THE INFLUENCE OF SUBJECT CULTURES ON THE TEACHING OF AN INTEGRATED PRE-SERVICE UNIT IN MATHEMATICS, SCIENCE AND TECHNOLOGY

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While science, technology and mathematics are commonly regarded as being inextricably linked, they mostly operate as distinct cultures in schools. This paper reports on the introduction of two integrated units in primary mathematics, science and technology into a post-graduate, pre-service Bachelor of Teaching (Primary & Secondary) course at Deakin University, Australia. The discussion of these units is situated in the context of a recently commenced research project Improving middle years mathematics and science: The role of subject cultures in school and teacher change[1]. *The influence of differing subject cultures on implementation of the units is discussed.*

Recent Australian initiatives such as Queensland's *New Basics Research Program* (see, for example, Education Queensland, 2003) and the Tasmanian *New Essential Learnings* framework[2] have attempted to break down the barriers between discipline areas by promoting generic formulations of thinking, learning and pedagogy, as well as new ways of organising curriculum.

However, while science, technology and mathematics are commonly regarded as being inextricably linked, they mostly operate as distinct cultures in schools, reflecting the different forms of knowledge they represent, their status in the curriculum, and their underlying values (Miller & Baker, 2001; Siskin, 1994). This is particularly true for science and mathematics, as technology is often either not represented at all or only in a token way.

Constructivist learning theories, and socio-cultural theories based on the work of Vygotsky, have underpinned two decades of research into student learning in both mathematics and science. However, these theories have taken rather different forms in the two subjects (Driver, Asoko, Leach, Mortimer & Scott 1994; Duit & Treagust 1998; Cobb, Wood & Yackel 1990).

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2 http://www.education.tas.gov.au/ooe/curriculumconsultation/publications/Essential_Learnings_1.pdf

This paper reports on the introduction of two integrated units in primary mathematics, science and technology into the recently re-accredited post-graduate, pre-service Bachelor of Teaching (Primary & Secondary) course, which commenced in 2004 at Deakin University, Australia. In particular, it addresses some of the issues arising in the implementation of the first of these units during the first half of 2004.

The discussion of these units is situated in the context of the literature on curriculum integration (see, for example, Venville, Wallace, Rennie, & Malone, 2002) and that of a recently commenced research project *Improving middle years mathematics and science: The role of subject cultures in school and teacher change* which includes members of the teaching team for the first unit.

A history of the units

The Bachelor of Teaching (Primary & Secondary) at Deakin University is a two-year, post-graduate, pre-service teacher education course, which qualifies its graduates to teach in both primary and secondary schools. The course, which has been offered for a number of years in on-campus modes across two campuses, as well as in off-campus mode, until this year contained a total of two units in primary mathematics education, together with one unit in primary science education, from a total of 16 (equally weighted) units.

As well as units in education studies and primary curriculum areas, students in the course undertake a total of four units in two different secondary teaching methods from the wide range offered, with only a few of the students planning to be secondary teachers of mathematics or science.

During 2003, as part of the re-accreditation process, the course was restructured to include a total of two integrated units in primary mathematics, science and technology education, together with an additional integrated unit in language and mathematics education in the middle years of schooling. The course also contains two integrated units in language, studies of society and the environment, and arts education, as well as a unit on health and wellbeing.

The driving force for the changes leading to the introduction of integrated units came from a number of apparently disparate sources: perceived problems with the previous course structure whereby studies in primary and secondary curriculum areas did not always match practicum placements; a strong commitment to integration from a small, cohesive group of staff who were experimenting with integration on a small scale; and an ideological commitment by some staff to school curriculum re-organisation along the lines of Queensland's *New Basics* and what was seen as likely to come about through the introduction in Victoria of *A Framework of "Essential Learning"* (see, for example, Victorian Curriculum and Assessment Authority, 2004).

Staff in the areas of mathematics, science and technology have a strong history of working together in research (for example in the ARC and DE&T funded project *Improving middle years mathematics and science: The role of subject cultures in school and teacher change* which commenced in mid-2003) and in teaching (for example in the Master of Education unit *Constructivism and Learning in Science and Mathematics* — see Deakin University, 1998). In addition, we have two staff members who are employed to teach in both mathematics and science education. Nevertheless, at the time of the reaccreditation, there was no strong commitment among staff in mathematics, science and technology to the integration of the disciplines in either schools or teacher education, with staff holding a range of views. Staff accepted that there would be advantages as well as disadvantages in working together in these units and planned for at least some integration of the units.

In keeping with previous teaching across a number of units in both primary mathematics and science education, it was decided that the second of the units would have a substantial “school-based” component, where classes are conducted in schools using a pattern of approximately equal time being given to workshops for our students, our students teaching children, and “debriefing” of the teaching segment.

In 2004, a total of approximately 200 students on two campuses are undertaking the first year of the newly accredited Bachelor of Teaching (Primary & Secondary) course on-campus, with an additional 45 Canadian students undertaking the integrated units in primary mathematics, science and technology education as part of a primary education course, together with a small number of newly enrolled off-campus students in the Bachelor of Teaching (Primary & Secondary) course who are continuing with the “old” course structure.

Aims of the units

The first of the two integrated units, *Developing Understanding of Mathematics, Science and Technology*, aims to introduce students to current principles and issues in the learning and teaching of mathematics, science and technology, and extend their understandings and critical appreciation of the nature of mathematics and science, their links with technology and the environment, and their personal and social relevance. In particular, it aims to promote students’ understanding of how children’s scientific and mathematical concepts develop.

The focus of the unit is very much on children’s learning, with a major part of the assessment (60%) being based on an analysis of children’s responses to task-based interviews and planned activity sequences to probe children’s understandings of mathematics and science.

The unit also aims to familiarise students with appropriate resources for the teaching of primary mathematics and science, and current national and state curriculum documents, policies and programs.

In terms of mathematics content, the unit focusses on the teaching of key mathematical concepts, terminology, operations and procedures related to number, measurement and data.

The second of the units, *Effective Teaching of Mathematics, Science and Technology*, aims to enable students to develop their repertoire of strategies to provide challenging, coherent, engaging and inclusive learning experiences for children. The focus of the unit is on curriculum planning and assessment, and the use of information and communication technologies in learning and teaching. This is also the unit in which most of the technology education occurs, as there is very little planned in the first unit.

Teaching the first unit in 2004

The first of the two units was taught for the first time in wholly on-campus mode during semester 1 of 2004. While most aspects of the unit were similar across the two campuses, the author's experience was at only one of these campuses so discussion from here onwards relates almost exclusively to what happened at that campus.

Figure 1 summarises the content and delivery of the unit based on a one-hour lecture for all students and a three-hour workshop each week. The lectures were shared among staff from the different areas, while the four workshop classes were staffed in a variety of ways ranging from a single staff member taking all of the workshops to various ways of sharing classes between mathematics, science and technology education staff.

	Lecture	Workshop
1	Introducing mathematics, science and technology education	▪ Floating and Sinking ▪ What is measurement? ▪ Unpacking properties used in Floating and Sinking ▪ Beginning Metric Activities
2	Early counting & young children's mathematics	▪ Early counting ▪ Counting in base five ▪ Place value concepts ▪ The number interview
3	Children constructing knowledge in mathematics, science and technology	▪ Air & flight ▪ A model for teaching measurement ▪ Metric Activities continued
4	Mental computation	▪ The four operations ▪ Number sense & the role of standard algorithms ▪ Base 5 subtraction ▪ Metric Activities continued
5	Learning and teaching mathematics, science and technology	▪ Movement ▪ Metric Activities continued ▪ Summary of metric system
6	Developing number sense using calculators	▪ Developing computational techniques ▪ Metric Activities continued
	April 12-16	Intra-semester break (1week)
7	Estimation	▪ Linking the metric system, place value & decimals
8	The investigation process in science	▪ Consumer Science ▪ The process of carrying out a statistical investigation
	May 3 – 21	Practicum
9	Problem solving in mathematics and technology	▪ Matter: Physical change ▪ Summarising, representing & analysing data
10	Higher order thinking, creativity	▪ Matter: Chemical change ▪ Some statistical techniques

Figure 1. Teaching Schedule for Semester 1, 2004

As can be seen in Figure 1, the content has been integrated to varying degrees across the weeks of the program. Based on our previous experience, as well as concerns expressed by the accreditation panel regarding how the units would adequately prepare our students to teach mathematics in primary schools, it was decided that a relatively self-contained unit on young children's development of number concepts and computation be included in this first unit. Unlike previous units, where typically there are three contact hours, this unit had four hours of contact each week, with approximately 45 minutes to an hour of each of the "non-number" workshops also being devoted to mathematics. This time was used to focus on the curriculum areas of measurement and data, with attempts made to draw the mathematics out of the science and technology activities wherever possible. In practice, the links were reasonably strong in Week 1 (Floating and Sinking) and Week 8 (Consumer Science), but rather tenuous in the other weeks.

Even within the mathematics content areas, there was some fragmentation due to a perceived need to cover a wide range of material. So, for example, in the area of measurement, as well as a discussion of what constitutes measurement, students' conceptions and misconceptions of various properties such as length, area, perimeter, volume, and a model for teaching measurement, a series of metric activities based on Johnson's (1987) article *Using a metric unit to help preservice teachers appreciate the value of manipulative materials* were used over a number of weeks.

Assessment for the unit consists of an assignment worth 60% of the total and a written examination worth 40%. The assignment consisted of three parts. In the first part, students used a structured interview together with a few open-ended questions to probe two individual children's understanding of number, combined data with that obtained by other students across four year levels, and analysed the data in terms of children's conceptual development observed and match with curriculum expectations. In the second part, students worked in pairs with small groups of children to probe children's understandings of science using activities they had planned. The third part of the assignment required students to reflect on the strengths and weaknesses of the various types of probes used and their implications for classroom practice. The written examination, which has yet to be done by the students, consists of three parts of approximately equal weight: one based on mathematics, one on science and technology, and one integrated.

The influence of subject cultures

As is the case for the integrated units in primary science and mathematics education developed at the University of South Australia (see, for example, Chartres, Lloyd & Paige, 2004), staff teaching in the units share a social-constructivist view of learning. Similarly, both groups recognise the differences in the nature of the academic disciplines and the fact that some time needs to be spent exploring topics in the different areas. However, unlike the introduction of the integrated units in South Australia, where a small group of staff had a long history of research and development in the use of interdisciplinary courses, we were faced with a relatively short time-line to develop three integrated units (one of these being the mathematics and language unit to be introduced next year) across two campuses, with a large group of staff and two modes of delivery (on-campus and school-based).

A number of issues arose in the implementation of the first unit. Firstly, many of our students are mature-aged students who have been away from University study for some time. Many also see themselves as future secondary teachers and are less than confident in primary classrooms. Although student evaluations suggest that most believed that the unit prepared them well for their experiences in the primary practicum, the reality of primary schools is that in most classrooms mathematics is taught for an hour a day, while science and technology receive much less time, and we needed to acknowledge this disparity. While we would have liked to have done better at integrating the material (and hopefully will do better next year) it was at times difficult to avoid fragmentation and early comments from students indicated that they were overwhelmed at times by the need to consider all three areas together.

In their extensive review of curriculum integration, Venville, Wallace, Rennie and Malone (2002) point out there is a broad spectrum of classroom practices that are described as integrated. Moreover, curriculum integration is often driven by enthusiastic teachers, who are frequently unable to articulate clear goals for their actions, with examples of integration being difficult to sustain over time. While "authentic work" is seen as a powerful means for engaging students, Venville, et al. question whether the critical issue regarding student engagement is that of good teaching rather than integration. They further argue that gains in understanding from a holistic perspective are often offset by losses from a disciplinary perspective and that arguments about integration are founded on differing views on the structure of knowledge. While, as a result of teaching in this unit and our involvement in the *Improving middle years mathematics and science: The role of subject cultures in school and teacher change* research project, has led some of us to having occasions for lengthy discussions and much serious reflection on the differences in the nature of science and mathematics, there have been no similar opportunities in teaching the unit to engage our students in more than the most cursory examination of these issues.

In particular, we have noted a number of significant differences in both the nature of science and mathematics and the ways in which they are taught in schools. Foremost of these — and almost self-evident — is the extent to which the mathematics curriculum is based on a cumulative notion of learning content. Only slightly more subtle is the difference in the extent to which, at least after the first few years of schooling, we rely on students' informal knowledge to shape their in-school understandings.

A more surprising difference was in what we assume to be the purpose and nature of "activities" in primary mathematics and science classrooms, where in mathematics activity appears to be most frequently designed to embody and illustrate mathematical concepts, while in science it is seen as either the act of investigation — that is of "working scientifically" — or an opportunity to "predict–observe–explain". Of course there are similarities as well, in terms of mathematical problem solving and investigations — "working mathematically" — as well as in the technology design process. These however appear to have less prominence in primary classrooms than do science activities that encourage students to make and test hypotheses and otherwise engage in science investigations. It is clear that process aspects of science receive more attention than those in mathematics, despite the frequent rhetoric in curriculum documents.

At times it has been very difficult to reach a shared understanding. For example, when science-based activities were shaping the workshop content, we were surprised at the instrumental view of mathematics being presented whereby using mathematics was seen as being equivalent to "doing" mathematics. While using mathematics and being aware of its uses in both society and other curriculum areas is indeed important, we would still maintain that there is a need to systematically develop both mathematics in schools and the teaching of mathematics in pre-service courses for primary teachers.

The second of the two units is about to commence. In a climate where curriculum integration is increasingly seen by many people as not only a good thing but as inevitable progress, it is important to step back, take time to reflect, and engage in serious debate about not only practical matters but theoretical positions. We would agree with Venville, et al. (2002) who propose that we need to adopt what they call a "worldly perspective that reflects a holistic view of knowledge … [where] the integrated paradigm and the disciplinary paradigm, must be considered together, overlapping rather than mutually exclusive" (p. 26).

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