A Literature Review of Science and Mathematics Integration

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Integrated curricula has gained a great deal of acceptance among educators. Many educators provide testimonials about the effectiveness of units they teach, and many professional organizations stress integration across the curriculum. However, few empirical studies exist to support the notion that an integrated curriculum is any better than a well-designed traditional curriculum. Some educators question integration across the curriculum, because in the effort to integrate topics, science and mathematics content becomes superficial and trivial. This paper presents a review of the literature on integrated curricula. It concludes with a call to action for members of School Science and Mathematics Association.

Curriculum integration has become incredibly popular among educators in recent years. The idea of connecting subject areas has considerable face validity, because it seems like common sense. In the real world, people's lives are not separated into separate subjects; therefore, it seems only logical that subject areas should not be separated in schools. Almost every national reform effort is currently stressing the need to integrate or make connections among the curriculum (National Council of Teachers of English [NCTE], 1996; National Council of Teachers of Mathematics [NCTM], 1989; National Council for the Social Studies [NCSS], 1994; National Science Teachers Association [NSTA], 1996).

Curriculum integration also serves as one of the cornerstones of the move toward creating schools that focus on the needs and interests of students. The National Association for the Education of Young Children (NAEYC), an organization specializing in instructional practices appropriate for the education of young children, has published numerous materials to guide teachers in the selection and use of materials for young children. Curriculum integration is also stressed in NAEYC reports (1987).

Similarly, the National Middle School Association (NMSA) publishes many books about the education of young and early adolescents. The NMSA book entitled *A Middle School Curriculum: From Rhetoric to Reality* (Beane, 1993) argued for an integrated approach in middle schools around personal and social concerns that interest adolescents. *This We Believe* (NMSA, 1982) stated that developmentally responsive middle schools provide "curriculum that is challenging, integrative, and exploratory."

It is also argued that the integration of content areas can help students learn to think critically and help develop a common core of knowledge necessary for success in the next century (Carnegie Council on Adolescent Development, Task Force on Education of Young Adolescents, 1989). Advocates cite the many advantages curriculum integration holds in helping students form deeper understandings, see the "big" picture, make curriculum relevant to students, make connections among central concepts, and become interested and motivated in school (Berlin, 1994; George, 1996; Mason, 1996). Integration is promoted as a way to help students make these connections among ideas. Advocates also state that curriculum integration is supported by sociocultural reasons; traditional curriculum is not relevant to students and does not focus on real problems and issues.

Those who support curriculum integration also claim that it is based upon psychology and human development. For example, Brooks and Brooks (1993), in defining constructivism, noted that deep understanding is constructed when students make connections between prior knowledge and new experiences — when they see connections among ideas. Therefore, meaningful learning occurs when new knowledge and skills are embedded in context, and students make connections among ideas. Thematic teaching is supported by brain research (Cohen, 1995), as well as research suggesting that people process information through patterns and connections rather than through fragmented bits and pieces of information (Beane, 1996).

However, in the midst of this rush to support an integrated curriculum, many educators question the effectiveness of an integrated curriculum and cite the paucity of research supporting an integrated curriculum over traditional curriculum. All schools and educators trying to enact an integrated curriculum face this critical issue and a number of other equally important ones. In this paper, several issues are discussed, including the lack of an operationalized definition of integrated curriculum, the role of integration in school curriculum, advantages and disadvantages associated with integration, and problems commonly encountered in trying to implement an integrated curriculum. These issues are critical to the understanding and implementation of integrated curriculum and also present areas for future research that can help prove or disprove the value of integrated curriculum.

Unfocused Definition of Integration

Despite the call for integrated curriculum, there is little existing empirical research supporting the notion that it is more effective than traditional, discipline-based curriculum. Berlin (1994) reported that, of 423 articles summarized at the 1991 Wingspread conference on integration, 99 were related to theory and research, and only 22 were research-based articles. Lederman and Niess (1997) echoed concerns that almost no empirical research exists supporting the use of integrated or thematic instruction.

One possible explanation for the lack of empirical research on curriculum integration is a conceptual issue that may cloud formulation of research questions. At the most basic level, a common definition of integration does not exist that can be used as a basis for designing, carrying out, and interpreting results of research.

Davison, Miller, and Metheny (1995) argued for clarification of the definition of integration, stating:

> Few educators would argue about the need for an interwoven, cross-disciplinary curriculum, but to many, the nature of the integration in many interdisciplinary projects is not readily apparent. A more pervasive problem is that integration means different things to different educators. (p. 226)

This ambiguity is evident in the sheer number of words used to describe integration: interdisciplinary, multidisciplinary, transdisciplinary, thematic, integrated, connected, nested, sequenced, shared, webbed, threaded, immersed, networked, blended, unified, coordinated, and fused. Lederman and Niess' (1997) editorial in *School Science and Mathematics* pointed out that many educators use the terms *integrated*, *interdisciplinary*, and *thematic* synonymously, and this only compounds the confusion.

Perhaps educators are tempted to use words such as integrated, interdisciplinary, and thematic because little agreement exists regarding the definition of integration. Berlin and White (1992) reported that in 1991, a group of 60 scientists, mathematicians, science and mathematics educators, teachers, curriculum developers, educational technologists and psychologists assembled at a conference funded by the National Science Foundation (NSF). These authors reported that, after three days of deliberation, the conference participants could not reach a consensus on the definition of integration of science and mathematics. However, one group proposed a working definition, "Integration infuses mathematical methods in science and scientific methods into mathematics such that it becomes indistinguishable as to whether it is mathematics or science" (p. 341). Berlin and White (1992) reported, however, that other conference participants feared that the merging of the disciplines might cause people to lose important philosophical, methodological, and historical differences between the two subjects.

Lederman and Niess (1997) defined integrated as a blending of science and mathematics such that the separate parts are not discernible. They used the metaphor of tomato soup: The tomatoes cannot be distinguished from the water or other ingredients. They defined interdisciplinary as a mixture of science and mathematics, in which connections are made between the subjects, but the two subjects remain recognizable. The metaphor is chicken noodle soup, where you can still recognize the broth, chicken, and noodles. Similarly, Jacobs (1989) defined interdisciplinary as "a knowledge view and curriculum approach that consciously applies methodology and language from more than one discipline to examine a central theme, issue, problem, topic, or experience." Finally, Lederman and Niess (1997) defined thematic as a unifying topic or subject transcending traditional subject boundaries.

Beane (1995) suggested that curriculum integration begins with "problems, issues and concerns posed by life itself" (p. 616). He stressed that an integrated curriculum must have social meaning. Beane (1996) defined integration with four characteristics: (a) curriculum that is organized around problems and issues that are of personal and social significance in the real world, (b) use of pertinent knowledge in the context of topic without regard for subject lines, (c) knowledge that is used to study a current problem rather than for a test or grade level outcome, and (d) emphasis placed on projects and activities with real application of knowledge and problem solving. He argued that other forms of integrated curriculum (such as parallel disciplines or multidisciplinary curricula) still focus on separate subject areas and, therefore, are not really integrated. The idea of organizing curriculum around projects as a relevant way to connect science, mathematics, and events, outside of the classroom was a consensus of the NSF-sponsored conference mentioned earlier (Berlin & White, 1992). Historical references to integration (Hopkins, 1937, as cited in Beane, 1996) defined integration similarly—as cooperatively planned, problem-centered, and integrated knowledge.

Jacobs (1989) presented a continuum of curriculum design options that move from discipline-based to parallel disciplines, multidisciplinary, and interdisciplinary units or courses, integrated day, and complete program. Underhill's editorial (1995) illustrated six perspectives on science and math integration that mirror some of the options presented in Jacob's (1989) continuum: math and science are disjointed; there is some overlap between science and math; math and science are the same; math is a subset of science; science is a subset of math; and there is major overlap between science and mathematics.

Lonning and DeFranco (1997) developed a comparable continuum of integration for science and mathematics, ranging from independent mathematics, mathematics focus, balanced mathematics and science, science focus, and independent science. They urged readers to ask two questions when integrating across the curriculum, "What are the major mathematics and science concepts being taught in the activity?" and "Are these concepts worthwhile? That is, are they key elements in the curricula and meaningful to students?" (p. 214). Similarly, Huntley (1998) presented a mathematics/science continuum on which both ends represent separate mathematics and science teaching, and the center represents integration. However, Huntley expanded upon the Lonning and DeFranco model by stressing that the center point, integration, occurs when science and mathematics are treated more than as two equal subjects but rather in a synergistic fashion.

Davison, Miller, and Metheny (1995) identified five types of science and mathematics integration: discipline specific integration (e.g., integration across mathematical areas), content specific integration (e.g., integrating one math concept and one science concept; for example, measurement with study of dinosaurs), process integration (e.g., measurement is a skill used in science and mathematics), methodological integration (using good teaching techniques such as the learning cycle model in mathematics and science), and thematic integration (taking a topic such as oil spills and integrating it with science, mathematics, language arts, and social studies).

Brown and Wall (1976) presented a similar view of science and mathematics integration, in which mathematics and science (on opposite ends of the continuum) are taught for their own sake, science is driven by math; math is driven by science; or science and mathematics are in concert with each other.

It seems that, despite the plethora of discussion, Davison, Miller, and Metheny's (1995) request for clarification of integration is still needed.

Does Integration Work?

Most of the literature on curriculum integration could be characterized as "testimonials." For example, Peters, Schubeck, and Hopkins (1995) described a thematic approach used in all K-8 classrooms at the Aleknagik School in southwest Alaska. These teachers reported that students were excited about learning and made their own connections among concepts, and teachers displayed a strong cooperative spirit.

Watanabe and Huntley (1998) reported that mathematics and science educators in the Maryland Collaborative for Teacher Preparation had many of the same beliefs about connecting science and mathematics curriculum as do classroom teachers. That is, they all believed (a) connections help provide students with concrete example of mathematical ideas, (b) math helps students understand science relationships, and (c) connections provide relevancy and motivation for students.

Of the few empirical research studies that have been conducted, most supported curriculum integration. Beane (1995) reported that, on traditional measures of school achievement, students who experience an integrated curriculum do as well as if not better than students who experience a separate-subject curriculum. Stevenson and Carr (1993) reported increased student interest and achievement in integrated instruction, as did Greene (1991). Greene also reported increased student interest and achievement scores on the National Assessment of Educational Progress (NAEP) for students in California who participated in year-long thematic units. Similarly, Vars (1991) reported that interdisciplinary programs produced higher standardized achievement scores than did separate subject area courses, but also acknowledged that interdisciplinary curriculum is frequently embedded into other reforms, such as block scheduling and multi-age grouping. It may be difficult to flesh out effectiveness of integration. McComas and Wang (1998) summarized several studies of college-age students that demonstrated greater achievement or interest in science when science was presented as an integrated program rather than a traditional sequence.

Bragow, Gragow, and Smith (1995) also reported benefits, especially increased interest in school. Similarly, McComas (1993) demonstrated that thematic units had a positive impact on student attitudes.

Despite these positive research findings, little from the results can lead to possible generalizations because of the lack of an operationalized definition of curriculum integration. A coherent, concise definition of curriculum integration is a necessary first step in stimulating research on the impact of integration on student learning.

Acceptance of Integration in Curriculum Design

Another issue raised in the literature is the ability to break from traditional academic disciplines. Scholars have traditionally organized knowledge within the major disciplines recognized today (science, mathematics, social studies, and language arts). Some consider academic disciplines a powerful way for organizing knowledge. For example, Gardner and Boix-Mansilla (1994) contended that academic disciplines "constitute the most sophisticated ways yet developed for thinking about and investigating issues that have long fascinated and perplexed thoughtful individuals...(and) they become, when used relevantly, our keenest lenses on the world" (p. 16-17).

However, others (e.g., Perkins, 1991) considered academic disciplines as "artificial partitions with historical roots of limited contemporary significance." Mason (1996) contended that contemporary school curriculum is moribund — a retrogradation to the factory system, where students proceed down a hallway to the next class. Mason said that factories have changed, but schools are out of sync with society and real life, where knowledge and skills are not separated.

Although disciplinary knowledge has been built up for centuries and forms the basis for exploring a particular area of knowledge, integration of subject areas is not a new idea either. A third grade unit on the study of boats at Lincoln School in New York in 1927 is outlined in Cremin's (1964) book, entitled *The Transformation of the School*. Berlin (1994) reported that since the turn of the century The School Science and Mathematics Association has published numerous articles on the topic. Lehman (1994) cited similar literature dating to the beginning of the century and noted that a number of curriculum projects have been developed with the intent to integrate science and mathematics. Some examples include Minnesota Mathematics and Science Project (1970), Unified Science and Mathematics for Elementary Schools Project (1973), School Science and Mathematics Integrated Lessons found in *School Science and Mathematics*, Lawrence Hall of Science's (1984) Great Explorations in Math and Science Project (GEMS), Fresno Pacific College's Activities That Integrate Mathematics and Science (AIMS Educational Foundation, 1986, 1987), and University of Chicago's Teaching Integrated Mathematics and Science Project (TIMS) (Institute for Mathematics and Science Education, 1995).

Paul DeHart Hurd (1991) stressed that the curriculum must be transformed because science is divided into 25,000 to 30,000 research fields, and currently data generated by this research is presented in over 70,000 scientific publications. Science is no longer characterized by pure disciplinary lines, such as biology, chemistry, geology, and physics. Rather, divisionary lines between the sciences are blurred, and new fields have emerged, such as biochemistry and geophysics. Hurd urged science educators to integrate the science curricula and use thematic science instruction, because science in daily life is not compartmentalized. He stated that traditional discipline-bound, fact-laden science courses are too narrow in scope to teach students how to learn in today's world.

Integration of science, mathematics, and other subject areas was a major focus in national reform initiatives: *Science for All Americans* (Rutherford & Ahlgren, 1990), *Everybody Counts: A Report to the Nation on the Future of Mathematics Education* (National Research Council [NRC], 1989), *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989), and the *National Science Education Standards* (NRC, 1996). For example, *Science for All Americans* stated, "The alliance between science and mathematics has a long history, dating back centuries. Science provides mathematics with interesting problems to investigate, and mathematics provides science with powerful tools to use in analyzing them" (p. 16-18). Beane (1996) noted that integration is now found in university courses and even college degrees. He said that, with the exception of school World Wide Web sites, the Internet is fully integrated. The whole language movement is seen by many in early childhood as a way to integrate across content areas (Willis, 1992), and Dickinson and Young (1998) advocated the use of language arts strategies to help teachers develop science literacy.

The NSTA's *Scope, Sequence and Coordination* project (1992) recommended replacing traditional high school discipline curricula (called layer-cake curricula) with 4 years of integrated science. In 1996, NSTA endorsed a new position statement on interdisciplinary learning in grades PreK-4 that represented the thinking of members of professional organizations that met to develop guidelines for integrating curriculum (NCTM, NCTE, IRA, NSTA, NCSS, Speech Communication Association, and Council for Elementary Science International). Rather than defining integration, the position statement outlined eight guidelines that all interdisciplinary/integrated curricula should meet:

1. Maintain the integrity of content drawn from the disciplines by using meaningful connections to sustain students' inquiry between and among these disciplines.
2. Foster a learning community in which students and teachers determine together the issues, questions, and strategies for investigation.
3. Develop democratic classrooms.
4. Provide a variety of opportunities for interaction among diverse learners — for example, discussion, investigation, product development, drama, and telecommunications.
5. Respect diversity of thought and culture.
6. Teach students to use a wide variety of sources, including primary sources, oral communication, direct observation, and experimentation
7. Use multiple symbol systems as tools to learn and present knowledge.
8. Use wide-ranging assessments to evaluate both the process and outcomes of student learning. (p. 6,8)

This position statement addressed some of the issues related to integration that are mentioned in Berlin and White's (1994) Berlin-White Integrated Science and Mathematics model, because it focused on ways of learning, ways of knowing, process and thinking skills, content knowledge, attitudes and perceptions, and teaching strategies.

Curriculum designed to integrate across subjects varies in its approach to connect subject areas. Certainly many projects such as AIMS and GEMS focus on integrating science and mathematics by using process skills, such as observing, classifying, and analyzing (Roebuck & Warden, 1998). The *Professional Standards for Teaching Mathematics* state, "The content is unquestionably a critical consideration in appraising the value of a particular task" (NCTM, 1991). However, Roebuck and Warden pointed out that few curriculum materials use the content of science or mathematics as a focus of integration. Venville, Wallace, Rennie, and Malone (1998) identified several additional forms of curriculum integration, including technology-based projects, competitions, and local community projects.

Disadvantages of Curriculum Integration

Critics claim there is little evidence that an integrated curriculum is any more effective than a well-prepared traditional curriculum. George (1996) listed a number of claims about an integrated curriculum that are not supported by research:

1. Addresses the real life concerns of students any more than a good traditional curriculum.
2. Presents more opportunities for problem solving.
3. Promotes independent learning by students.
4. Provides more effective involvement with the environment.
5. Provides more opportunities for student involvement in planning the curriculum.
6. Allows teachers more opportunity to be "facilitators."
7. Permits learning in greater depth.
8. Permits students to capitalize on prior learning more effectively.
9. Allows for more application of curriculum outcomes.
10. Permits more concrete experiences for slower learners or more enrichment opportunities for able students.
11. Encourages more transfer or retention of learned information.
12. More effectively renews and invigorates career teachers with new experiences.
13. More effectively promotes achievement, personal development, or harmonious group citizenship.

St. Clair and Hough (1992) also stated that few studies support interdisciplinary curriculum.

According to Lederman and Niess (1997) research existing on integrated and thematic instruction seems to show that science and mathematics instruction is severely restricted, because concepts included are narrowed to a specific framework. They stated that the current science-technology-society (STS) approach is an example in which achievement results were disappointing. These authors favored the interdisciplinary approach in which connections can be made among topics but each subject area retains its own identity. The argument is made that each discipline possesses unique conceptual, procedural, and epistemological differences that cannot be addressed through an integrated or thematic approach.

Roth (1994) described her own experience teaching a fifth-grade unit around the theme of 1492. Roth's experiences frustrated her, because her science was confined to this theme, and she was unable to integrate science into the theme without distorting and diminishing the science content she wanted to cover. Therefore, she urged caution when planning interdisciplinary instruction. Davison, Miller, and Metheny (1995) raised similar concerns regarding integration of mathematics and science by asking the following questions:

"To what extent can these integration efforts represent bona fide integration of science and mathematics?"

"To what extent has the integration of science and mathematics been merely cosmetic?" (p. 226).

Mason (1996) also identified several logistical problems that may be disadvantages for using an integrated curriculum. For example, mathematics is sequential, and adding mathematics concepts here and there in the curriculum could confuse students if they do not have prerequisite knowledge and skills. In other words, adding bits and pieces of mathematics for the sake of integrating might leave wide gaps in subject matter. Further, Mason described a typical example of integration, such as "the rain forest," and stated that students would be asked to graph the number of endangered species. He questioned how valuable it is to make dozens of graphs. Another logistical problem is that many teachers, in an effort to force integration, trivialize the problem. For example, "A poem about photosynthesis may not help one understand photosynthesis as a process, or poetry as a genre" (p. 266). Gardner and Boix-Mansilla (1994) pointed out that prerequisite skills are often needed before students can use an integrated curriculum, and schools may not have time to teach skills and put them in an integrated curriculum at the same time. If children do not have prerequisite background, curriculum integration may be developmentally inappropriate; integration becomes contrived and is formed around trivial themes.

Lonning and DeFranco (1997) argued that integration can be justified only when connecting science and mathematics concepts enhances the understanding of the subject areas. They argued that there may be some things better taught separately; integration only makes sense when it grows out of a school's curricula. Otherwise, it may be shallow and lack meaning. They warned that teachers should not force integration for the sake of integration. Similarly, the NCSS (1994) warned,

> Integrative aspects have the potential for enhancing the scope and power of social studies. They also, however, have the potential for undermining its coherence and thrust as a curriculum component that addresses unique citizen education goals. Consequently, programs that feature a great deal of integration of social studies with other school subjects — even programs ostensibly built around social studies as the core of the curriculum — do not necessarily create powerful social studies learning. Unless they are developed as plans for accomplishing major social studies goals, such programs may focus on trivial or disconnected information. (p. 165-166)

Obstacles to Enacting Integrated Units

One of the true tests of any educational idea is that it can be successfully implemented in a "real" classroom, with "real" students, and within the structure of a "real" school. Mathematics and science educators in the Maryland Collaborative for Teacher Preparation reported that although they had positive attitudes about connecting science and mathematics, some had problems enacting the curriculum (Watanabe & Huntley, 1998). Some teachers had reservations about the time it took to infuse integration into an already packed curriculum. Similarly, Lehman (1994) found that, although teachers have positive perceptions about integrated curriculum, these perceptions do not carry over into practice. Teachers felt they did not have time to add integrated ideas into an already overcrowded curriculum, and they were not aware of available integrated resources. Beane (1995) suggested that teachers who fear they will not be able to cover all their curriculum in an integrated approach consider the fact that the separate subject curriculum is already too dense and not everything is covered now. He suggested that curriculum integration allows the most important and powerful ideas in the discipline to surface while solving real-life problems.

Concerns about time may be related to the structure of the school day (Venville, Wallace, Rennie, & Malone, 1998). Jacobs (1989) cited the structure of the school day (particularly in high schools) as a major problem, because the structure does not allow enough time to integrate. Unless teachers team teach (an approach popular in middle schools), they typically do not have opportunity to work with other teachers (Mason, 1996). In fact, Mason suggested that many teachers do not know how to collaborate to create integrated curriculum.

Teacher education is another problem limiting implementation of integrated curriculum (Roebuck & Warden, 1998). Preservice teachers do not take integrated classes in general studies, do not experience methods classes with teams of faculty and, therefore, do not know how to integrate across the curriculum (Mason, 1996). Typically, teachers (especially secondary teachers) are certified or licensed in specific disciplines and, therefore, do not possess knowledge to integrate. Berlin (1994), in summarizing Lynn A. Steen's presentation at the 1991 Wingspread conference, also cited inadequate teacher preparation for integration. Steen stated that few science teachers, with perhaps the exception of chemistry and physics teachers, have enough mathematical background to integrate advanced mathematics with science, and few math teachers could teach even one area in science. Lehman (1994) reported that less than 50% of 221 preservice and in-service teachers surveyed felt they had sufficient content background to integrate science and mathematics. Models for undergraduate preparation such as Lonning, DeFranco, and Weinland's (1998) may be useful in helping teachers learn how to integrate across the curriculum.

Student assessment is also seen as a limitation to enacting an integrated curriculum. Standardized tests still measure, for the most part, disciplinary knowledge (Mason, 1996). Berlin and White (1992) stated that Wingspread participants cited assessment practices as an impediment to implementation of integrated curricula. Further, the standards movement (NCTM, NRC, NCSS, NCTE/IRA) is moving along disciplinary lines. Standards do not exist for themes or integrated ideas.

Discussion

Several implications can be gleaned from this literature review. These implications provide foci for members of the School Science and Mathematics Association to provide leadership in clarifying issues, challenge basic assumptions, and solve problems associated with integrating science and mathematics.

In spite of a plethora of literature about curriculum integration, there is little research evidence that curriculum integration is a better way to provide instruction than traditional discipline-specific methods. Berlin and White (1992) reported that the Wingspread conference participants identified several benefits of integration, including helping students bridge understanding between concrete and abstract representations, providing opportunities to put ideas together and deepen understanding, developing quantitative and causal appreciation of reality with emphasis on information use rather than acquisition, and encouraging relevant, exciting science and mathematics in schools (p. 341). However, research is critical to determine whether these benefits actually exist, and the results can be used to inform school-based practice.

There still appears to be a lack of consensus about the definition of integration. Models presented in the October 1998 special issue of *School Science and Mathematics* provide a catalyst for this discussion, but the debate continues. Clarification of definitions would help the science and mathematics community eliminate confusion when discussing curriculum and instructional approaches that aim to integrate curriculum. In addition, a concise definition could provide the stimulus for the design and implementation of research on the impact of integrated curriculum.

Integrated curriculum has focused mostly on using process skills. Curriculum publishers have given little attention to designing curriculum materials that use science or mathematics content as the curriculum's central focus. Some STS and project-based curriculum projects focus on issues and topics as a means to integrate across the curriculum. However, the implication from this literature review is that educators are still searching for good curriculum materials that provide sufficient, high-quality science and mathematics content.

Problems enacting an integrated curriculum, including time and structure of the school day, also need to be overcome before integration becomes commonplace in schools. Many U.S. schools are turning to block scheduling as a way to provide teachers, particularly at the middle, junior, and high school levels, with larger segments of time to teach (Canady, 1995). A 90-minute segment of time in a block schedule (rather than the traditional 45- or 50-minute periods) may afford teachers the necessary time to integrate the curriculum.

More models of teacher preparation, such as the one presented by Lonning, DeFranco, and Weinland (1998), are needed to prepare teachers to integrate the curriculum. To prepare preservice teachers to design and implement integrated units, preservice teachers must be familiar with state and national reform recommendations. Preservice teachers should receive instruction in the integration of science and mathematics, including the opportunity to critique integrated curriculum materials. It is also important that preservice teachers have opportunities to experience the teaming process, both in the development of an integrated unit and in implementation, with an experienced classroom teacher. This is consistent with the suggestions made by Lehman (1994) and Mason (1996).

The pressure of state proficiency and standardized tests seems to be a limiting factor in implementing an integrated curriculum. Because most of these tests still examine content separately, one can question whether the understanding, skills, and knowledge learned in an integrated unit would transfer to these tests. Integrated units developed by teachers need to contain assessments focusing more on student performance and use more authentic forms of assessment, utilizing portfolios, written projects, and performance tasks. This focus on assessing students in more authentic situations is consistent with the *Assessment Standards for School Mathematics* (NCTM, 1995), Wiggins (1993), and Hart (1994).

Finally, it is ironic that despite the interest in integrated curricula, standards for individual disciplines remain separate (e.g. NCTM, NRC's *National Science Education Standards*, NCTE/IRA, and NCSS). Future discussions for establishing a set of standards for integrating content areas are essential if progress is to be made in moving integrated instruction into more modes of inquiry, problem solving, critical thinking, and processing information. This is not to say that there is not content specific knowledge or that all content areas should be integrated all the time. Integration can be justified only if the understanding of the content is enhanced and if integration is the best way to teach the concepts (Lonning & DeFranco, 1997).

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