Curriculum Integration:

Eroding the High Ground of Science as a School Subject?

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This paper explores the issue of curriculum integration, with a particular focus on science as a discipline and its relationship with other subjects. We present our exploration in the form of our research journey, one that is yet to be completed. The journey has involved several strands of research and some unexpected turns. Some readers may not agree with the directions we have taken because of our questioning the primacy of science as a discipline and how it is represented as a school subject. And in fact, it is the nature of the school subject that seems to us to hold the key to understanding curriculum integration. So let us begin by explaining what we mean by a 'subject' and how it relates to the academic discipline it represents.

A 'minimalist' definition of school subject is provided by Stengel (1997) as 'that which is taught and learned in school' (p. 958). The simplicity of the definition does not do justice to the depth and complexity of the relationship between the concepts 'school subject' and 'academic discipline'. Stengel suggests that academic discipline and school subject have a range of possible relationships including continuous, discontinuous, and different-but-related. She argues that the manner in which stakeholders interpret the relationship between these concepts has a direct impact on curriculum in terms of purpose, practice and substance. Goodson and Marsh (1996) take a more contextual approach by using a 'block in a mosaic' (p. 150) metaphor to describe the school subject. They say that the subject mosaic has been painstakingly constructed over the centuries and is but one prism through which we can view the structure of schooling. In this paper, we use a combination of these two approaches to define what we mean by school subject. From Stengel we borrow the idea of that which is taught and learned in school, acknowledging the relationship this has with the notion of academic discipline. From Goodson and Marsh we borrow the idea of a block in a mosaic to portray the notion that school subjects, such as science, mathematics, English and art, for example, are single pieces of a complex picture that makes up a school system.

Goodson (1992) characterised the school subject in the British, American and Australian high school curriculum as 'unchallengeable high ground' (p. 23) that hardly felt the effects of the waves of curriculum reform of the 1960s. Nearly a decade later Goodson's words still ring with truth. Throughout the western world, curriculum documents stand as evidence that the school subject is as strong as ever. The Australian Education Council, for example, described National Statements and Profiles in eight curriculum areas, including science (Curriculum Corporation, 1994a, 1994b), and the states and territories in Australia have developed their own versions of this curriculum document, all of which are structured in specific learning areas — or subjects (for example, Curriculum Council of Western Australia, 1998; Victorian Curriculum and Assessment Authority, 2001). In England, the National Curriculum (Department for Employment and Education, 2000) defines a range of subjects to be taught as a core curriculum in all schools. Goodson (1992) points out the 'uncanny' resemblance of the core curriculum to the definition of public and grammar school subjects established in the 1904 Regulations and confirmed in the School Certificate Examinations of 1917. Siskin (1994) claims that in English high schools the 'arrangement into (subject) departments has been... taken for granted' (p. 9). Similarly, in the United States (US), Kliebard (1986) characterises the school subject in the high school curriculum as an 'impregnable fortress'. Roderick and Camburn (1999) comment on how the move from primary to secondary schools still results in North American pupils having to cope with dramatic increases in the structure of academic schedules, including the movement from isolated subject to isolated subject. In a similar way, the familiar set of entrenched US school subjects is described by Rogers (1997) as a scheduling device rather than a programme of

learning. In the Netherlands, de Brabander (1993) demonstrated that not only are subjects as strongly compartmentalised as ever but also different subject areas have different status. Further, the relative rankings of subjects in different societies show a remarkable correspondence (de Brabander, 2000) with science and mathematics ranked most highly. Regardless of the range of cultures and social structures in each of the countries described above it would appear that subjects constitute the foundation of curriculum structure.

There is, however, a persistent movement that is threatening the high ground of the school subject, a movement called curriculum integration. Integration is not a new phenomenon (Furinghetti & Somaglia, 1998; Hirst, 1974; Vars, 1991; Wraga, 1997) and it has endured alternate waves of popularity and ill repute over the past century. There is considerable breadth to the literature base, including classroom testimonials and research reports, as well as theoretical attestations of avid supporters and equally avid opponents. What is the status of curriculum integration? Can it, or even should it, challenge the high ground of the school subject? In particular, is science as a school subject under threat from curriculum integration? In this paper we try to answer these questions from two perspectives. First, we review and critically analyse the literature about curriculum integration from a science education perspective. Second, we examine the theoretical implications of the relationship between integrated curriculum and science as a school subject and suggest some future directions for integrated curriculum development. Before embarking on this discussion, however, we describe how our research journey led to our current understanding of curriculum integration.

Our journey begins

The background and rationale for writing this paper are embedded in our own research agenda. Over the past several years, our research in Australian middle schools has involved us in documenting teaching and learning in science integrated with mathematics and/or technology (Budgen, Wallace, Rennie & Malone, in press; Wallace, Rennie, Malone & Venville, 2001; Venville, Wallace, Rennie & Malone, 1998, 1999a, b; 2000; Venville, Rennie, Wallace & Malone, 1999). We started our research programme with an open-ended view of integration and the examples we found were frequently in tension with the disciplinary culture of the Australian education system. We observed that teachers were struggling to overcome some of the constraints of such a culture. They were unable to articulate clearly the advantages and disadvantages of integrated teaching practice and they rarely had a well-developed rationale for what they were doing. We investigated what pupils were learning, particularly in science, but also in technology and mathematics, and were sometimes critical that pupils were not always learning key scientific concepts in integrated settings (Wallace, Malone, Rennie, Budgen & Venville, 2001; Venville et al., 1998; Venville, Rennie et al., 1999). We then stepped back somewhat and considered what we felt we knew and what we needed to know about curriculum integration (Wallace, Rennie et al., 2001). We came to the conclusion that integration is a particular ideological stance which is at odds with the hegemonic disciplinary structure of schooling.

A leap in understanding for us was the realisation that even the word ‘integration’ implies that the ‘normal’ state of a curriculum is a disciplinary format and that to integrate is a step beyond that status quo. We reflected on our own research and wondered whether what we had done was to conduct research about one curriculum paradigm (integrated) from within another curriculum paradigm (disciplinary). Drawing on Kuhn’s (1962) work, Duschl (1994) suggests that during periods of flux in investigative science, there is considerable disagreement about methodology. Perhaps our questions, our background knowledge, the design of our investigations and the methods we used for evaluation of evidence were inappropriate for an integrated curriculum. We also recognised confusion in the literature and noted other research about integrated curricula embedded in theoretical and

methodological frameworks drawn from a disciplinary perspective. For example, Schug and Cross (1998) question the ability of teachers to work within an integrated curriculum to improve achievement, facilitate accurate accountability and generate appropriate curriculum materials. They suggest there are only difficult-to-measure benefits of curriculum integration. We suggest that Schug and Cross came to these conclusions using criteria derived from a discipline-based perspective. We further suggest that what they mean by achievement is judged in terms of how well pupils do in subject-based examinations and tests, and that difficult-to-measure really means not-well-established or accepted.

Other reviewers have also noted this confusion or contradiction. For example, Young and Gehrke (1993) critique Jacobs' (1989) interdisciplinary approach to curriculum because it maintains the perception that disciplines are still the fundamental entities that structure the nature of knowledge. They say that Jacobs' method of patching together the disciplines to create a whole is misguided.

> We do not need to create the whole: the whole already exists, we are in it… The part cannot know the whole; the part exists by virtue of the existence of the whole. (p. 447)

Rather, they prefer Smith's (1982) postmodern position on curriculum reform arguing that the teacher should 'undergo a fundamental change that must come from a deep experiential understanding of the unity and coherence of being' (Young & Gehrke, 1993, p. 449). In a recent research programme involving interviews with teachers implementing integrated curricula, Hargreaves, Earl, Moore and Manning (2001) argue for a 'fundamental change' in teachers' perspectives from one of fragmentation to one of wholeness. One of the teachers from the Hargreaves et al. (2001) study commented, 'we still have not integrated the subjects together…. I don't see how you are going to move math and science together' (p. 107). For this teacher, the notion of integration is about putting the subjects together, not about starting with knowledge in an holistic sense, or about starting with the aims or outcomes of the educational enterprise (Hirst & Peters, 1970). The first point of reference for this teacher is the subject matter and this seems to us to represent the point of contention. If you must have 'the subject', can you also have 'integration'? Is it necessary for Goodson's (1992) 'high ground' of the school subject to be eroded away entirely for integration to take place?

An overview of our journey

This paper is structured around five explorations and two positions about curriculum integration in general and the integration of science in particular. The explorations are the stages of our research journey, where we focused on a particular issue about integration to see where it would lead us. The first exploration is about integration itself, what it is and how it manifests in the school environment. The second exploration looks at the question of why we should or should not integrate, focusing particularly on the issues of pupil's engagement and adolescent alienation. Third, we examine how integration challenges what Tylack and Tobin (1994) call the grammar of schooling. In the fourth exploration, we ask what seems to have been a significant question for some theorists, do pupils' learn better, and in particular, better science, in an integrated setting? More importantly, we question whether this is a valid question to ask. In the fifth and final exploration we investigate integration as a curriculum ideology and note apparently competitive arguments concerning integration versus disciplinary-based curriculum. These explorations lead to two complementary positions, one theoretical and one pragmatic. We develop the theoretical position that integration is an ideological stance about curriculum with roots planted in a view of knowledge that can be described as worldly, experiential, contextual and organic rather than mechanistic, objective and framed within subjects, but we are also able to align the notion of curriculum integration

with a subject-dominated curriculum structure. Our second position develops a ‘pragmatic approach’ by examining instances of successful practice and suggests future directions for integrated teaching and learning.

Exploration 1: What is an Integrated Curriculum?

The literature is replete with descriptive examples of projects falling under the broad umbrella of curriculum integration, many involving science. It is not our intention to provide a comprehensive review of these projects. However, even a cursory glance through this literature would reveal that the term integration is used in myriad ways. For many commentators, the absence of a clear theoretical framework is part of the problem in developing a consistent theoretical and practical understanding of integration (Lederman & Niess, 1998). Although science and mathematics integration has been vigorously pursued since the 1930s (McBride & Silverman, 1991), there is a wide range of views on how integration should be described (Davison, Miller & Metheny, 1995). Fogarty (1991), for example, suggests a continuum of integration with several models arranged upon it. At one end of the continuum is a fragmented model and at the other end is what Fogarty calls a shared model, where disciplines share overlapping concepts and skills within a framework of shared planning and teaching between disciplines. Marsh (1993) also suggests that the various forms of curriculum integration can be considered as a continuum, from ‘discipline-based options’ with separate subjects taught at different times, to ‘internal orientation’ where pupils encompass activities that are jointly planned and implemented by pupils and teachers. The complexity of cross-curricular issues is emphasised by Grundy (1994) who outlines six different approaches to integration, including the integration of content, organisational practices, teaching practices, skills and competencies, assessment practices, and inclusive curriculum practices.

Drake (1991, 1998) describes a progression in the process of curriculum development through multidisciplinary, interdisciplinary and transdisciplinary approaches, each stage involving fewer distinctions between subjects. For example, in a multidisciplinary approach the pupils are expected to make the connections among subject areas, like science and mathematics, themselves. The disciplines are connected through a theme or issue that is studied at the same time but in different classrooms. In an interdisciplinary approach the subjects are interconnected beyond a theme or issue and the connections are made explicit to the pupils. A transdisciplinary approach does not begin with the disciplines but begins from a real-life context. A topic such as ‘water’ could be examined considering the influence of social, political, economic, media, global, environmental, and technological aspects (Drake, 1998).

While acknowledging some of the advantages of a continuum for categorising different forms of integration, Hargreaves, Earl and Ryan (1996) criticise the need for educators to classify in such a way. They suggest that a continuum does not capture the complexity of integration and possibly clumps together behaviours that in fact do not belong together.

> (E)ducational continuums often embody implicit values where movement along the continuum is construed as growth or progress towards a better state. However, progress along a continuum does not guarantee continuation towards progress. Given the many different kinds of curriculum integration, more integration is not always better. Sometimes it can be worse. (p. 103)

In a similar way, interdisciplinary models such as those suggested by Fogarty (1991), Marsh (1993) and Drake (1991) are criticised by Panaritis (1995) because of the implied value position that more integration is better than less. Panaritis points out the detrimental effects of statements, for example, that ‘science teachers "only" integrated parts of their curriculum’,

or ‘the way English and social studies treated literature was "merely parallel"’ (p. 627). In the light of these comments Drake (1998) argues that, although she sees the continuum moving into higher degrees of integration with more connections, ‘one position is not superior to another: rather, different approaches are more appropriate than others according to the context in which they are used’ (p. 19). Case (1991), on the other hand, refers to different types of integration, rather than a continuum. His four types are: 1) fusion of formerly separately taught elements (e.g. science, mathematics and technology), 2) insertion of one element into a larger set (e.g. writing science stories in history classes), 3) correlation between elements that remain separately taught (e.g. reference to hypotheses in science and mathematics), and 4) harmonisation of different skills, concepts, attitudes, etc., across separately taught elements (e.g. critical thinking). Hargreaves et al. (1996) hail Case’s (1991) typology as acknowledging the complexities of integration in practice without reducing integration to a ‘singular continuum along which teachers’ "progress" can be measured and controlled!’ (Hargreaves et al., 1996, p. 105).

In our own empirical work we began our research journey by looking for school-based examples of integration involving science. After consultation with policy makers, school administrators and teachers, we observed many different classrooms where some part of the curriculum was claimed to be integrated (Venville, Wallace et al., 1999b). While some of these examples involved modifications of the school timetable and the formation of teaching teams, in all cases the separate subjects of science, mathematics and technology were retained as the vehicles for assessment and reporting. Examples of so-called integrated teaching ranged from deliberate and explicit attempts to integrate by the teachers, including thematic (e.g. Olympics, the environment) and cross-curricular (e.g. numeracy, computing skills) approaches, through to more incidental and informal efforts, such as science fairs and local community projects (e.g. mapping a wetlands area). Other approaches included whole school specialisations (e.g. horticulture, marine studies). In terms of capacity to ‘bridge the boundaries’ of the different disciplines (Venville et al., 2000), the most promising approaches were those where the course content was focused around problem-based projects or issues where the subject boundaries were blurred. That is, integration involved some form of culminating event or events requiring the assembly and application of an array of outcomes that might come from different subjects. One example of this approach, described in Venville et al. (2000), involved technology-based projects providing a centrepiece for pupil work in science, mathematics and technology, in this case, designing a solar powered boat.

Our initial exploration of what an integrated curriculum looks like in practice found a broad spectrum of classroom practices that were described as integrated. As we noted earlier, researchers’ attempts to classify integrated classroom practice along various continua have been criticised because they imply that more integration is better. In the examples of integration we examined, we could not say that some were better, merely that they were different. Further, we could not say that integration was better than subject-based curricula. With these new understandings, we shifted our focus onto the reasons behind teachers’ decisions to integrate.

Exploration 2: Why Integrate?

Throughout the period of our work in schools, we noticed many instances of enthusiastic teachers implementing what they called integrated curricula. However, notwithstanding this enthusiasm, it was not clear to us why teachers were doing this and frequently the teachers themselves were unable to articulate clear goals for their action. Indeed, as we ourselves pondered the reasons for curriculum integration, we were struck by the complexity of the question. Thirty years ago, Hirst (1974) and Hirst and Peters (1970) suggested that an integrated curriculum could be justified through a view of knowledge that is unified or perhaps even chaotic in nature. In a logical extension of this unified view of knowledge, Hirst

(1974) explained that subjects restrict pupils' thinking and development by making the process of learning artificial and alien compared with their life experiences. In one sense, it would appear that curriculum integration has some intrinsic virtue, in terms of the way that knowledge is organised — as connected, embodied, ecological, harmonised knowledge. Under this view of knowledge, the learner is seen to be at one with nature, entwined and implicated in local and global conditions, large and small (Davis, Sumara & Luce-Kapler, 2000). In another sense, it seems that integration is being used to attend to some more immediate practical questions about pupils' connection to schooling, particularly problems associated with adolescent alienation and under achievement in the early secondary school years (Hargreaves et al., 2001). We recognise that these two perspectives, one about theories of knowledge and knowing, and one about the practicalities of pupil engagement, provide different ways of thinking about the question, 'why integrate?' In this exploration, we chose to focus particularly on the practical issues, leaving our treatment of knowledge structures until later in the paper.

Problems associated with the schooling of young people, including pupils' anxiety and alienation, transitions from year to year, and fragmentation of the curriculum are well described in the literature. Roderick and Camburn (1999), for example, provide bleak statistics that reflect the levels of alienation from school for urban adolescents in Chicago: 'Over 40% of entering ninth graders fail a major subject in the first semester (English, mathematics, history, or science), while 20% fail two or more'(p. 305). Cormack (2000) also found that middle schools are 'marked by increasingly diverse populations of students and new (multi)mediated experiences that run across traditional age, geographic, cultural and political boundaries' (p. 60). The issues confronting middle schooling are clearly multifaceted and invite a range of responses, including curriculum responses.

Cumming (1994a; 1994b) discusses a number of issues regarding the education and development of young adolescents, such as curriculum and school structure, health, welfare, justice and employment, and the current responses to these issues by schools and other agencies who work with young people. Cumming's (1994a) paper draws on a number of studies that show, among other things, that a significant number of pupils find the traditional curriculum lacks relevance and cohesion, the teaching practices are alienating or simply boring, and schools consist of rigid structures and procedures. Cumming describes many contemporary issues that are critical to pupils, such as adolescent fitness, weight loss and gain, adolescent sexual behaviour, bullying, suicide, smoking, drinking, racism and crime. He concludes that an integrated approach within and between schools, but also amongst community agencies and organisations, is necessary to address these issues.

Pupil engagement with the intellectual work of school is important to pupils' achievement and to their social and cognitive development. However, research has suggested that pupil engagement in instructional activity, particularly in the middle school years, is generally low. Engagement is 'a psychological process', involving pupil attention, interest and effort in the work of learning (Marks, 2000, p. 154). One US study looked at 3 669 pupils in their social studies and mathematics classrooms to investigate the effect of restructuring the systems relating to pupil support and academic work on pupils' engagement (Marks, 2000). Restructuring involved linking the systems of participation, including connections for pupils among school, family, friends, and work. Attempts were made to provide authentic academic work, which involved pupils intellectually in a process of disciplined inquiry to solve problems with relevance in the world beyond the classroom and of interest to them personally. 'Authentic work', as described by Marks, involved looking at knowledge in a connected state to the world beyond the classroom. Marks concluded that authentic instructional work is a powerful contributor to engagement for elementary, middle and high school pupils and the effect is enlarged as pupil grade level increased. The results showed that tapping standards of intellectual quality, for example, higher order thinking, depth of knowledge, substantive

conversation, and connectedness to the world beyond the classroom, do promote engagement and satisfaction. This approach stood in contrast to traditional approaches that were described as alienating work. These sources of pupil disengagement were found in bureaucratically organised schools and included school work of low cognitive level which was perceived as meaningless, and resulted in impersonal relationships with teachers and other pupils (Marks, 2000).

In a similar vein, Lee and Smith (1995) conducted a study comparing pupil achievement and engagement in high schools that were characterised as having 'traditional' versus 'restructuring' practices. Restructuring practices included keeping pupils in the same homeroom throughout high school, encouraging parents to help within the school, and using interdisciplinary team teaching. They found that pupils in restructuring high schools had higher learning gains in major subjects, such as science, and were more academically engaged than in traditional high schools.

In our own work, we observed several instances of integrated classroom environments that held pupils' interest and enhanced learning across the curriculum. These lessons were characterised by high levels of teacher and pupil engagement and interaction. Teachers and pupils in these classes had a clear sense of direction and the work was cognitively challenging. Participants were emotionally involved and there was a high level of trust and co-operation. Teachers regularly made links to the real world and from science to other disciplines. These features were present whether the class was taught by a team of teachers or a single teacher, and whether the science content matter was chosen to fit a theme, a technology project, a community project or arranged in some other manner. This observation made us wonder whether, in the quest to engage pupils, the critical issue is one of good teaching rather than integration, however that might be achieved.

In summary, one of the practical arguments for integration, particularly in the middle school years, is that it enhances pupil engagement with school. Several studies show that providing an authentic curriculum well connected to pupils' needs and interests, and to the world outside of school, can result in reducing alienation and raising participation and engagement. Sometimes this authenticity is associated with integrating across the disciplines and sometimes it is to be found within a disciplinary paradigm. We also noted the importance of good teaching in this equation. However it is also clear that these kinds of curricula (including integrated) are not particularly common in middle and high schools. Given the systemic nature of the problem of pupil alienation and lack of engagement at these levels, and the potential of integrated practice to address these problems, why is integration so difficult?

Exploration 3: Why is Integration Difficult?

Not withstanding the push for integration as a way of enhancing middle school pupils' engagement, in our own work we found that examples of integration are piecemeal and idiosyncratic. They seem to rely on local champions harnessing local resources to address local issues. Few of the examples of integration we observed were sustained over time. Why is integration so difficult? We suggest that integration challenges what Tylack and Tobin (1994) call 'the grammar of schooling'. Grammar underpins the culture of schools and is reinforced by the customs, rituals, ceremonies and artefacts of everyday school life (Deal & Kennedy, 1982). Once established, the grammar of schooling is difficult to change. Many factors contribute to the strength and persistence of the grammar of secondary schools, including teacher recruitment and identity, subject histories, assessment structures, department politics, subject status, pupil futures, and an overcrowded and content-laden curriculum (Hargreaves et al., 1996). Indeed, much of what happens in secondary schools

appears designed to protect subject interests (Siskin, 1994), and this may explain why curriculum integration and collaboration across subject boundaries are so hard to achieve.

Schools play a role of upholding prevailing moral and political values and some parents may be concerned that integrated programmes reduce the level of the academic discipline or change the traditional relationship between teachers and pupils (Kaplan, 1997; Marsh, 1993). An integrated curriculum does not accord with the ongoing expectation in many countries that the school curriculum should be academically oriented, emphasising written work and individual study and focusing on examinable aspects of the syllabus (Kaplan, 1997). The co-existence of more conventional curriculum requirements and university entrance examinations at a higher level of the school is a common argument against the implementation of an integrated curriculum. Pupils are expected to participate in middle school subjects that prepare them for study later in their academic career (Clark & Clark, 1994; Hargreaves et al., 1996). The persistence of traditional patterns of assessment, parental pressure for traditional academic standards and subject-based qualifications, instructional periods, textbooks, curriculum guides, staff who were trained in their disciplines and have developed long-standing attachments to them (Helms, 1998) and the lack of a culture of school collaboration, all pose significant barriers to the implementation and continuation of an integrated curriculum (McBride & Silverman, 1991; Hargreaves et al., 1996).

Wallace and Wildy (1995) describe a case study of a physics teacher in a school where the grammar of schooling, in particular the social and cultural context, presented barriers to the implementation of a new physics syllabus with constructivist underpinnings. The researchers expected that teachers teaching the new syllabus would provide pupils with opportunities to construct personal and social meaning of the subject matter. The teacher initially experimented with a more context-based approach, however, the researchers observed a return to an emphasis on content coverage over understanding and teaching towards the examination. The teacher identified a number of compelling reasons for extending what he was already doing rather than making significant changes to his teaching strategies. He was concerned that pupils learn the discipline of physics with its structure of recognised and established protocols and conventions, without which he felt the structure of the discipline disappeared. The teacher's track record of proven strategies for teaching physics, the comfort that he and his pupils had with those strategies, the recognised protocols and conventions of the discipline, the unwritten trust between parents, pupils, school community and teachers, the aspirations of the pupils and, most importantly, the culture of schooling to achieve academic success exemplify the well entrenched grammar of schooling.

In another case study, Roth (1993) demonstrated how the grammar of schooling proved to be an impediment in terms of pupil assessment across disciplines. Roth pointed out that a pupil learned both differentiation and integration through applications in physics before the topics were studied in his mathematics courses. Due to the school's strict subject matter divisions, however, the pupil received credit for his work only in his physics course and not in mathematics. Costa (1997) also documents that a school's unique culture plays an important role in determining what knowledge is made available and negotiated in chemistry classrooms. Costa found that curricula differences are linked to expectations about the school's function. Thus, although chemistry may be offered at two schools, how pupils and teachers construct the meaning of chemistry may differ at each school. Costa concluded that what pupils learn about science depends upon the shared practices, values and resources of their school community.

In our own research (Venville et al., 1998) the persistence of the grammar of schooling was expressed in many different ways. For example, many science teachers felt that pupils needed to learn the basic content in subjects like chemistry before integrated teaching could

proceed. Some teachers were concerned that teaching in an integrated way might lead to science, mathematics and technology becoming an 'amorphous mass'. In another example, high school mathematics teachers expressed concern at the heterogeneous nature of integrated classes and the difficulty of changing from the traditional arrangement where classes are streamed into homogeneous ability groups. There was often a tension in schools between teachers' loyalty to their subject colleagues and leaders, and their colleagues and leaders in the integrated learning team. Some teachers complained that while activities were organised around interdisciplinary tasks, they were still required to report in terms of pupil outcomes in the separate disciplines. While official documents exhorted teachers and pupils to 'understand the arbitrariness of any division of knowledge into... subjects or categories' (Curriculum Council of Western Australia, 1998, p. 27), teachers found the subject-based nature of curriculum organisation, including school and state curriculum structures and supports, to be anything but arbitrary. There were also cases where teachers had difficulty convincing parents, who were used to the traditional subject structures, of the efficacy of more integrated approaches, particularly those parents who aspired university entrance for their children and were well aware of subject-based entry examinations.

Support for the traditional subject structures was a recurring issue in our research. As we have seen, it is deeply entrenched as part of the grammar of schooling and indeed we began this paper by positing that traditional school subjects like science occupy 'high ground' status. What is it about science as a school subject that determines its high status? To answer this question we turn to the work of Bernstein who analysed the nature of worthwhile school knowledge. Bernstein (1971, 2000) uses the concepts 'classification' and 'frame' to describe the underlying structure of curriculum. By classification he refers to the nature of the differentiation of the content of one subject compared with others. Where classification is strong, the content of the subject is well insulated from the content of others by strong boundaries. Where classification is weak, there is reduced insulation of content and the boundaries of the subject are weak or blurred. 'Classification thus refers to the degree of boundary maintenance between contents', wrote Bernstein (1971, p. 49). The content of school subjects like physics, chemistry and biology, for example, is well differentiated between that subject and each of the other science subjects and, therefore, these are strongly classified. In contrast, the content of a subject like general science is more weakly classified, because the boundaries between physics, chemistry, geology and biology have been broken down.

Bernstein's (1971) concept of frame refers to the specific pedagogical relationship between the teacher and the pupil. Frame refers to the strength of the boundary between what may be taught and learned and what may not be taught and learned. Where framing is strong, there is a sharp boundary; where framing is weak, there is a blurred boundary between what may and may not be appropriate content. According to Bernstein (1971), 'frame refers to the degree of control teacher and pupil possess over the selection, organization and pacing of the knowledge transmitted and received in the pedagogical relationship' (p. 50). To return to the previous example, although a subject like general science may be weakly classified, it still may be strongly framed if the science content within it and how that is taught is tightly prescribed. If the teacher or the pupils may vary the content or the pedagogical activities to pursue a specific interest, for example, then the subject will be weakly framed. Through this analysis of classification and frame, Bernstein generalises about the European (particularly British) approach to secondary schooling. He says that depending on the specific strength of classification and frames within schools, curriculum is generally rigid, differentiating, hierarchical and highly resistant to change. Bernstein claims that the highly classified and highly framed structures of the traditional subjects, like physics and chemistry, provide for pupils who are university bound, but for those who are not, these subjects can be seen as meaningless.

The hierarchical nature of Bernstein's concepts of classification and frame have been extended and utilised by Parker (1994) and de Brabander (2000). Parker claims that the more strongly classified and strongly framed a subject is, the higher is its status. Conversely, weakly classified and weakly framed subjects have lower status. Subjects like physics and chemistry, therefore, have a high status because they are strongly framed and strongly classified, whereas a subject like general science is more likely to be weakly framed and weakly classified and have a lower status. A subject such as physical science, combining physics and chemistry, will be less strongly classified than either physics or chemistry, but may still be strongly framed. Its status would be intermediate between physics or chemistry and general science. Parker (1994) was able to demonstrate empirically the relationship between classification, framing and status of science subjects in the Western Australian science curriculum. De Brabander (2000), while investigating the conceptions or definitions of knowledge that teachers 'transmit', noted both the status differences and evidence of power differences between subcultures in secondary schools, including between school subjects. His findings suggested that teachers classified knowledge on two dimensions, first, as everyday knowledge or academic knowledge and, second, as general or specialised knowledge. Subjects with everyday knowledge were considered 'soft', that is, the knowledge they offer is not easily testable, it is subjective and relatively open to debate, as opposed to subjects providing 'hard' academic knowledge that is characterised as testable, objective, and established. Art education and social studies were characterised as offering everyday knowledge whereas mathematics was viewed as the classical academic subject. Biology and Dutch language (the mother tongue in de Brabander's research) were considered 'in between'. General subjects offer knowledge that is called for on many different occasions. Specialised subjects, on the other hand, offer knowledge that is only useful on infrequent, special occasions. Biology, physics and chemistry were clear examples of specialised knowledge and Dutch language was considered the most general subject.

If we consider an integrated approach to learning within the schemes proposed by Bernstein, Parker and de Brabander, integrated topics would invariably be weakly classified and weakly framed, everyday rather than academic and general rather than specialised. Integrated topics, by their very nature, are weakly classified because their content is not well insulated from that of other subjects. They are intended to blend the content from several subjects. An integrated topic is weakly framed because there is not a strong boundary between what may be taught and learned and what may not be taught and learned. The content of integrated subjects is varied and largely determined by the interests of the pupils and the teacher. Subjects such as science, when offered in an integrated curriculum, are often based on content that is difficult to test, subjective and relatively open to debate. They therefore can be considered 'soft' knowledge, in contrast with the 'hard' content knowledge found in subjects such as physics and calculus. Topics taught in an integrated curriculum offer knowledge that is called for on many different occasions, rather than knowledge that is infrequently used, and therefore can be classified as 'everyday' rather than 'academic'. Using Bernstein, Parker and de Brabander's arguments, each of these classifications points to a low status for topics taught within an integrated curriculum. Low status subjects are considered to contain content that is perceived as less worthwhile than others and are selected and studied by pupils on the basis of these perceptions (Parker, 1994).

It seems, then, that two related ideas, the grammar of schooling and the high status of the discipline-based school subject, work together to make curriculum integration difficult. It is evident in the literature and through our own research, that the notion of the grammar of schooling subsumed many of the barriers to the implementation of an integrated curriculum. These barriers include such things as school structure and timetabling, academic courses, assessment, parental preferences, established curriculum documents and teachers with discipline-based qualifications. These well-entrenched and well-supported features of schooling are difficult to erode because they support learning and assessment in a discipline

structure. Further, by drawing on the theoretical work of Bernstein, Parker and de Brabander, we see why traditional school subjects like physics and chemistry have high status, and conversely, why science integrated other subjects has low status. Together these ideas explain some of the difficulties educators experience in trying to integrate curricula. They also explain why integration in high school occurs more easily in the lower years, rather than the upper years. Here the high ground status of traditional, disciplinary, subject-based curricula dominates, providing a barrier to the implementation of an integrated curriculum.

Exploration 4: What is Being Learned in Integrated Settings?

It is not possible to examine learning in integrated settings without considering the issue from a particular perspective. The kind of learning observed (or not observed) depends on the perspective adopted. Gains in understanding from a holistic perspective, for example, can easily be interpreted as losses from a disciplinary perspective, and vice versa. In some of our previous work, while we did notice some gains in pupils' capacity to transfer knowledge, we chose to highlight deficiencies in specific subject matter knowledge. We recorded many instances of pupils retaining naive scientific and mathematics understandings and an absence of remedial teaching to address such deficiencies. For example, in a technology programme based on bridge design, we found pupils with several important scientific misconceptions about forces (Venville, Wallace et al., 1999a). In another technology-based project on rocketry, pupils were found to have misunderstandings about mathematical terms used in the rocket design, such as circumference, parallel, diameter and congruent (Wallace, Malone et al., 2001). In a third example, a solar boat project, pupils did not have good theoretical explanations for the science concept of an electric current flow (Venville, Rennie et al., 1999).

Other research, also from a discipline-based perspective, reported a range of pupil understandings of science in integrated contexts. Ritchie and Hampson (1996), for example, described a semester-long interpretive study of a series of technology-based projects in a Year 6 classroom in an Australian primary school. Some pupils constructed understanding of science concepts in their technology projects, learning about concepts such as fulcrum, length of load and effort arms, projectile range, and energy conservation through a creative marble machine project. Other pupils were able to draw and describe the operation of a simple electric circuit after completing a creative toy project that included a simple circuit and several lessons on the topic. In contrast, a further pupil had not grasped a basic understanding of simple circuits, was confused about the model of an electric circuit developed in class and was unable to demonstrate that she understood what would happen if one of the wires in a circuit was cut.

Other studies have attempted to incorporate some broader and more holistic perspectives into their evaluation of pupil learning, focusing on outcomes such as pupil motivation, attitude, cooperation and capacity to transfer and apply knowledge. Wicklein and Schell (1997) present four case studies of multidisciplinary approaches to integrating science, mathematics and technology education in high schools in four different states of the US. The most successful aspect of one innovation was the improved motivation on the part of the at-risk ninth grade pupils in this programme to attend class. However, from a disciplinary perspective, the most disappointing aspect was that some pupils in the programme had difficulty in grasping the instructional content of this team-taught course. In another study, Clark and Clark (1994) also report improvement in the affective areas, pupils became more involved and excited, and demonstrated less competition and more co-operation. In contrast, Henderson and Landesman (1995) found that there was no difference in attitudes towards mathematics or self-perception or motivation in mathematics as a result of a thematically

integrated mathematics unit. However, on mathematical concepts and applications the experimental pupils achieved better results than the control pupils.

Ross and Hogaboam-Gray (1998) reported on the effect, on pupils' learning of integrating science, mathematics and technology in a Canadian Grade 9 course. The study found benefits for pupils in the integrated setting in terms of their ability to apply shared learning outcomes, pupil motivation, ability to work together and attitudes to appraisal of group work. Lamb, Householder and Bailey (2000) describe a project that prepared school teams of science, mathematics and technology teachers and an administrator to set goals for their local schools regarding the implementation of electronic technology and integration of content across curricular areas. The teachers reported that their pupils expanded their knowledge and skills in problem solving, teamwork, technical expertise and creativity. Similarly, Hargreaves et al. (2001) found that middle school pupils studying integrated units of work accessed skills such as higher-order thinking, problem-solving, application to real world problems, creativity and invention, and collaborative and individual learning.

According to one of the teachers from the Hargreaves et al. (2001) study, pupils who had been studying an integrated curriculum had better skills in essay writing, comprehension and research, while pupils in more traditional curriculum settings had better content knowledge:

> A lot of our kids don't have the knowledge base, but they are very good at the skills. That's helped them out when they go to high school. They may not know all there is to know about the opening of the West and the railroad, but when it comes to essay writing, they're really good at it. When it comes to supporting their answers or reading for context or detail, they are good at that. If they are told that they have to develop a research project, they're great at coming up with an inquiry question. They're really good at using key words in context and finding the information that they need. But they don't know all the facts. So you're kind of damned if you do and damned if you don't. (p. 110)

As we flagged at the beginning of this exploration, evaluating learning in integrated settings is a multifaceted issue. The fluidity of defining exactly what is meant by integration is one part of the problem. Another part lies in describing the nature of the learning and the lack of measures for such learning. Further there is a dearth of close-up research into what pupils know and can do in integrated settings. When the high ground of the school subject plays a role, the subject is emphasised, privileging learning in the subject content. But if integration is the focus then things other than learning content become important. Perkins and Simmons (1988) note that assessment of learning in integrated settings characteristically neglects all but the content and urge more attention to assessment of problem-solving and inquiry skills.

One approach to analysing the research on integrated curricula is to think about learning in terms of the claims being made for integration (Ross & Hogaboam-Gray, 1998). Three arguments seem to permeate the literature — the focus argument, the transfer argument and the motivation argument. The focus argument is based on the belief that pupils are more likely to learn when their attention is focused on a few objectives rather than diffused among many (Berlin & White, 1994). The transfer argument refers to the ability of pupils to apply their knowledge when and where it is needed (Brown, Collins & Duguid, 1989). The motivation argument is based on the belief that pupils are switched on to learning through working on meaningful tasks, connected to their social and personal concerns (Cumming, 1996).

These arguments also have important implications for learning in the disciplines. By way of illustration, we will examine the notion of focus more closely. Focus is one of the key

arguments for integration — that is, pupils are more likely to learn when their attention is focused on few, rather than many, objectives. If the focus of the activity is on constructing a bridge, for example, then it is likely that knowledge about forces may be useful, but it is not necessarily central to the core bridge-building activity. If, however, the focus is on learning about forces, then the bridge building can be seen as simply a vehicle for that learning. In this context it is unlikely that integration — of science, mathematics and technology, for example — can achieve the diverse goals of all three subjects as well as focus pupil's attention on an overarching goal, such as building a bridge. Learning gains in one area, we argue, are often offset by losses in another.

In summary, we found the research on learning in integrated contexts to be generally fragmented and lacking in theoretical continuity. Evaluation of pupil learning depends on the learning perspective. For those who value the traditional, discipline-based subjects, the learning must be evaluated in terms of understanding the important concepts in the subject. But for those educators who value integrated curriculum, the outcomes are not so well defined. We have arrived at a position where it seems that research on learning in integrated settings needs clarification of the theoretical assumptions that underlie the integrated paradigm. Unfortunately, it is not at all clear what these assumptions are or whether it is possible to reconcile assumptions about integration with those about the subject discipline.

Exploration 5: Can Curriculum Integration be Reconciled with the Disciplines?

It seems to us that integration is a stance about curriculum underpinned by certain ideological assumptions. These assumptions are associated with particular value positions about ways of knowing which, in turn, inform stances of the importance of the subject matter and the structure of schooling. Most of the arguments for, and against, integration appear to turn on an epistemological axis. Proponents of integrating science, mathematics and technology, for example, argue that these three disciplines have many natural connections and overlaps — common concerns about the nature of 'truth', for example, and about the relationship between the pure and applied fields of each subject. Opponents say that each discipline operates under fundamentally different (and irreconcilable) epistemological assumptions, such as the differences in the use of 'empirical evidence' and 'data' (Lederman & Niess, 1998).

These different epistemological positions appear to underscore the different philosophical and practical stances taken by various curriculum reformers. Take, for example, the different positions espoused by Howard Gardner and Ted Sizer on school reform (see Hatch, 1998). On the one hand, Gardner argues that 'robust understandings of important phenomena and concepts depend on the study of disciplines like history, the natural sciences and mathematics, and the development of capabilities to use the methods and approaches of those disciplines' (Hatch, 1998, p. 19). On the other hand, Sizer's position is that disciplines are 'artificial creations, artefacts of evolution and history, that fragmented and compartmentalised knowledge' (Hatch, 1998, p. 19). According to Sizer, the epistemological niceties of the disciplines constrain teachers' abilities to connect with the way children see the world. Gardner emphasises the importance of disciplinary skills and understandings in the learning process; Sizer focuses on breaking down traditional curriculum structures to address real-world interdisciplinary problems and issues. Pena, Brown-Adams and Decker (1999) suggest that such pro and con discussions about curriculum integration represent a struggle for control over what is taught in public schools.

Another strong advocate of curriculum integration, James Beane (1991, 1995) argues in a similar vein to Sizer. He claims that subject areas or disciplines 'are actually territorial spaces carved out by academic scholars for their own purposes' and that 'their boundaries

limit our access to broader meanings' (Beane, 1991, p. 9). Similarly Hargreaves and Earl (1990) assert that:

> Secondary schools are deeply entrenched in an academic orientation that is perpetuated by a large number of beliefs and traditions that make this academic orientation among the most powerful of the 'sacred' norms of secondary schooling. This pervasive academic orientation creates a curriculum that is unbalanced, is content-driven, has limited relevance for many students, and results in fragmentation of student experience and balkanisation of secondary schools and their departments. (p. 209)

Other scholars have been pressing for greater integration of pure and applied fields of study. McBride and Silverman (1991), for example, support the integration of elementary and middle school science and mathematics. They argue that these subjects are closely related systems of thought and are naturally correlated in the physical world, that science can provide concrete examples of abstract mathematics concepts and, conversely, mathematics enables the deeper understanding of science concepts. These researchers, and others, claim that children learn science and mathematics more effectively when they can connect experiences concretely with the principles they are studying in various subjects, including technology (Hamm, 1992; LaPorte & Sanders, 1993; Perkins & Simmons, 1988; Sanders, 1994).

A moderate view of the middle school curriculum that encompasses both integrated and discipline-based approaches is presented by Hargreaves and his colleagues (1996, 2001). In a similar manner to Beane, they suggest that conventional subject structures 'skew the curriculum towards the academics, in a way that can be demotivating for many less able pupils, who find such work unnecessarily difficult and remote from their experiences' (p. 109). They do not see a conventional, subject-divided curriculum as one suited to the needs of the early adolescent and suggest that the curriculum should have greater integration between and beyond subject areas. However, while Hargreaves et al. (1996) support an integrated approach, they do not believe that curriculum integration and subject specialisation are mutually exclusive alternatives. Hargreaves et al. dismiss the claims by some advocates of integrated curricula that subject boundaries should be dissolved and subjects abolished as 'idealistic and irresponsible' (p. 107). Instead they suggest that subject boundaries should be 'redefined' and 'softened'. Hargreaves and his fellow commentators pinpoint the needs of the people, the purpose of the curriculum and how well it fits the setting, as important guidelines for designing a curriculum that may include both discipline-based subjects and integrated subjects. This moderate view resonates with the views of earlier educators such as Hirst (1974) and Hirst and Peters (1970) who formulated the 'means-ends model'. This model emphasised the need to determine the aims or objectives of the course before planning a curriculum and that these aims should be diverse and complex in interrelationships. Planning curriculum units, according to Hirst and Peters, becomes the organisation of the best means to achieve those ends whether in the form of subject, topic, project or a combination of these. 'There would seem to be something seriously wrong with any form of education in which the organization of the means becomes more important than the ends it serves' (Hirst & Peters, 1970, pp. 71-72).

From a practical perspective, Rogers (1997) claims that much of the world works without strict adherence to disciplinary frameworks and that disciplines are just one way of organising knowledge in contemporary society. She suggests that learning pathways should be organised around a collection of understandings and ways of looking at the world, rather than narrowly arranged around the academic disciplines. An alternative way of looking at knowledge, suggested by Rogers (1997), is through a profession, such as architecture, that knits together knowledge from several disciplinary areas and operates according to an

internal set of standards. Thus professions have multi-disciplinary knowledge organised in ways that are pragmatic and cross boundaries. In this sense, it is rather paradoxical that university entrance requirements are strongly subject-based, with the high status subjects of science and mathematics serving a filtering purpose rather than providing pre-requisite knowledge!

Another moderate view of a approaches to curriculum integration, but from a different philosophical perspective, is presented by Caskey and Johnston (1996). They claim that pupils' future academic achievement may be compromised if middle schools focus on the emotional needs of adolescents. To maintain pupil achievement and public confidence in the middle level school as an academic institution, Caskey and Johnston (1996) suggest that educators need to be sure to create an authentic, rigorous middle school curriculum. This can be achieved, according to these authors, by the implementation of a balanced programme including appropriate use of discipline-based direct instruction, cooperative learning experiences, and self-directed, inquiry-based knowledge construction.

The foregoing examples are illustrative of the ideological divide between the proponents and opponents of curriculum integration, and those who take a more moderate view. Given the foundational nature of the arguments, it is perhaps surprising that the idea of curriculum integration has received so little critical scrutiny in curriculum documents and teachers' implementation plans (Lederman & Niess, 1998). In our own work, for example, we found that teachers had some broad notions that integration would be good for building teamwork, developing links across the curriculum and making school more relevant for pupils. However, these advantages were seen as 'taken for granted', rather than the subject of debate. Teachers were so consumed by the issues of implementation (scheduling, meetings, forming teams, building content knowledge, designing curriculum themes, activities and assessments) that they had little time for critical discussion. Implementation failure was attributed to these additional pressures rather than to some underlying flaw in the integration idea.

In this exploration we have described integration as a particular ideological stance about curriculum, with a distinct and separate structure compared with traditional discipline-based subject approaches. We also raised questions about whether it is necessary that these ideological positions remain separate and opposed? Or is there some way of re-examining these positions so that the apparent hostility between the proponents and opponents of curriculum integration can be ameliorated? Is it possible to provide teachers with a philosophical foundation on which to make informed decisions about curriculum integration, its implementation and what the outcomes might be?

Thus far in our journey, we have explored five questions: what is an integrated curriculum? why integrate? why is integration difficult? what is being learned in integrated settings? and can integration be reconciled with the disciplines? Our explorations have led us towards developing some directions for curriculum integration and teaching in integrated contexts. We develop these directions from both theoretical and practical positions. Our first position is theoretical, about an alternative way of conceptualising integration, and our second position is practical, about what can be done in schools and in classrooms.

Theoretical Position: A Worldly Perspective

Through the last exploration we described curriculum integration as having a distinct and separate structure compared with traditional discipline-based subject approaches to curriculum. A strong temptation is to postulate two paradigms, a discipline-based paradigm, and an integrated paradigm situated at two ends of a continuum, and many of the authors we have quoted take this view. However, our theoretical position proposes not two separate

paradigms, but a single, worldly perspective incorporating both integrated and disciplinary paradigms. We develop this worldly perspective by reviewing some of the arguments about the essence of curriculum integration, how these arguments deal with the disciplines and what they say about the nature of knowledge.

What is the essence of curriculum integration?

What is curriculum integration? As we have established, there is a diverse and complex array of curriculum arrangements falling under the broad umbrella of integration (Venville, Wallace et al., 1999b). There are calls for a 'common definition' for the 'basis for designing, carrying out, and interpreting results of research' (Czerniak, Weber, Sandmann & Ahern, 1999, p. 422). We consider this view to be narrow and driven by the opinion of some researchers that 'there is little existing empirical research supporting the notion that it [curriculum integration] is more effective than traditional, discipline-based curriculum' (Czerniak, et al., 1999, p. 422). Such a view is also divisive because it is based on the need to establish that one approach is better than the other. We don't believe that this offers the best way forward. Nevertheless, for the purpose of developing a useful conceptual structure (in a broader sense than a definition) for theorising, we draw together several rich descriptions that encapsulate what we consider to be the central elements of integration.

Drawing from the work of Bernstein (1971), Hargreaves and his colleagues (1996) argue that curriculum integration entails subordinating previously insulated subjects or courses to some relational idea, which blurs the boundaries between the subjects. What is important from Bernstein's interpretation of an integrated curriculum is that the relationships between subjects should be rigorous, robust and at a high conceptual level, rather than practical and loosely constructed topics and themes with superficial references to 'natural connections'. For example, Hargreaves et al. suggest a legitimate integration could be encouraged between biology and sociology through the high conceptual level concepts of genetic and cultural codes. Conversely, Hargreaves et al. cite the example of 'railways' as a low level, practical theme around which elements from different subjects, like science and social studies, can be linked loosely rather than integrated at a high conceptual level.

Beane (1995) defines integration as a curriculum that begins with 'problems, issues and concerns posed by life itself' and takes this one step further to say that the central focus of curriculum integration 'is the search for self- and social meaning' (p. 616). Beane explains that pupils are engaged in seeking, acquiring and using knowledge in an organic — not an artificial — way. According to Beane, then, integrated curricula begin by working with young people to examine the problems, issues and concerns of life as it is being lived in a real world. In a similar vein, Rogers (1997) describes a curriculum that uses a sense of knowledge based in the real world and in the child's experience. Rogers suggests that such a curriculum would engage pupils in rigorous and deep learning and encourage them to begin mapping their own understandings as a result of their experiences. Interestingly, neither Beane nor Rogers exclude learning within disciplines. Instead, they argue that by working through themes, to broaden and deepen understanding of the world and ourselves, we must draw on the disciplines of knowledge. From this perspective, an integrated curriculum draws on the disciplines as a source of explanation and inquiry to answer and explore organic, or real life, issues relevant to young people.

As we noted earlier, even the term 'integration' itself implies that disciplines are the normal state of knowledge and that the process of bringing the disciplines together through integration is but a step away from the status quo. In contrast, the term worldly, when used in conjunction with knowledge, portrays a metaphor of knowledge about life in a natural, undivided, holistic sense. This worldly or organic view of knowledge is repeated in conceptualisations of an ecological approach to teacher education (Wideen, Mayer-Smith &

Moon, 1998). For example, developments in ecology, biology, chemistry, astrophysics, quantum theory and human consciousness research call for radical re-visioning of our current fragmented mechanistic worldview, because these developments portray knowledge about the world as complex, creative, ever-evolving and deeply interconnected (Wideen et al., 1998). A unified approach, according to the biologist Edward Wilson (1998), 'cannot be acquired by studying disciplines in pieces but through pursuit of the consilience among them' (p. 14). This approach requires a radical shift from thinking of content in compartmentalised sub-units, to thinking of contexts that emphasise inter-connectedness.

It seems clear that the central elements of the arguments about integration hinge around the structure of knowledge and the way knowledge is presented in the curriculum. From an integrated perspective, the boundaries of the disciplines are blurred, and the contexts in which learning occurs are paramount, suggesting the need for an interconnectedness among the strands of knowledge rarely evident in a subject-dominated curriculum. However, acknowledging the confusion surrounding the use of the term integration, we have proposed the term worldly to encompass these ideas about knowledge and curriculum. To explore this conceptualisation further, we need to consider how knowledge is structured, particularly from the perspective of adolescent children for whom integrated curricula are often designed.

Knowledge and a worldly perspective

What we really want to know is whether knowledge is, for example, one complex body of interrelated concepts, a unity of some sort, or whether it has some other organisation. Hirst and Peters (1970) claimed that there are seven fundamentally different domains of knowledge and experience, each of which involves concepts of a particular kind with distinctive tests for objective claims. These domains include science, mathematics, morality, aesthetics, religion, awareness of mind, and philosophy. For example, Hirst and Peters describe the domain of the physical sciences as being concerned with truths that stand or fall by observational tests through the senses. Although Hirst and Peters maintain the radical independence of each of these domains they also emphasise the interrelationships. They explain that the development of knowledge and experience in one domain may be impossible without the use of elements of understanding and awareness from other domains. Interestingly, Hirst and Peters argue that even when incorporated into another domain the elements of the original domain retain their own unique character and validity. For example, however independent the domain of science may be, our understanding of the physical world is tightly dependent on our mathematical knowledge. It is also commonplace that scientific discoveries involve us in new moral dilemmas. Hirst and Peters create an analogy for the development of distinct yet interrelated experience and understanding with the building of a jigsaw that is somewhat akin to Goodson's (1996) blocks in a mosaic metaphor. They emphasise that achieving educational objectives demands that adequate attention be paid to systematically developing the pupil's experience and knowledge that are both independent and yet intimately interrelated, just like the pieces of a jigsaw.

Rogers (1997) claims that the child's perception of what knowledge looks like may be very different from how schools represent knowledge as subjects. If Rogers is right, then looking at alternative views of knowledge and how its representation informs the shape of the curriculum would be a fundamental task in curriculum development. O'Loughlin (1994) formulated philosophical questions about how young adolescents (12- and 13- year-olds) view knowledge and their relationship to it. She investigated what conceptions of knowledge adolescents carry with them as they commence middle schooling, and the nature of the epistemological shift that occurs for pupils during this period. She found that when describing their sense-making experiences pupils conveyed a sense of 'environmental knowing' (p. 45). For both girls and boys, knowledge came from contact with parents, friends and teachers in specific contexts they often described in graphic detail.

> ... a young boy learns about salmon spawning as he and his friend fish in an alpine stream with an adult relative. His enthusiasm is infectious as he describes this encounter with the world in its physical, cognitive, affective and social dimensions. Much of his school learning seems 'unreal' in comparison. (O'Loughlin, 1994, p. 44)

For these pupils, knowledge arises out of their experiences and these experiences are expressed in terms of activities undertaken, projects performed and, for girls in particular, by means of verbal exchanges (O'Loughlin, 1994). Gaining school knowledge was seen by many boys as something they did for their parents, or so that they could be successful in later life, even though they thought of school knowledge as being seldom linked with reality and not very enjoyable. But young adolescents thought that becoming knowledgeable was something different, something they did for themselves, as an activity, a process in which they were physically engaged with people they knew and with whom they felt comfortable. 'Gaining knowledge is very clearly about an encounter with the world at this stage of the pupils' lives' (p. 46). O'Loughlin claims that the adolescent view of knowledge and its obtainment is not about a narrow reasoning process, or a cognitive gain, but more inclusive of the social and environmental contexts within which learning occurs. Often these contexts are missing in the way knowledge is structured in schools.

Rogers (1997) suggests that sources of authority, other than the academic disciplines, can offer meaningful frameworks for structuring knowledge in schools. For example, as noted earlier, she proposes professions such as architecture as an alternative. As a profession with real-world relevance, architecture draws together knowledge from several disciplinary areas and operates according to its own set of standards. Particularly in a project or problem-based curriculum, architecture presents one example of an alternative, perhaps more immediate or useful, set of standards by which pupil work and learning can be evaluated. In our own work, for example, we observed a technology teacher who involved her pupils in the design and construction of a bridge using mathematics and scientific principles. The bridge was evaluated for strength by placing weights on it and for aesthetics by a visiting English teacher. This is an example of how a set of standards from a profession, like architecture or engineering, could be used to evaluate pupil work in integrated contexts.

There are some well-established curricula and research projects that epitomise connectedness between the nature of knowledge and the nature of the child. For example, the Waldorf curriculum attempts to 'embody the philosophical vision of Steiner to educate the whole child: spirit, soul, and body; head, heart, and hands; thinking, feeling and willing' (Nicholson, 2000, p. 578). At Waldorf schools, the classroom teacher ideally remains with the same pupils from grades one through eight. 'The teacher maintains a close relationship with the students as "loving authority", characterised by guidance and by rules' (Nicholson, 2000, p. 579). In Germany, the PING Project (Practising Integration in Science Education) emphasises collaboration and the relationship between humanity and nature (Riquarts & Henning-Hansen, 1998). The phenomenological movement also embraces such themes as learners' personal, social and cultural contexts and the relationship between the learner and the world (Davis, Sumara & Luce-Kapler, 2000). Thus we see that in some quarters there is a strong movement to structure knowledge in ways that breakdown the potential barriers created by discipline boundaries. New structures are cognisant of context, they blur subject boundaries and draw upon notions of how learners come to understand the complex world around them. Sometimes it is appropriate that their learning is broad and holistic, rather than focused and compartmentalised. It is the success of the modern western mind-set that has resulted in the pursuit of depth and the meticulous analysis of the part in place of breadth and the comprehension of the whole (Smith, 1982). But parts are, in the final analysis, fragments. And it is the fragmentation that supporters of integrated curricula decry.

Describing a worldly perspective

We propose that curriculum integration be incorporated within what we are calling a worldly perspective that reflects a holistic view of knowledge. This perspective represents pupils' knowledge grounded in their experiences, relationships and contexts. Of course, disciplinary knowledge is a component of this knowledge but it is not necessarily labelled as such. In fact, from a worldly perspective, it is necessary that the two paradigms, the integrated paradigm and the disciplinary paradigm, must be considered together, overlapping rather than mutually exclusive. We note that from within the disciplinary paradigm the existence of two separate paradigms is consistent with the divided nature of knowledge, however this is inconsistent with our worldly perspective. From a worldly perspective the disciplines are there, but they are omnipresent rather than omnipotent. They are, as Goodson (1996) pointed out, blocks in the mosaic of the curriculum. We also recognise that the worldly perspective exists within a frame. Worldly knowledge is connected in some way to the experiences, contexts and needs of the school community. However, worldly knowledge also draws from, but is not bounded by, the constraints of traditional disciplines.

Thus we take the theoretical position that the integrated and disciplinary paradigms fall within what we call a worldly perspective. We argue that the separation of integrated and disciplinary paradigms is artificial and does not describe the world as it is. A worldly perspective acknowledges high status science subjects such as physics, chemistry and the like but allows for these subjects to evolve within a broader framework than currently exists.

Practical Position: A Pragmatic Approach

Our theoretical position provides a way of reconciling the apparent antagonism between the proponents and opponents of curriculum integration. We recognised that the curriculum structure based around school subjects is well supported by the long established grammar of schooling and within that structure, the subject of science held high status. Although curriculum integration may present some challenge to the high ground of science as a school subject, we suggest that the challenge be interpreted in the context of a worldly perspective. This perspective acknowledges the contribution of the academic disciplines but places the disciplines within a holistic, more organic view of knowledge. This view resonates with Hirst and Peter's (1970) suggestion that practitioners focus on developing the pupil's knowledge and experience that are both independent and yet intimately interrelated. We suggest that a framework and rationale for teachers and curriculum developers who chose to implement an integrated curriculum do not necessarily depend on subordinating the subject. Rather we argue that success depends on a number of factors other than the content of the curriculum. We demonstrate this by describinginstances of successful integration.

We begin by noting that in our own work, instances of successful integration — where teachers were making genuine attempts to integrate and the classroom atmosphere seemed conducive to learning — were patchy. Rarely was integration a school-wide phenomenon; instead it relied on a few dedicated teachers or teaching teams. Further we noticed that over time, and especially if things weren't going well, teachers tended to drift away from integrated practice towards discipline-based teaching. Discipline-based teaching, because it was so familiar, was the 'default option'. Our work has extended over several years and during this time we have noticed a number of examples of integrated teaching, identified at the beginning of the project, reverting to more traditional forms at the end of the period. Integration also ebbed and flowed as teaching teams configured and reconfigured. Changes in methods of curriculum delivery were often associated with changes to staff and school leadership. In one example, a thematic approach to the middle school curriculum initiated and supported by one principal was changed significantly with the transfer of the principal to

a new school. In another case, the promotion and transfer of a key learning area leader to a new school resulted in the dissemination of ideas about integrated teaching to a new setting. In yet another study of several schools' uptake of a technology programme with an integrated focus, Treagust and Rennie (1993) found that successful implementation required committed leadership by someone with time to reflect on and document progress, and time for participating teachers to accept ownership of the technology initiative, to plan and implement modifications and to see changes in pupil outcomes.

What we found in our work is consistent with the extensive literature on school and curriculum reform (Sarason, 1990). Reforms, including curriculum integration, rarely have a lasting impact on classrooms. When reform does make a difference in individual classrooms, the impact often erodes over time. People, not the nature of the innovation, appear to be the major determinant of success or failure of the innovation (Fullan, 1993). However, as this study demonstrates, there is evidence that some reforms do take hold in some schools. In these schools, teachers are able to maintain the lessons of their reform experiences and apply them to other schools. The key factor here is the energy and goodwill of the participants in the reform process — including teachers, pupils, principals and other stakeholders — and their capacity to translate reforms into positive classroom experiences.

Another factor that seems crucial to success is the ability to build on the needs of participants in ways that made best use of the skills and competence of the teachers in the prevailing circumstances. Of course, these circumstances will differ from community to community. Based on detailed studies of diverse curriculum reforms in a number of countries,

Black and Atkin (1996) conclude that there is not one hard-lined approach to curriculum that will be successful on all counts. What works, according to Black and Atkin, depends on the context. We drew similar conclusions from our own studies. A pragmatic approach to implementing curriculum integration does not rely on completely dissolving disciplinary boundaries, but on a degree of integration that fits the needs in the local context.

Looking more broadly, we found some examples of where a contextual, community-linked approach to integration has been successful and sustained over a considerable time frame (Drake, 1998; Fleming, 1993; Lawton, 1992; Levak, Merryfield & Wilson, 1993; Stephens 1991; Reeves, 1999). The threads of similarity weaving though these programmes suggest a well developed philosophy and theory that includes an integrated approach to teaching and learning, and commitment and understanding from the whole school community (Drake, 1998; Fleming, 1993; Stephens, 1991). Further, well-articulated plans or guidelines for the integrated curriculum that are documented in the school plan and accepted by the community contribute to the sustainability of such programmes (Levak et al., 1993). In addition, flexibility allowing teachers to utilise alternative approaches to working across disciplines, instead of forcing connections where connections do not exist, seems to engender success (Levak et al., 1993). Teachers in our study found it contrived and irritating when they were required to 'fit in' or 'find' content from a particular subject that did not articulate naturally with the integrated theme, topic or project (Venville, Wallace et al., 1999b).

A further thread to many of the positive stories of integration is that the integrated aspects of the curriculum have local community or environmental connections (Levak, Merryfield & Wilson, 1993; Tchudi & Lafer, 1993; Williams, Bidlack & Winnett, 1993; Williams & Reynolds, 1993). For example, Chandler (1998) reports a teacher's experience in developing an interdisciplinary curriculum unit that utilises the community's close ties to the sea. Williams, Bidlack et al. (1993) describe an interdisciplinary high school curriculum that allows science, social studies, and English teachers to integrate curriculum by approaching

a river study with the goal of inspiring young people to take action. Each project team worked to produce scientific data, to research social and cultural information, and to solve problems on its section of the river. One of the benefits of the project was that it provided an outlet to apply what pupils learned to real situations. A common outcome claimed from these projects was that pupils found new meaning to their lives through the units and they felt that schoolwork related to their out-of-school learning and experiences (Levak et al., 1993; Rice, 1994). These examples demonstrate that integrated teaching works best in contexts that not only connect the disciplines but the experiences of the teaching and learning community to form a mutually reinforcing web with the experiences of the community beyond school (Howe & Bell, 1998).

In our own work we found that cross-disciplinary linkages were enhanced in connected contexts, where pupils and teachers were also found to be working in team environments and where pupils were able to call upon community and family support — what other science educators (Ritchie & Hampson, 1996; Roth, 1993) have called learning communities. In one classroom from our project, we noted pupils within groups sharing knowledge about bridge design (Venville, Wallace et al., 1999a). Learning was also evident between groups as pupils picked up ideas by watching other groups at work. Typically, integrated teaching was conducted in the context of learning area teams of three or four teachers with complementary specialities. In one school, for example, where pupils designed and made electric-powered vehicles, pupils sometimes called upon family and friends to assist with technical or other advice in the design and construction of their projects (Venville et al., 1998). In the same school, the science, mathematics and technology teachers modelled teamwork by working together to support the programme.

Frequently, the teachers in our integration studies said that the most important enabling factor was quality communication time to allow teams to meet, to plan projects and to co-ordinate their teaching. Often resources were not readily available and teachers found themselves developing teaching materials outside school hours. Thus the gains in terms of developing viable and interesting integrated programmes were often offset by the time required to do so, the energy invested in forming new relationships and the frustrations experienced by the lack of curriculum support. In some cases, when, over time, the losses outweighed the gains, teachers reverted to more traditional, subject-based curriculum approaches. Thus we see that an essential ingredient of school reform, including implementing an integrated curriculum, is collaborative time for the teachers involved (Howe & Bell, 1998; Panaritis, 1995; Raywid, 1993). The time necessary to examine, reflect on, amend, and redesign programmes is not auxiliary to teaching responsibilities, it is absolutely central to such responsibilities. This is an issue that has been raised in the literature and through our own research: teachers need extra collaborative time to implement an integrated curriculum.

If we draw these threads together we see that a worldly perspective allows for what we call a pragmatic approach to integrated curriculum. A pragmatic approach is underlain by the recognition of context, it accommodates the local education system, provides for the needs of the pupils and benefits from the skills and knowledge of the teachers involved. Further, we find integrated curricula are more likely to be successful if they have been based on a well-developed plan that is shared with the whole school community. Strong connections with the local community or environment, team structures and quality time for collaboration are also aspects that are likely to engender success in an integrated approach to schooling. None of these factors depend on dismissing entirely the school subject, rather they provide opportunity to encompass the subjects, draw from them as needed and also allow the subjects to ‘look outside themselves’, as it were, to see what contribution can be made to meeting school and community needs.

We end this section of the review by providing three diverse 'images' of the kind of curriculum that we have in mind, i.e. one that exemplifies a worldly perspective. The first image is derived from our own observations of integrated practice involving the use of technology-based projects (Budgen et al., in press; Venville et al., 1998). Pupils in one high school worked on a technology project for 10 to 12 weeks which included technology, science and mathematics research components. An example of a technology project brief was to 'design and produce an electric powered vehicle that can climb a steeper gradient on the standard test track than anyone else's.' The technology research component investigated traction options, materials and construction techniques, motor mounting options and power transmission systems. The science research component investigated friction, gears and pulleys, torque and power transfer and how scientific trials influenced their choice of traction, gearing and drive options. The mathematics research component examined the effects of changing variables on standard Lego model hill climbers and recording, presenting and analysing their group's results from the time trials. This technology project modelled a 'real-world' problem, requiring practical problem solving skills and drawing on scientific and mathematical knowledge as well as other knowledges as required. With some further development this curriculum task could easily be connected to other branches of science and mathematics as well as the social sciences — ecology, transportation, economics and politics are just a few that come to mind.

The second image is adapted from the work of Davis, Sumara and Luce-Kapler (2000), three Canadian educators who propose some radical new ideas about learning and schooling. They use the example of a clock to illustrate how knowledge is holistic and complex. Understanding a clock, they say, requires a recognition that the clock is 'embedded in social and natural environments' (p. 63). Study of a clock must, therefore, include such aspects as the role of the clock in shaping lives, the historical circumstances of its invention, the role of the clock in solving the longitude problem (Sobel, 1995), the materials used in its construction, the scientific principles involved in clockwork motion, and the effects of its use on nature. This 'curriculum of the clock' incorporates some science but makes far broader connections to history, sociology, geography and ecology as well as worldly themes that transcend the disciplines.

The final image is taken from the work of Harvard University biologist Edward Wilson (1998). In his controversial work, he proposes that science be unified with other branches of knowledge in a movement he calls 'consilience.' True reform, according to Wilson, must involve the consilience of science with the social sciences and the humanities. Every pupil, he proposes, should be able to answer the question, 'What is the relation between science and the humanities, and how is it important for human welfare?' (p. 13). Wilson lists ethnic conflict, arms escalation, overpopulation, abortion, environment and endemic poverty as a few issues of universal concern. These problems, he says, can only be solved by integrating knowledge from the natural sciences with other disciplines. What pupils and scholars require, he argues, is 'fluency across the boundaries… to provide a clear view of the world as it really is' (pp. 13-14).

While these three images are at different levels of abstraction, they have some features in common. They each focus on a theme — a project, topic, issue or problem — that transcends the disciplines. These themes draw from within, across and beyond disciplinary boundaries allowing for integration at a high conceptual level. The choice of theme depends on the context, experience and needs of the school community. In some communities, a study of electric powered vehicles may be appropriate; other communities may chose to focus on a scientific and socio-cultural treatment of ethnic conflict or some other issue. It is not our intention here to specify what such a curriculum would look like, but to tentatively suggest some new ways of thinking about how it might be done.

Journey's End or a New Journey Begins?

Within this paper we have traced our journey towards a better understanding of integrated approaches to curriculum. We began by recognising that the discipline-based curricula that champion the school subject hold the 'high ground' in terms of established and preferred curricula practices. Further, we recognised that integration of curriculum is not a new phenomenon and continues to be implemented in various ways. We examined the literature and the findings of our own research to conduct five explorations about integrated curricula. The first exploration was about how integrated curricula manifest in school settings. We found a wide variety of integrated practice, most of which coexisted with traditional disciplinary approaches. We resisted placing these versions of integration along a curriculum continuum because of the implication that more integration was synonymous with better integration. The second exploration raised the question, 'why integrate?' While acknowledging both epistemological and practical reasons for curriculum integration we focused on adolescent issues, particularly engagement. This led us to speculate on whether the answer to problems relating to pupil engagement lies in curriculum integration or in good teaching practices or more flexible approaches to curriculum design.

The third exploration questioned why curriculum integration seems to be so difficult to implement and maintain in school environments. We proposed a general answer to this question in what Tylack and Tobin (1994) called the 'grammar of schooling'. Integrated curricula challenge many aspects of established practices, rituals, beliefs and hierarchies of traditional school establishments. We drew attention to the work of Bernstein as a way of explaining the high status of school subjects such as science that are strongly bounded and strongly framed. The fourth exploration addressed the issue of what is being learned in integrated settings. The trends we found in the literature and in our own research showed that there were losses as well as gains when pupils learned through an integrated curriculum. The losses tended to be related to the conceptual understandings of content knowledge from more traditional, disciplinary subjects such as science or mathematics. The gains we felt were largely in the affective areas of motivation and interest and also process and higher level cognitive skills. As science educators we questioned and reflected on our own loyalties to the content knowledge of our subject area and wondered whether we had brought our own prejudices to the way we were researching pupil learning in integrated settings. This led to our fifth and final exploration where we examined the assumptions underlying the ideological basis of curriculum integration. We found some contested ground and concluded that competition between disciplinary and integrated paradigms was not constructive and some way of reconciling the two was needed.

These five explorations led us to two complementary positions about curriculum integration — one theoretical and one practical. The first, theoretical, position explained the apparent divide between the proponents and opponents of curriculum integration. We postulated that it was unhelpful to work with two paradigms — disciplinary and integrated. The disciplinary paradigm requires a view of knowledge that is divided into separate disciplines, each with its own set of epistemological assumptions. In retrospect we realised that we began our journey from within this paradigm, because the disciplinary-based, subject-centred curriculum is the status quo. Although we found it useful to describe the two paradigms as a way of teasing out the epistemological differences, we realised that from a worldly perspective of wholeness and unity, it is necessary to incorporate disciplinary approaches to schooling. This simple observation is critical in terms of linking our theoretical position with our practical position, a pragmatic approach to integrated curricula.

Our final position is to promote a pragmatic approach to curriculum integration. A pragmatic approach to curriculum integration embraces the established disciplines and does not attempt to ignore them. Rather, a pragmatic approach is one that recognises, and attempts

to meet, the needs of pupils, the school and the local community. We explored examples of successful integration and found common threads that may promote successful implementation and sustainability. These include well-developed and articulated reasons for curriculum integration that are supported by the school community, and sufficient time and flexibility for implementation. While curriculum integration is challenging and eroding the high ground of school subjects, it is doing so in a way that is reshaping and re-establishing subjects, rather than eroding them away altogether. High status science, one might argue, is a subject with much to lose within a more worldly perspective. This is not our argument, however. Instead, we see opportunities to change the shape of the subject in ways that make it more relevant, more interesting and, dare we suggest, more integrated with the ways in which pupils structure their knowledge.

We began this review with some explorations and we ended with some positions. However, as T.S. Eliot (1963) wrote, 'to make an end is to make a beginning. The end is where we start from.' So where do we start in developing a new set of explorations? Several possibilities come to mind. For example, what are the practical tensions involved in incorporating science into a worldly perspective? How are practising scientists managing these tensions in their own work? What new kinds of educational communities of practice are required to institute a worldly paradigm? What kind of assessment practices might be possible and appropriate under a worldly paradigm? How and what do pupils learn within a worldly paradigm and how does their learning contribute to their scientific literacy? These are just a few ideas for the future. We hope that these questions help guide our educational quest to connect and incorporate scientific ways of knowing into more unified and integrated ways of looking at the world.

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