into PCK. Magnusson et al. (1999) also advocated observing, analysing and reflecting on others’ teaching as a means of appreciating/developing PCK. “It could well be argued that teacher educators need to provide opportunities for student-teachers to examine, elaborate, and integrate new knowledge and beliefs about teaching and learning into their existing knowledge and beliefs.” (p. 1285).

Simulation may Offer One Answer

As the learning via the ‘real thing’, that is, the apprenticeship model is problematic then maybe modeling or simulation of the apprenticeship model could offer a viable alternative in primary science teacher preparation. The act of simulation involves imitating, modeling or duplicating the behavior, appearance or properties of some situation or some process by means of something suitably analogous. Typical simulations include modeling, role-plays, scenarios, computer games, and films. In education, simulations are valuable pedagogical tools especially where the real life situations or processes under study are not readily accessible to learners or are hazardous. Pilots in simulators, civil defence scenarios, medical procedures performed on ‘dummy’ patients and novice lawyers engaging in mooting sessions are all commonplace instances of simulations that are recognized and widely used strategies for gaining access to specific communities of practice. Today computer simulations and the emergence of the virtual world are offering new and enhanced possibilities for learners to enter and interact with the world of experts through experiences and activities that provide greater authenticity. The learning opportunities are deemed more authentic in that they more closely mirror the real life situations and conditions that the learner will face, and the response and actions that they will need to take when they become fully-fledged members of a specific community of practice.

Background to This Study

In this present study, set in New Zealand, a science teacher educator (author of this paper) had been engaged in action research for several years to develop pedagogies that extended her student teachers' thinking about teaching science beyond good classroom management and activities that transmit information. She wanted her student teachers to delve into the complexity of issues that underpin deep and meaningful learning for learners (Loughran et al. 2008) and focus on developing pedagogies that were student-centred. To achieve these goals she saw the need for student teachers "to be immersed in a context of participatory learning where constructivist pedagogies are preached and *practised*" (Hung et al. 2006, p. 40) and where they could begin to construct their professional knowledge through meaningful activities. Through the experience of learning to teach science in constructivist ways (as she herself had experienced during her secondary science teaching career) she believed student teachers' confidence and interest in teaching science would grow as a natural consequence.

As part of her ongoing professional reading and research the teacher educator had encountered a science education initiative that held much promise for supporting the type of professional learning she was promoting in her science education programmes. The initiative, known as *Primary Connections: linking science with literacy* (Australian Academy of Science 2005), has the stated purpose "to improve learning outcomes in science and literacy through a sophisticated professional learning programme supported with rich curriculum resources that will improve teachers' knowledge of science and science teaching and thereby improve teachers' confidence and competence for teaching science and the literacies needed for learning science" (p. 1). This very sophisticated professional learning programme—comprising professional learning workshops, exemplary curriculum resources, and opportunity to practise science teaching supported with resources and reflections on practice—has at its core a teaching and learning model closely aligned to the pedagogical approaches and learning goals of the New Zealand Curriculum (Ministry of Education 2007). The teaching and learning model incorporates the 5Es model (Bybee 1997), consistent with constructivist and sociocultural views of learning, which 'is based on an inquiry and investigative approach in which students work from questions to undertake investigations and construct explanations. ... Assessment is integrated with teaching and learning" (Academy of Science 2005, p. 2).

The results of the first trialling of the programme involving 106 trial teachers, many of whom initially had low self-efficacy in science teaching and limited science content knowledge, indicated significant rises in teachers' confidence to teach science. The findings also indicated rises in the amount of time devoted to science teaching in their classroom programmes and more focus on their students' learning outcomes and teaching through inquiry (Academy of Science 2005, p. 3). Findings from students revealed similar positive outcomes in terms of their enjoyment of science, the quality of their learning and the raising of the status of science in the school curriculum.

The science educator in this study had used the *Primary Connections* curriculum resources for several years, selecting various activities for use in her workshops with a Year 2 science education option class. She was impressed by the quality of the resources and found them very flexible and easy to adapt to the New Zealand context. Each topic contained extensive coverage of the science background, linkages to literacy, and the 5Es approach as it applied to that topic. The teaching notes to support the 5Es stages and activities were detailed and designed to guide a teacher through every aspect of each lesson, for example, outlining learning outcomes, background science concepts and skills, teaching sequence for the lesson including focus questions and photocopiable activity sheets. As she became more familiar with the 5Es model as used in the *Primary Connections* units she began to appreciate more and more the applicability of the approach to the New Zealand science curriculum and to her own beliefs and values about science and how it should be taught. Dissatisfied with some features of the Year 2 optional science education course that she was currently teaching, the science educator began exploring the possibility of selecting a *Primary Connections* unit to teach as a component of the course the following year in a form of role-play. She rationalized that if her student teachers participated as 'students' and then reflected on their learning experiences and the actions of their 'teacher' (the course lecturer) they might gain some insights into the thinking and basis upon which expert science teachers make decisions about their pedagogy for particular science topics/concepts. Their personal exposure to the 5Es approach may also address some evaluation feedback from previous student teachers in the course that requested more hands-on science in the programme. The experience could have the added bonus of enhancing the student teachers' science content knowledge.

On further reflection the teacher educator began to identify more potential advantages in simulating the primary classroom in her workshops through role-play. She could, for example, introduce the construct of PCK to her student teachers, help them begin to recognize elements of PCK in action and even help to develop the beginnings of their own tentative PCK. She considered the exercise somewhat of a gamble given she was not an experienced classroom primary teacher and the manner of simulation was a radical shift from her normal pedagogical practice. However, in her considered opinion the risk was well worth taking given the 'hit and miss' opportunities her students were provided authentic science teaching experience in their allotted undergraduate practicum (teaching practice) times. She felt the guidelines provided in the *Primary Connections* unit, her initial training and one year's practice as a primary teacher followed by 25 years experience as a secondary science teacher, and four years as an evaluator of primary education would stand her in good stead for this teaching role. Her chances of carrying it off successfully seemed reasonable. 8 of the 24 two hour workshops would be used to teach a *Primary Connections* unit called '*It's Electrifying*'. The student teachers would be required to keep science journals (a reflective tool used in the *Primary Connections* approach) and to write an evaluation of the suitability of the programme for the New Zealand context for course assessment purposes.

The teaching initiative became part of the teacher educator's ongoing action research programme and in this phase of her research the overarching research question that guided her inquiry was:

- How effective was simulation of the primary science classroom as a pedagogical tool for promoting the PCK development of student teachers in a science education programme?

To guide data coding and analysis, the following sub questions were asked:

- did the simulation enhance student teachers' science content knowledge?
- did the simulation raise student teachers' awareness of the components of PCK as identified by Magnusson et al. (1999)?
- did the simulation promote the development of tentative PCK by student teachers?

The study involved the science education teacher as researcher and 11 students in an optional second year teacher education science course. All students had undertaken the first year science education course (30 h duration), which was the only compulsory science course in the 3-year primary teaching degree.

Methodological Approach

This inquiry was conducted within an interpretivist paradigm using a case study approach (Bryman 2008; Cohen et al. 2007) and an action research design known as *practical action research* (Creswell 2005). The action research component involves a dynamic, flexible and iterative methodology, allowing the researcher to spiral back and forth between reflections about a problem, data collection and action. The methodology, as outlined by Creswell (2005), comprises a general spiral of generic steps that allows the researcher to pursue solutions to identified problems in collaboration with other researchers or mentors, and to enter the spiral at any point appropriate to the particular action research project. To contribute to the trustworthiness of the research process (Guba and Lincoln 1989) particular attention was paid to strategies that would maximize the quality of data gathering and processing within the constraints of the study. For instance, while the representativeness and typicality of the findings might be compromised by the small sample size, strategies such as prolonged engagement and triangulation (Cohen et al. 2007; Guba and Lincoln 1989; Patton 1990) helped to promote the dependability, confirmability and credibility of the study. Participant observation, a semi-structured focus group interview by a fellow researcher and analysis of documents such as course planning notes and student teachers' reflective journals (Moon 1999) were utilized to reduce the likelihood of researcher bias (Erikson 1998) and produce sufficient evidence to allow convergence (Bell 1999; Keeves 1998).

Data Analysis and Interpretation

As this study is concerned with understanding the meanings that the participants ascribe to particular experiential activities, activity theory has been used to frame the data collection and analysis. Activity theory is "a framework that could be used to analyse teaching and learning activities within constructivist epistemologies at a particular instance. It examines the activities that teachers and students are engaged in, the types of physical tools/mental models that they use in the activities, the goals and intentions of the activities and the learning outcomes, and/or artifacts produced within the socio-cultural contexts in which they operate" (Hung et al. 2006, p. 42). It maps/tracks the evolution of an 'activity system' over time by depicting the system at given instances in time. The activity system evolves at the macro–level (the context) due to the *in-situ* emergent nature of actions and cognition at the micro-level, i.e., at the individual processes of the activity system (see Fig. 1 below). As

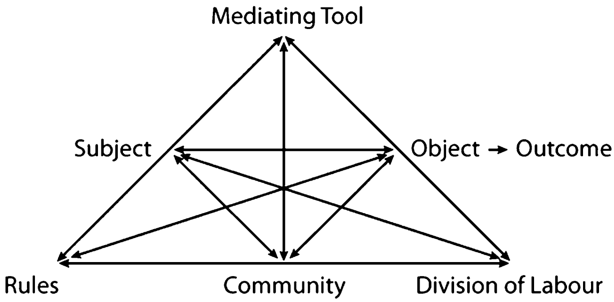

Fig. 1 Model of activity theory, adapted from Engeström (1999)

the processes that comprise an activity system proceed they all undergo some form and degree of transformation such that the nature of the entire system evolves. Goals can thus be reconceptualised as the student teachers (in this case) acquire new pedagogical and scientific understandings and the rules and division of labour are adapted accordingly. Research methodologies are best developed once the activity system has been entered by the researcher(s) and an appreciation gained of the intricacies and workings of the system.

Since it is closely related to sociocultural views of learning and communities of practice, activity theory is therefore a useful way for examining how simulation could function as a mediational tool that connects the communities of primary science teachers to primary student science teachers.

Thus in this study the undergraduate course/programme is viewed as an *activity system*, which the teacher educator entered several years before this phase of the study began (see Fig. 2 below). The original goal (*object*) was to develop a teaching and learning programme using various pedagogical strategies (*mediational tools*) that would provide student teachers (*subject*) with the beginnings of a professional knowledge base for future primary science teaching (the *outcome* of the activity system). Since that time the goal has transformed to a more student teacher-centred goal, that is, their evaluation of a teaching and learning model in science. It is hoped that the *outcome* reflects more focus on the PCK development of student teachers, since this category of their professional knowledge base emerged as a critical factor in becoming successful science teachers as the processes and interactions of the activity system got underway. Practical action research (Creswell 2005) became the chosen research methodology to monitor the system.

The *community* within this system consists of the lecturer and the student teachers, where the student teachers, as the *subject,* are working towards an evaluation of the *Primary Connections* 5Es approach for use in NZ primary classrooms as their goal or *object* (Note: a copy of this evaluation task can be obtained from the author). To achieve

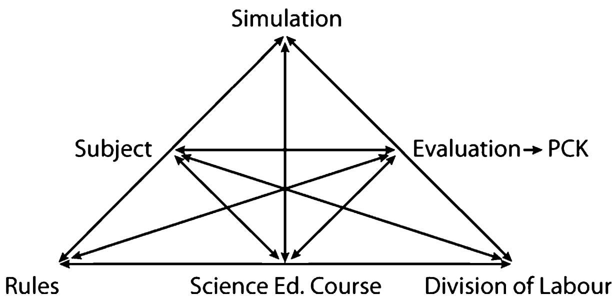

Fig. 2 Model of the activity system for the Primary Connections simulation

this goal, the simulation of a primary classroom experiencing the *Primary Connections* unit ‘It’s Electrifying’ is used as a *mediational tool* or ‘enabler’ to connect the community of novice primary science teachers with the community of expert primary science teachers i.e., teachers who demonstrate pedagogies commonly identified as good practice in current science education research. In the simulation the lecturer plays the classroom teacher’s role and the student teachers take on the roles of Year 7/8 students. On completion of each ‘lesson’ all participants come out of role and reflect on the learning and teaching that has taken place, both in terms of science content and pedagogy. *Rules*, that is, working norms for teaching and learning within this community existed when in and out of simulation. For example, when in role the lecturer was to follow the *Primary Connections* guidelines faithfully and use the language of a Year 7/8 classroom, especially scientific jargon. Student teachers were to engage in the learning as if they were Year 7/ 8 students and follow typical classroom protocols like ‘hands-up’ for questions and answers. There was a *division of labour* with the teacher/lecturer as facilitator and the students/student teachers as constructors of meaning. The activity within the system was considered authentic and meaningful since it offered the student teachers the opportunity to appropriate personal understanding and meaning of the components of PCK from both the perspective of learner and teacher. Also, the lecturer could gain deeper understanding of what it means to teach primary science. Collectively the participants could transform the unfamiliar content of the *Primary Connections* unit “into their own patterns of discourse according to the needs of the authentic tasks and concepts at hand. This authenticity in discourse is achieved from a coevolutionary process of interaction between the parties involved” (Hung et al. 2006, p. 52).

Findings

The Activity System in Action

As the simulation unfolded and the processes of teaching and learning proceeded, many interesting dynamics came to light as the participants interacted. For example, all participants went into role with ease and felt very comfortable and involved. The student teachers responded positively to the lecturer’s pedagogy and appreciated her attempts at portraying the PCK advocated by the *Primary Connections* programme. (Note that pseudonyms have been used for the participants.)

> **I** So how well do you think Alison played the role of primary teacher?
> **Elaine** She did it really well. Like, sometimes I didn’t know if she was in role or not. [...] Did she really not notice? It was good, it was fun.

The working norms or rules for teaching and learning that existed within this community shifted in a natural way as the participants went in and out of role. On occasions the boundaries between real and imagined became blurred as the student teachers found it difficult to stay in role and wanted answers, which were not always forthcoming. Despite some frustration at not getting straight answers the student teachers came to realise the value of Alison’s pedagogical strategies.

> **Elaine** She would always repeat back to us what we were saying to clarify our understanding which I think was where what Eliza was saying where we’re like ... ‘what? Why can’t you just tell us if we’re right or not!’ you know, but she was

> getting us to really think deeply and sort of critically about what we were saying and what other people were saying and whether if we could back up what we're saying with reasons and stuff. She was always questioning us and making us explain what we meant.
> **Carol** It was frustrating at times, to the point where we were getting up and having to draw the diagram on the board ourselves but it worked. And I think that's important in the classroom, that you get kids to explain themselves and it was very relevant ... what she did was really relevant to what we need to be doing.
> **I** Anyone else want to add to that?
> **Eliza** I reckon it was good because no question was a stupid question. And no one laughed at you if you didn't actually know.
> (focus group interview)

Alison herself found the pressure to 'simply tell' difficult to ignore at times and fell into transmission mode, but the student teachers were forgiving.

> **Eliza** Yeah, she muddled some very good things that we could be doing as primary school teachers too; like, even at times she would sort of get [...] or say, 'well, you know, I feel like saying the answer' and she sort of said, you know, how hard it can be sometimes, so that was really good.
> **I** Right, so she was sort of verbalising her thought processes to let you into what she was thinking.
> **Eliza** Yeah.
> (focus group interview)

The student teachers were somewhat surprised at their own reactions and the depth of understanding they gained about learning.

> **Elaine** We just really got to see how engaging and stuff it is for the kids and how—like, I don't think she really made it any harder for us ... you know, a few little things we developed [a little] but it was still really interesting, I think we all learned something from it ... it is a really good unit, the kids are going to learn so much from it.
> **Gina** I also think that doing it from the learner's perspective we also were able to critique it more deeply because if we just looked at it from a teaching perspective, we didn't see those little flaws or the good points from when we're actually receiving it, you know, you can sit back and think oh well if I was a kid I could really engage with that—well, I engaged with it.
> (focus group interview)

Simulation as a Pedagogical Tool for Promoting PCK Development

As a mediational tool within the activity system, role-play proved to be very effective at enabling the student teachers to begin exploring the boundary between novice and experienced teacher. The unusually prolonged nature of the role-play provided the student teachers with insights into science teaching and learning processes, both from the perspective of learner and teacher, and there is clear evidence of their growing awareness of the nature of PCK in the findings. In the following extract from the focus group interview the student teachers reveal the value of the experience from their perspectives.

> **I** Ok. So tell me how Alison used this programme in your ... course. Anyone want to comment about that?
> **Elaine** She taught us as if she was teaching the students. So we knew how to teach it; like, it was kind of [all a role].
> **I** Oh ok, yeah, right. Adding to that, anybody?
> **Gina** Yeah, it was good because we got to see it from the learner's point of view now so we know if we were to go teaching we've sort of—we've been in their shoes. And at the same time she'd stop and then she'd sort of get us to think about the teacher point of view so yeah [...] all the same.
> **I** Elaine did you want to say something?
> **Elaine** Yeah sort of the same sort of thing is that although we were the students during it, we also went and discussed and evaluated how it worked from the teacher—what the teacher was actually doing as well and we kept note of all of that in our science journals and stuff and taking note of what ... how it was being taught.
> **I** Right, right. Anyone else want to add to that?
> **Zane** It also helped being the students because we could ... and with Alison stopping periodically to explain different phases that we were going through. Like, first there was the engaged phase where she gave us the activities to partake in and it was really good to see it from the students' point of view of to how easy it is to draw them into a unit without doing anything amazing—you just give us a voicebox or whatever and let us play around with it for an hour and we [hooked on the] topic. It was a car that goes and lights up and we were amazed!
> (Focus Group Interview)

The simulation gave the student teachers a platform from which to reflect about issues and problems they may face as novice primary teachers of science. Interestingly, they identified and took ownership of potential solutions offered by the role-play experience and their confidence and enthusiasm about teaching science was boosted through awareness that resources of the calibre of *Primary Connections* were readily available to support them as novice teachers

> **Zane** .... and what *Primary Connections* does is it gives teachers a way of teaching and it explains it and it goes in-depth and it actually enables them to teach it rather than making them feel left out or uneasy about it. So it was just another resource that we can draw on and I definitely will be.
> **I** Great, great. Anyone else want to comment on Alison's purpose?
> **Gina** Well, it also sort of opened our eyes to even, like, the New Zealand curriculum it doesn't quite have that structure in it, it's a [core] statement and sometimes it can be quite overwhelming, especially for beginning teachers, to sort of look at it and think, 'what do I do?' But it sort of just opened the fields, you know, there's all these resources [and ... ones] like the building sites concept, you know, how to actually get that knowledge behind your unit.
> **J** Anyone else want to comment?
> **Louise** It just made it a lot more approachable because- yeah, like they've said that science can be such a complicated thing and it scares a lot of teachers off; maybe [they're] looking into it too much at primary level. So yeah, the *Primary Connections*

just made it that much more approachable for those that might not normally look [into it] too much.

(Focus Group Interview)

Enhancement of Student Teachers' Science Content Knowledge

For all student teachers the simulation facilitated further development of their science content knowledge. They acknowledged understanding of the lecturer's reasons for choosing the electricity topic

Steve Well, I guess the 'It's Electrifying' was at a higher stage, which was probably quite relevant because we're older as well, and then it had a bit more detail, I guess, than some of the lower ones. So it kind of got us really thinking and we didn't obviously know that much about the battery when we got into it so it was quite ... it was good for us as well.
Carl We also had a few side lessons where we explored a little bit more than what you could in a class, like cutting opening the battery and having a look at what's inside it, which is ...

(Focus Group Interview)

Their science journals recorded many instances of new science learning occurring, including the nature of science.

This [cartoon history of Volta's life] was really interesting because I never thought that the battery was invented so early in time and it showed what work and how long it had taken to lead up to the invention of the battery

(Science journal entry, Nancy)

I found with all our discussing we did, we learnt something from each other eg a circuit can have others coming off it!! (never knew that before today!)

(Science journal entry, Nora)

Cutaway diagrams, this was a new technique to me. I found it very useful to explain how the torch worked

(Science journal entry, Gina)

It was interesting discovering the different ways with which you can create a switch

(Science journal entry, Gina)

With the increased content knowledge came a hint of greater confidence in their ability to understand the topic and hopefully to teach.

Elaine I thought she just thought that electricity is a unit that a lot of people don't feel very confident with as well—like a lot of people will kind of go, 'oh no, I don't really know how that works' and so she thought it would be a good idea for us to learn about it or feel a bit more confident with it.
I Do you think Alison achieved her purpose?
Students *[Several voices]* Yes.

Raising Awareness of the Components of PCK

Their growing awareness of PCK components and formation of some personal concepts related to each component was very apparent and directly related to their simulation experiences. Here

Gina comments in her reflection journal on a key aspect of *knowledge of students' understanding of science* that she had learned during an electric circuit role-play activity

> Avoiding misconceptions, it is important that the teacher makes sure the students don't build misconceptions such as "we are carrying electrons to the bulb"—must say "you are the electrons—what are you picking up at the battery and taking it to the bulb"
>
> (Science journal entry, Gina)

Similarly Steve alludes to *orientations towards science teaching* and *knowledge of assessment* when he notes

> I am beginning to see the importance of the EXPLORE part of the *Primary Connections* programme. There's no difference at any age when it comes to experiencing science by doing, instead of just listening. It allows the students to make formative assessments about the work they do, and increases their observation skills by being involved in the process of investigation, planning and understanding of how it works
>
> (Science journal entry, Steve)

Zane also picks up on *orientations towards science teaching* as he identifies *knowledge of instructional strategies* and when and how to use them through *knowledge of students' understanding of science.*

> **Zane** I also think the activities in it [the 'It's Electrifying' unit] were a bit more sophisticated and more relevant for us as well; like, [so if] the cross-sectional drawings, the labelled diagrams—there was a lot more terminology in it than there is in the younger books and I think for me particularly it gave me a broader awareness of all the things that science does involve and if you say the wrong word you're actually talking about a whole different thing of what you want the students to do. I think when [she asked us] to do a cross-sectional drawing and we came back with eleven different things that were all wrong, because we all took it our own way.
>
> (Focus group interview)

For the *curriculum* component of PCK the student teachers gained science content knowledge but they also became more aware of their own national science curriculum as they drew parallels between the *Primary Connections* programme and the New Zealand Curriculum.

> **Elaine** Um well it was an Australian programme so it's not written for the New Zealand Curriculum but it just made us have a look at how easily you can fit it in with the New Zealand curriculum and that it does just transfer straight across—you can use achievement objectives from the New Zealand curriculum to fit in with it really easily so it's really useful. Yeah, and so it just showed us how it does relate to the New Zealand curriculum and it's perfectly relevant in New Zealand, it's not just for Australia.
>
> (focus group interview)

The Object as Evidence of Tentative PCK

The evaluation task, which required students to evaluate the Primary Connections programme for the New Zealand primary education context, proved to be a showcase for the student teachers' growing awareness of the professional knowledge base that primary science teachers draw and act upon, particularly the components of PCK. In giving positive endorsement to the *Primary Connections* programme for use in New Zealand classrooms and illustrating the close linkages between the programme and the New Zealand curriculum, they highlighted their understanding of the purposes of science education; curriculum requirements, including scientific literacy; student learning of science: and effective pedagogy and assessment. Students felt the keeping of the science journal throughout the unit was a very useful part of the assessment because, while it informed the evaluation task, it also had longer-term value as a source of possible PCK.

> **Carl** I think it's probably one of the few assignments that we can actually use again. I mean, if we teach a unit in *Primary Connections*, we can flip back through the journal just to see how it all works, what we did, see what we liked, see what we didn't like, and remind us what we should be doing with the kids. Whereas writing, let's say, or some of the other assignments we get, you finish them and you throw them in a box and you never really look at them again.
>
> (focus group interview)

Conclusion

As Lloyd et al. (1998) and Magnusson et al. (1999) intimated in their studies, and on the basis of this small but potentially significant pilot study, simulation may be a viable means of laying strong foundations for novice teachers' future PCK. Nilsson (2008) describes learning to teach as a complex business, and as science educators we need "to teach from the point of view of student-teachers' experiences in order to create a deeper understanding of *their* needs and concerns and how this may impact on the learning-to-teach process" (pp. 1281–1282). Certainly the simulation gave the science educator opportunity to engage in student-centred pedagogy that met learning needs and it enabled student teachers to reflect from both sides of the teaching-learning boundary. Subject matter and pedagogy were taught together through simulation, and reflection through different lenses helped student teachers transform the type of knowledge they acquired during course work into the type of knowledge they might need to teach in a primary school context.

However, since no pre-service course can cover all the science that teachers will be called upon to teach over their careers, the simulation must model inquiry-based approaches to teaching and learning and quality instances of PCK to have worthwhile and long-term effects. Experiences like the 'It's Electrifying' help to cultivate independent learning and equip student teachers to face new science teaching challenges with more confidence. It should be noted that the students taking part in this study did elect to take this optional course and their very affirmative responses to the simulation experience may well be a reflection of a pre-existing disposition towards the subject of science. Despite this possible bias, the simulation did enable student teachers to see the complexity of science teaching while at the same time offering a way forward by encouraging them to conceptualise their teaching (Nilsson 2008).

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