Chapter 49
Curriculum Integration: Challenging the Assumption of School Science as Powerful Knowledge

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Curriculum Integration Defies Definition

To define curriculum integration, we first must consider curriculum. David Scott (2008) said that curriculum can refer to a system at a number of levels including national, institution or school and that it has four dimensions, including aims or objectives, content or subject matter, methods or procedures, and evaluation or assessment. To create a definition or description, it is probably most helpful to consider curriculum integration in relation to the second of these dimensions, that is, the content or subject matter of a curriculum. This dimension is related to questions about what knowledge should be included and what items excluded in a curriculum and how these items of knowledge should be arranged (Scott 2008). Dominant modes of curriculum in the twenty-first century are focused on established, canonical knowledge located within disciplines such as physics, mathematics, history and literature. The disciplines themselves almost always provide the structure of the curriculum (Scott 2008). This is widely referred to as a disciplinary, or traditional, approach to curriculum.

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In our own work we found that curricula that are referred to as 'integrated' can take on a number of forms that can only be described as 'different' from the traditional approach to curriculum. In a previous review, we came to the conclusion that curriculum 'integration is a particular ideological stance which is at odds with the hegemonic disciplinary structure of schooling' (Venville et al. 2002, p. 51). All curricula with which we are familiar include some form of disciplinary knowledge. It is the structure of the curriculum that determines whether it can be considered disciplinary or integrated. For example, Charles Anderson and colleagues (2008) describe learning progressions through upper elementary and high school that focus on preparing students for environmentally responsible citizenship. One of the learning progressions is 'Water' and includes the role of water and substances carried by water in earth, living and engineered systems (including the atmosphere, surface water and ice), groundwater, human water systems, and water in living systems. Anderson et al.'s learning progression can be considered integrated. While it contains disciplinary-based concepts, it is not structured around the traditional disciplines of science such as biology or chemistry, or other non-science disciplines such as geography.

Marlene Hurley (2001) found the existence of multiple forms of integration throughout the twentieth century and suggested that there seems to be a paradox between the demand for a general definition of integration and research that illustrates a need for multiple definitions. The demand for a definition is ongoing – see Charlene Czerniak's (2007) overview, for example. During the 1990s, some researchers described curriculum integration along a continuum (e.g. Drake 1998) but others (e.g. Panaritis 1995) criticised this approach because of the implication that movement along a continuum is progress towards a better state. In our own research, we used a definition of curriculum integration that is inclusive of the broad spectrum of implemented curricula that we have observed:

> An integrated curriculum enables students to look toward multiple dimensions that reflect the realities of their experiences outside and inside school. (Venville et al. 2008b, p. 860)

With such a broad definition, a number of progressive programmes reported in the literature could be considered integrated. For example, contextualised instruction (e.g. Rivet and Krajcik 2008), authentic tasks (e.g. Lee and Songer 2003), community connections (e.g. Bouillion and Gomez 2001), science technology and society (e.g. Pedretti 2005), place-based education (e.g. Guenewald and Smith 2008), democratic schools (e.g. Apple and Beane 1999), futures studies (e.g. Lloyd and Wallace 2004) and youth-centred perspectives (e.g. Buxton 2006), all include approaches to education that involve students looking towards multiple dimensions that reflect the real.

Curriculum Integration as a Contentious Issue

Integrated approaches to curriculum remain a contentious issue, with ardent commentators presenting a number of arguments either supporting or opposing its implementation in schools (Hatch 1998). These arguments have tended to be either epistemological (focused on the structure and utility of knowledge) or affective (focused on students' attitudes and engagement with science). On the epistemological front, disciplines create a sense of order about the complex world and provide students with the specialised knowledge that they need to solve complicated, discipline-based problems or to create rigorous explanations of focused aspects of the world. For example, Howard Gardner (2004) argued:

> The disciplines are important human achievements. They are the best answers that human beings have been able to give to fundamental questions about who we are, physically, biologically, and socially. (p. 233)

Alan Schoenfeld (2004) pointed to research that shows that 'disciplines matter in teaching and learning to teach' (p. 237) and that '[c]lassroom activities must foster active engagement with the content and processes of the discipline, with students developing and testing ideas in ways consistent with the paradigms of the disciplines they study' (p. 238). Michael Young (2008) claimed that 'knowledge that takes people beyond their experience has historically been expressed largely in disciplinary or subject forms' (p. 10) and suggested that the disciplines are the epistemological price that we pay for a better understanding of the world.

Supporters of curriculum integration argue that knowledge in the real world is holistic and the division of knowledge into subjects for teaching and learning in schools is a historical artefact and simply a pragmatic method of curriculum delivery (Hatch 1998). Dan Young and Nathalie Gehrke (1993) point out the paradox of the phrase 'curriculum integration', which is supposed to reflect the notion of wholeness and coherence, the totality and unity of existence. The paradox comes from the suggested need, particularly in school systems, to patch together the disciplines to create a whole. 'We do not need to create the whole: the whole already exists' (Young and Gehrke 1993, p. 447). Others argue that learning for adolescents is about life experiences in familiar contexts and relationships and interactions that they have with trusted people and that compartmentalized, disciplinary knowledge and narrow reasoning processes are not consistent with this way of understanding knowledge (O'Loughlin 1994).

On the affective front of the debate, supporters refer to the statistics showing adolescent disengagement with traditional approaches to schooling and suggest that integrated approaches to curriculum motivate and interest students in ways that disciplinary content, delivered in traditional pedagogical ways, fails to do. Science teacher, Elaine Senechal (2008), for example, claimed that a multi-disciplinary project in which she was involved, about air quality in the surrounding school environment, was 'a powerful tool for engagement and motivation' (p. 105). Other commentators go further and suggest that the reason why an integrated approach to teaching and learning tends to be more engaging for young people is that it better reflects the realities of students' experiences outside school; 'it makes learning more applied, more critical, more inventive, and more meaningful for students' (Hargreaves et al. 2001, p. 112). Michael Apple and James Beane (1999) explain that integration:

> …involves putting knowledge to use in relation to real life problems and issues… Rather than being lists of concepts, facts and skills that students master for standardized achievement tests (and then go on to forget, by and large), knowledge is that which is intimately connected to the communities and biographies of real people. Students learn that knowledge makes a difference in people's lives, including their own. (p. 119)

Apple and Beane's comments, made in 1999, reflect another powerful argument that is currently impacting the perceived role of science within the curriculum, namely, connection to 'real problems', 'real lives' and the 'real world'. Edgar Jenkins (2007) argued that students need better, more realistic ideas about the multiple realities of what constitutes science in the real world and wonders 'whether a subject-based curriculum can provide students with the inter- and cross-disciplinary perspectives required to respond to challenges of this [global] kind' (p. 278). The 'real world' argument can be considered to be both epistemological and affective, because it responds to issues related to knowledge and emotion, and perhaps reflects both these arguments in unison.

'Scientific Perplexities' of the Real World

The problem with most real-world issues in which adolescents of today are likely to be interested is that they are part of science, where Jerome Ravetz (2005) explained, facts are uncertain, values are in dispute, stakes are high, and decisions are urgent; these factors make these topics difficult to define and difficult to assess. Ravetz (2005, p. 11) bids '[f]arewell to the old classifications, such as physics, chemistry, biology' and welcomes 'new ones, like GRAIN – short for genomics, robotics, artificial intelligence and nanotechnology'. Ravetz claimed that these new sciences involve a complex of issues and that, whatever the solutions, they will neither be determined by science alone, nor will they be simple or easy. He refers to them as 'scientific perplexities' (p. 33) that are beyond what Thomas Kuhn referred to as 'normal' science.

One example of a contemporary scientific perplexity is the notion of environmental sustainability. Ravetz (2005) claimed that the growing realisation, since the 1960s, that our industrial civilization is unsustainable and that we are polluting ourselves and exhausting key resources, has changed our perception of reality. This change, according to Ravetz, is a revolution in thinking, somewhat akin to the Copernican revolution or the revolution of Charles Darwin's Theory of Evolution by Natural Selection. This notion of a 'paradigm shift' is also reflected in the writings of Fritjof Capra (e.g. 1982) who claimed that 'we live today in a globally interconnected world, in which biological, psychological, social, and environmental phenomena are all interdependent' and that 'the holistic conception of reality, [is] likely to dominate the present decade' (Capra 1996, p. xviii).

We have noted previously that a common thread in many integrated programmes in schools is that they have connections with the environment in some way (Wallace et al. 2007). A quick glance at recent National Association for Research in Science Teaching annual international conference programmes reveals terms such as global climate change, sustainable development, global atmospheric circulation, environmental action projects, climate, energy use and air quality, environmental knowledge and attitudes, ecological literacy, ecosystems understanding, and ecomorphism. For example, Nir Orion and Carmit Cohen (2008) discuss a new module, 'Oceans and the earth systems', that has been developed as part of an environmental-based interdisciplinary component of the Israeli high school earth sciences program. Real-world scientific perplexities, including the issues of environmental sustainability, are clearly becoming part of the real world of science education.

Discordant Metaphors of Science as Both a 'Holistic' and 'Fragmented' Discipline

We note a dissonance in the metaphors in the literature about science in our modern, global society of the twenty-first century. On the one hand, metaphors reflect 'holistic', global science; on the other hand, the metaphors reflect the 'fragmented' nature of science as a discipline. For example, Capra's (1996) thesis is that earlier schools of science based on mechanistic, easily quantifiable models are in opposition to the holistic awareness of today's scientific phenomenon. In biology, Capra suggested abandoning the concept of the cell as a fundamental building block of life, and suggested the cell be thought of in symbiotic partnership with organelles and other cells. Chaos theory, as described by John Briggs and David Peat (1999), encourages scientists to go beyond their mathematical and scientific origins and embrace myth, mysticism, poetry, literature, art, religion and philosophy to create an interconnected view of the universe, our world, our society and ourselves. A more classroom-based example of the holistic metaphor is presented by Michelle Lunn and Anne Noble (2008). By establishing clear links between art and aesthetics and science as a creative process, these researchers demonstrated that science is holistic and can encompass emotions that traditionally have been considered unscientific (such as wonder, love and passion) and that formed natural connections with art, music, dance, meditation, yoga and processes of imagination.

In stark contrast with the holistic views of science discussed above, others point to the fragmentation of 'science' into a chaotic array of sub-disciplines or specialties. Lyn Carter (2008) explored the implications of globalisation for science education and noted the 'increase in the sheer size and scope of contemporary science research in increasingly fragmented subdisciplines' (p. 625). Moreover, Jenkins (2007) argued that science in schools is promoted as a 'coherent curriculum component' but further argued that, in reality, it 'fosters an untenable but enduring notion of a unifying scientific method that ignores important philosophical, conceptual, and methodological differences between the basic scientific disciplines' (p. 265).

A Variety of Factors Impact on the Implementation of Integrated Science Curricula

Jeong Suk Pang and Ron Good (2000) commented that many variables can significantly affect the success or failure of integrated programmes. These include teachers' variables, such as subject matter knowledge, pedagogical content knowledge and beliefs, as well as their instructional practices. Other factors might be contextual, such as administrative policies, curriculum and testing constraints, and school traditions. Our own research (Venville et al. 2008b) showed a strong relationship between educational context and the way in which an integrated, community-based project about the environment was implemented. Within the context of a traditional high school, we found that the form of curriculum integration implemented was quite different from that implemented in a purpose-built middle school with a similar demographic. The contextual factors included such things as school organisation, classroom structure, timetable, teacher qualifications, collaborative planning time and approach to assessment.

Factors inhibiting curriculum integration in many ways match, but also oppose, the enabling conditions. Factors working against curriculum integration include community wariness that integrated teaching approaches might be 'watering down' the curriculum (Wallace et al. 2007). Ellen Brantlinger and Massoumeh Majd-Jabbari (1998) found that, while college-educated, middle-class parents espoused support for open, integrated, multicultural, student-centred education, their narratives actually revealed a preference for conservative practice. They preferred factual, tightly sequenced, subject-area-bound and Western-oriented curricula because, the authors suggest, generations of their class have had relatively uncontested success within this traditional approach to curriculum. An integrated curriculum is not consistent with the expectation in many places that the school curriculum should be academically oriented, emphasising written work and individual study and focused on examinable concepts and ideas (Kaplan 1997).

Teachers with different disciplinary backgrounds and the high turnover of staff in some schools also provide barriers to ongoing curriculum integration. For teachers, teaching out-of-discipline, content knowledge was found to impact on both their confidence and ability to teach science in a reform-based manner (Kruse and Roehrig 2005). This is often compounded with beginning teachers who have limited pedagogical knowledge and experience in managing classroom activities. Lee Shulman and Miriam Sherin (2004) argued that 'one of the most significant factors influencing the effectiveness of teaching … is the teachers' own subject matter knowledge and pedagogical content knowledge' (p. 136). Ralph Levinson (2001) found that it is challenging, even for science teachers, to address the ethics and controversies of contemporary science issues. He concluded that few teachers, whatever their speciality, can handle these areas with much confidence or expertise, but he noted that this is not due to any inadequacy on their part, but to the complexity of the issues. Collaboration between teachers with different disciplinary expertise is certainly possible, as we have seen in our own research between mathematics, science and design and technology teachers (Venville et al. 2000), but it is not easy. Jeff Marshall et al. (2007) encouraged interdisciplinary cooperation as a minimum for integrating physics and mathematics in order to increase meaning and relevance for high school students.

The Nature of Science Learning from Integrated Curricula

Evaluations of science learning that result from integrated programmes of work in schools have produced notoriously ambivalent conclusions. In a review of the literature from the 1940s to the early 1990s, Gordon Vars (1991) found more than 80 normative or comparative studies reporting that, on standardised achievement tests, students in various forms of integrated programmes performed better than, or at least as well as, students enrolled in separate subjects. Colin Marsh (1993) tracked some of the major research on integration from the USA, UK and Asia over the previous 50 years and found that there was limited evidence of either a positive or a negative effect. David Perkins and Rebecca Simmons (1988) noted that assessment of learning in integrated settings tends to focus on the disciplinary content and neglect other factors that could be more consistent with an integrated approach to teaching and learning. Hurley (2001), for example, limited her meta-analysis to quasi-experimental research that measured achievement in the science and/or mathematics disciplines. The results from 31 studies showed that, overall, student achievement effects for science were slightly larger than for mathematics (effect size of $d = 0.37$ compared with $d = 0.27$ standard deviations), suggesting that curriculum integration is better for science than it is for mathematics achievement. She identified multiple forms of curriculum integration and found that, when examined with achievement effects, these forms had different outcomes. Science achievement was greatest when mathematics was used in total integration with science or to enhance science. In contrast, both these forms had small effects for mathematics achievement. Student achievement effects were greatest for mathematics when it was taught in sequence with science, that is, when the subjects were planned together conceptually, but taught separately.

Some studies have attempted to incorporate broader and more holistic perspectives into their evaluation of student learning, focusing on outcomes such as student motivation, attitude, cooperation and capacity to transfer and apply knowledge. In the 31 studies included in her meta-analysis, for example, Hurley (2001) noted anecdotal evidence that curriculum integration has a positive impact on attendance, student discipline, knowledge of academic resources, study habits, student enthusiasm and student engagement. Specific examples of recent research into student learning with broader perspectives might include work conducted by Stephen Ritchie et al. (2008) who investigated, through an interpretive methodology, what happened when a class of fourth-grade children co-created, with their teacher, a publishable eco-mystery that integrated both fiction and non-fiction. They found that the activity maintained the students' interest and motivation and enabled them to demonstrate fluency with, and understanding of, scientific phenomena as well as develop their literacy skills using both narrative and factual genres. Moreover, Anne Rivet and Joseph Krajcik (2008) found a correlation between science achievement and the frequency with which students verbalised links between science ideas and a project that they were examining that involved the context of a bicycle helmet and safety.

In our own research, we found that, when data were viewed from a science discipline-based perspective, the learning of science concepts in integrated classroom contexts might not be as robust as might be expected if the teacher had focused on a conceptual change approach (Venville et al. 2003). If the same data were scrutinised from an integrated perspective, however, then learning outcomes such as students' ability to transfer ideas from one context to another, the application of science understandings to practical contexts, and students' general motivation and perception of the relevance of their school work were recognised and valued (Venville et al. 2000). Further still, we found that other forms of learning, such as the students' use of sources of knowledge to make key decisions about integrated projects, could be another way of defining the success of an integrated project (Venville et al. 2004). We have previously suggested that evidence about the impact of integrated programmes on student learning has not been easily identified, or might be understated because of the difficulty that researchers have in finding a way of viewing 'learning' that is consistent with the holistic view of knowledge underpinning integrated curricula (Venville et al. 2008b). The kind of learning documented can be different depending on the theoretical and/or methodological framework which the researchers adopt.

What Is Powerful Knowledge in Science?

Gregory Kelly et al. (2008) argued that, in many current, education-based debates, questions about knowledge have the underlying assumption that there is a corpus of canonical, disciplinary or received wisdom that is beyond criticism. They further assert that these assumptions are translated in curriculum documents into key criteria, standards or educational outcomes that are narrowly focused on what is readily measurable or amenable to standardised achievement testing. Julie Bianchini and Gregory Kelly (2003) concur and describe the Californian science curricula standards as a long list of scientific facts that students are expected to master and suggest that they have a regressive flavour of received wisdom. 'As more and more attention in the schools turns to the issue of preparing students for high-stakes tests, there is a real risk of reducing the opportunities for students to engage in contextually authentic science… [The] consequences are particularly salient to urban children of poverty who are often most at risk of failing to meet these external mandates' (Buxton 2006, p. 719).

Evidence to support Buxton's (2006) assertion is provided by Wayne Au (2007), who showed that the primary effect of high-stakes testing is that curricular content is narrowed to those subjects included in the tests, subject-area knowledge is fragmented into test-related pieces, and teachers increase the use of teacher-centred pedagogies. Kelly et al. (2008) claim, however, that there is a new generation of international scholars who question the nature of academic disciplines and that a new way of viewing knowledge is emerging. An example of this new way of viewing knowledge is provided by Richard Duschl (2008) who argued that science classrooms should be conceptualised as ‘epistemic communities’ (p. 277). According to Duschl, science learning and assessment should focus on three integrated domains: conceptual structures and cognitive processes; epistemic frameworks used when developing and evaluating scientific knowledge; and social processes and contexts that shape how knowledge is communicated, argued and debated.

In contrast, Michael Young (2008) expressed concern that recent trends to reduce subject-specific content and include broader perspectives, such as those suggested by Duschl (2008), while perhaps more engaging and relevant to students, inevitably disadvantages some children, particularly those from poor families with low levels of social capital. He argued that disciplinary knowledge is ‘powerful knowledge’ (p. 14) because of the intellectual power that it gives to those who have access to it. In a similar vein, Na’ilah Suad Nasir et al. (2008) argued that denying students the opportunity to acquire powerful knowledge (in this case, mathematics) is a disservice, particularly to students from disadvantaged social circumstances. They asserted that mathematics knowledge acquired in everyday contexts should only be used as leverage to support, and not to limit, students’ deeper engagement in more abstract mathematics that will give them access to higher education and more choices in potential occupations.

Young (2008) claimed that Basil Bernstein’s concept of knowledge structures is one way of exploring the possible implications of different forms of curricular organisation. Bernstein (e.g., 2000) used the concepts of ‘classification’ and ‘frame’ to describe the underlying structure of curriculum. Classification refers to the degree to which the content in a subject differs from other subjects. Framing refers to the amount of control that the teacher and students have over the selection, organisation and pacing of the content in a subject. Lesley Parker (1994) found that the more strongly classified and framed a subject is, the higher is its status. Subjects such as physics and history, being strongly classified and framed, have high status, whereas subjects such as environmental science have weaker classification and framing and thus lower status. Cornelis de Brabander (2000) found that teachers considered subjects with everyday knowledge to be ‘soft’ (i.e. not easily tested), subjective and open to debate. Subjects containing ‘hard’ academic knowledge were testable, objective and well established. All these systems of examining the status of knowledge indicate that the more discipline-based a subject is, the higher its status, and the more integrated it is, the lower its status.

Our own recent research (e.g. Venville et al. 2008a), however, illuminated a case study of integrated classroom teaching and learning that opposed this view that highly framed and highly classified disciplinary knowledge can be considered powerful knowledge. We observed students learning about the health of a nearby lake. The implemented curriculum was weakly framed because the boundary between what was taught and learned and what was not taught and learned was not clearly defined. The content varied and was determined by the interests of the individual students and the teacher. The topic also was weakly classified because the content of science was not well insulated from the content from other school subjects including society and environment, english, mathematics, art and technology and enterprise. The kind of learning observed in this case study could also be considered to be ‘soft’ (i.e. difficult to test in an objective way), subjective and relatively open to debate. In this case study, the absence of high-stakes testing enabled a broad spectrum of content to be considered at inconsistent depths by different students and a broad spectrum of innovative teaching strategies. The teachers justified these approaches by claiming that the students ‘need stimulation’ and that the approaches helped students to ‘respond’, gave them ‘ownership’, made them ‘empowered’ and ‘connected to their own world’, ‘changed their attitudes’ and, finally, resulted in them ‘actively making decisions and changing their world’.

We contended that the very factors that were considered to render the topic as weakly classified and weakly framed through schema such as Bernstein’s were the very factors that also indicated the power for students of this approach to learning. The power of the knowledge taught and learned during the case study was that it was integrated and provided the students not only with powerful scientific knowledge, but also with powerful values in social and civic responsibility, power to think in ways that are appropriate to the problems and issues that face the community in which they live, power to communicate and debate these issues, and power to think about ways in which these problems and issues can be addressed.

Conclusion

In this chapter, we have described seven points of tension around which the issues of curriculum integration circulate. The first point of tension is that there are multiple forms of curriculum integration described in the literature and this multiplicity defies a focused definition. Second, curriculum integration is a contentious issue with commentators presenting convincing arguments for and against its implementation in schools, based on both epistemological and affective perspectives. Third, contemporary and real-world science includes a number of complex ‘scientific perplexities’ (including environmental sustainability) that are difficult to consider from within a single discipline and, at the same time, require a depth of knowledge from a number of disciplines to understand. Fourth, the discipline of science itself reflects opposing metaphors that suggest it is becoming a more holistic, interconnected discipline and simultaneously a more fragmented and disparate discipline. Fifth, there are a number of factors that impact on the implementation of an integrated curriculum with the status quo seeming to be a disciplinary approach. Sixth, science learning outcomes that have been measured from integrated approaches to curriculum are neither excellent nor poor. Measuring learning outcomes other than content knowledge that can be more relevant to an integrated curriculum is difficult and often ignored by both teachers and researchers. Finally, powerful knowledge has traditionally been knowledge from within the highly defined and highly insulated school disciplines. While this continues to be the case in most school contexts, there is mounting evidence that integrated teaching and learning can leverage a different kind of power for students.

All of the factors discussed in this chapter are adding to the complexity of what should be included in the science curriculum and to the contentiousness of how science should be taught in schools. The important question is about the degree to which we can abandon science as a coherent, well-insulated and established discipline that offers students a profound framework of knowledge and processes on which to base their learning. As we asked in a previous review (Venville et al. 2002), is it necessary for the high ground of science as a school subject to be eroded away entirely for curriculum integration to take place? Is school science under threat from curriculum integration and new, holistic world views? How can science as a school subject coexist with more holistic approaches to teaching and learning? These questions are worthy of our serious attention.

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