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TEACHING PRIMARY TEACHER EDUCATION STUDENTS HOW TO TEACH SCIENCE

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This paper describes a problem-based pedagogical approach adopted in a compulsory science and technology curriculum subject within a Bachelor Education (Primary) degree. Students demonstrate their content knowledge, collaborative skills and pedagogical content knowledge within a criterion referenced assessment framework. A quasi-experimental pre/post-test design is used to assess students' developing content knowledge, scientific conceptions and complexity of their reasoning. In addition, ongoing feedback and evaluation procedures are built into the subject, which has allowed tutors to make continual improvements to the subject.

Objectives

The context for the pedagogical approach described here is a compulsory science and technology curriculum subject within a Bachelor of Education (Primary) degree that tackles the complex integrated skills required by pre-service teachers, to address problems identified in various national and international research reports related to the teaching of science (e.g. AAAS, 1990; Goodrum, Hackling & Rennie, 2000; Harris, Jensz & Baldwin, 2005; Millar & Osborne, 1998). The common problems identified include the lack of time devoted to science in the primary classroom, the lack of content knowledge possessed by teachers and, the lack of resources. This subject was designed to address these problems.

Significance

The research reported here demonstrates the dramatic improvements in both content and pedagogical content knowledge (PCK) that can be achieved by primary pre-service teachers if they learn how to teach science through being immersed in a collaborative, problem-based learning environment. The team teaching illustrated how collaborative models of teaching and learning that involved the planning and implementation of authentic learning experiences both for themselves and for their future pupils could generate a challenging, enjoyable, and deeply satisfying classroom climate.

Theory

The pedagogical approach is informed by current research in science education and is theoretically underpinned by social constructivism. Social constructivist philosophy holds that students are active throughout the learning process in constructing their own understandings of scientific phenomena (Schwandt, 2003). In constructing these, students are likely to develop alternative conceptions of the phenomena in question. The instructor's role in such a classroom is to challenge students' emerging conceptions by asking questions that expose their thinking and to direct attention to other, more scientifically correct, possibilities that emerge from the practical activities designed to challenge any initial alternative conceptions they may have held (Schwandt, 2003).

Equally important as part of the theoretical framework, was a commitment to the development of students' pedagogical content knowledge (PCK). Shulman (1986), describes PCK as a form of knowledge that is specific to a particular teaching/learning situation. That is to say, the PCK of science is distinct from the PCK of mathematics. Grossman (1990) identified four central components of PCK: knowledge of, and beliefs about, purpose; knowledge of students' conceptions, curricular knowledge; and, knowledge of instructional strategies. Other researchers have extended this definition to include aspects of assessment, content knowledge and demonstrated the interrelationships amongst the components (e.g., Appleton, 2002).

Given that the pre-service teachers we encounter had generally finished their studies of science at the end of the compulsory years of secondary school, their content knowledge was problematic. Despite the fact that their conception of the subject was to learn how to *teach* science, they did not *know* the science content they had to teach nor the processes of science. Consequently, a problem-based learning approach was adopted to teach one component of the primary science syllabus: astronomy. Problem-based learning has been shown to be effective in such diverse contexts as medicine (e.g., Albanese & Mitchell, 1993), civil engineering (e.g., Johnson, 1999) and education (e.g., Hmelo-Silver, 2004).

Cooperative learning has also been shown by research to be effective in engaging students in tasks (e.g., Johnson, Johnson & Stanne, 2000; Slavin, 1990). Moreover, if appropriately scaffolded, collaborative approaches can reduce the workload for an individual while the group collectively works on the larger task. The adoption of such strategies seemed appropriate given the time constraints of the university timetable and of the teacher education course.

Design and procedure

A quasi-experimental pre/post-test design is used to assess students' developing content knowledge, scientific conceptions and complexity of their reasoning. The decision to focus on the content strand that involved astronomy was, in part, based on many observations of primary classrooms during practicum visits to schools where *the content* was taught using a project based approach where pupils undertook research to produce posters on a topic that was included in the syllabus.

The team-teaching approach to the delivery of the subject involved a minimum of two tutors teaching in each tutorial. This approach enabled the team to demonstrate explicitly, through modelled practice, collaborative approaches to problem-solving and analytical and critical thinking skills that the pre-service teachers could then apply both within their cooperative learning groups and, later, in the context of the primary classroom and schools in which they will teach. Ongoing feedback and evaluation procedures were built into the subject through the use of one-minute Harvard Papers. These allowed the tutors to make continual improvements to the subject *in situ* and cater for the needs of students.

Creation of the Problem-based learning environment

The Astronomy Diagnostic Test (ADT) (CAER, 2004) was administered at the first meeting of the subject. Immediate marking of the ADT gave students feedback concerning their prior knowledge, lack of content knowledge and the alternative scientific conceptions they held. Confronted by their appalling results, students clearly understood that there was *a problem*. For example, one student articulated in class that *[I]f I don't know the content then how will I know how to teach it?*

Various cooperative learning strategies were employed (think-pair-share; roundtable; numbered-heads-together and jigsaw) to analyse research literature on alternative scientific conceptions held both by primary pupils and their teachers.. Students realised that they first had to address their own alternative conceptions so that they would not pass these on to their students. Comments made by them during one tutorial included: *There are many misconceptions among students, adults and* *teachers; Misconceptions are easily passed on;* and summatively, *I learnt lots of new things from the research papers and saw the collaborative approaches as a valuable teaching tool.*

Constructing curriculum and the learning environment

In their groups, students constructed a curriculum to meet the content-knowledge deficits identified by the ADT. This gave them a real purpose and motivation for the learning that was to take place. Each of the constructed curricula was unique because each group had specific content-knowledge requirements to be met and alternative conceptions to be redressed in order for them to be able to teach the content of the Earth and its Surroundings strand of the NSW Science and Technology K-6 syllabus in valid ways.

Resources for their learning were supplied. A compendium of 31 astronomy related projects and required equipment such as basketballs, tennis balls, tape measures globes, polystyrene balls, modelling clay etc. Any hints on how to teach the content had been carefully removed from the projects in the compendium so that students could begin to construct for themselves the PCK necessary to teach the material, first to their peers in the group and, later after reflection, to pupils in their classes.

A criterion-referenced assessment framework was employed where students were provided with a set of clearly specified performance outcomes on a number of criteria for each assessment item. Each of the assessment items had both an individual and a collaborative component. The feedback provided to the student was both formative and summative.

Findings

Evidence shows that the pre-service teachers who have experienced this approach are engaged and motivated by the transformed subject. Engaging in authentic science during tutorials has challenged their alternative scientific conceptions and required them to reconceptualise their current understandings of scientific concepts. In doing so, students are enacting the processes essential in teaching the scientific concepts to primary-age students and concurrently developing their PCK.

The emerging PCK became evident in one face-to-face interaction with a group when one student said *[B]ut I wouldn't teach it this way*. When asked why, the group responded in ways that reflected an early stage of understanding of the pedagogical issues. They made comments about the need to break the task into *manageable chunks* over a series of shorter lessons in order to *scaffold the learning of their future primary students*.

Consistent with collaborative learning principles, the task of acquiring the content knowledge was too great for any one individual to execute on their own in the time available. The approach motivated individuals to engage with their content both as students and as teachers and facilitated the following: face-to-face promotive interaction; positive interdependence; individual accountability and personal responsibility; interpersonal and collaborative skills; and the development of critical reflection of both their own, and their group's, performance (Johnson & Johnson, 1990).

Individualised programs tailored to the individual group's needs required everyone in their different roles to be involved and working at different levels: students as teachers, students as learners, and the members of the tutorial team as facilitators and mentors.

Sessions that followed were almost chaotic, but nonetheless were characterised by continuously high levels of task orientation. Student comments relating to the collaborative approaches used include: *I* *loved the Jigsaw activities – everyone brought something different; Cooperative learning is great and useful; and, We had a cooperative day where we got together and did it.*

In terms of learning outcomes, the success of the approach is demonstrated for this most difficult of primary science content areas by the fact that analysis of the post-treatment Astronomy Diagnostic Test (MANOVA) revealed that their content knowledge significantly improved (effect size=**1.99** (Cohen's d)). In addition, their alternative conceptions significantly reduced (effect size=**0.688**) and they acquired a significantly increased ability to explain the astronomical phenomena they will be required to teach in primary science (effect size=**1.33**).

Evidence from the analysis of the feedback questionnaires completed by students at the end of a subject indicated that, where previously they had been afraid of teaching science, did not know the content, could not explain the reasons for certain scientific phenomena or were simply bored by the subject, they were now enthused, motivated and committed to improving their content knowledge. They now had a much deeper knowledge of how to address their own and their future pupils' alternative conceptions. More importantly, they are acquiring the skills on how to teach science content in interesting and engaging ways.

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