Integrating Science and Mathematics Education: Historical Analysis

Donna F. Berlin
The Ohio State University

Hyonyong Lee
Kyungpook National University

A number of national science and mathematics education professional associations, and recently technology education associations, are united in their support for the integration of science and mathematics teaching and learning. The purpose of this historical analysis is two-fold: (a) to survey the nature and number of documents related to integrated science and mathematics education published from 1901 through 2001 and (b) to compare the nature and number of integrated science and mathematics documents published from 1990 through 2001 to the previous 89 years (1901-1989). Based upon this historical analysis, three conclusions have emerged. First, national and state standards in science and mathematics education have resulted in greater attention to integrated science and mathematics education, particularly in the area of teacher education, as evidenced by the proliferation of documents on this topic published from 1901-2001. Second, the historical comparison between the time periods of 1901-1989 versus 1990-2001 reveals a grade-level shift in integrated instructional documents. Middle school science continues to be highlighted in integrated instructional documents, but surprisingly, a greater emphasis upon secondary mathematics and science education is apparent in the integration literature published from 1990-2001. Third, although several theoretical integration models have been posited in the literature published from 1990-2001, more empirical research grounded in these theoretical models is clearly needed in the 21st century.

During the past century, one distinctive effort to improve science and mathematics education is an approach that recognizes the commonalities between science and mathematics and seeks to appropriately and effectively integrate these two disciplines in teaching and learning (Berlin & White, 1998; Lee, 2000; Pang & Good, 2000). In 1991, the first comprehensive bibliography of integrated science and mathematics teaching and learning literature was published by Berlin. Spanning a time period of approximately 90 years from 1901 until the first half of 1991, 555 documents were categorized into five sections: curriculum, instruction, research, curriculum-instruction, and curriculum-evaluation. Publication deadlines led to the inclusion of literature from only the first half of 1991.

Recently, the second volume of the bibliography of integrated science and mathematics teaching and learning literature was published (Berlin & Lee, 2003). Using the same five categories, 402 documents were identified for a period of approximately 10 years, the second half of 1991 through 2001. These two unparalleled volumes of integrated science and mathematics teaching and learning literature provide the data for this historical analysis. The purpose of this historical analysis is two-fold: (a) to survey the nature and number of documents related to integrated science and mathematics education published from 1901 through 2001 and (b) to compare the nature and number of integrated science and mathematics documents published from 1990 through 2001 to the previous 89 years (1901-1989).

A number of national science and mathematics education professional associations (and, recently, technology education associations) are united in their support for the integration of science and mathematics teaching and learning. The national education reform documents published by the following associations recommend the integration of science and mathematics education: American Association for the Advancement of Science (1989, 1993, 1998); International Technology Education Association (1996, 2000); National Council of Teachers of Mathematics (NCTM, 1989, 1991, 1995, 2000); National Research Council (1989, 1990, 1996); National Science Teachers Association (1992, 1997).

The following excerpts from national educational reform documents attest to the significance and timeliness of this compilation and analysis of the literature related to integrated science and mathematics teaching and learning. These documents address the interrelated

nature of science and mathematics, along with implications for curricula and instructional practice.

Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993), while recognizing the uniqueness of each discipline, suggests a symbiotic relationship between science, mathematics, and technology.

> It is the union of science, mathematics, and technology that forms the scientific endeavor and that makes it so successful. Although each of these human enterprises has a character and history of its own, each is dependent on and reinforces the others. (p. 3)

A similar position is reflected in the Connections Standard promoted by the mathematics education community. Opportunities for students to recognize and apply mathematics in contexts outside of mathematics are central to this process standard.

> School mathematics experiences at all levels should include opportunities to learn about mathematics by working on problems arising in contexts outside of mathematics. These connections can be to other subject areas and disciplines as well as to students' daily lives. (NCTM, 2000, p. 65)

The current national science and mathematics standards that guide both state curriculum frameworks and local courses of study affirm the importance of the integration of science and mathematics education.

> The science program should be coordinated with the mathematics program to enhance student use and understanding of mathematics in the study of science and to improve student understanding of mathematics. (National Research Council, 1996, p. 214)
>
> The opportunity for students to experience mathematics in a context is important. Mathematics is used in science, the social sciences, medicine, and commerce. The link between mathematics and science is not only through content but also through process. The processes and content of science can inspire an approach to solving problems that applies to the study of mathematics. (National Council of Teachers of Mathematics, 2000, p. 66)

Based upon current reform documents in science and mathematics education, there is strong philosophical support for the integration of science and mathematics education as a way to enrich science and mathematics learning experiences and improve student understanding of and attitude toward these disciplines. This historical analysis has been prepared for classroom teachers, teacher educators, curriculum reformers and developers, and educational researchers interested in the exploration of the topic of integrated science and mathematics teaching and learning.

Bibliographic Data

The main purposes for both the first (Berlin, 1991) and second volumes (Berlin & Lee, 2003) of the bibliography of integrated science and mathematics teaching and learning literature are to

1. Provide strategies and activities for classroom practice, policy decisions, and research.
2. Facilitate the development of new curriculum and instructional materials.
3. Stimulate additional research.
4. Identify K-12 and teacher preparation and enhancement models.
5. Present a century-long portrayal of trends and issues.

To initially locate science and mathematics integration literature for both volumes, relevant journals were identified using the Current Index to Journals in Education provided by the Educational Resources Information Center (ERIC). ERIC indexes more than 1,100 journals, including science and mathematics education journals published throughout the world. Journals targeting teachers of mathematics and all the sciences for grade levels P-16 were included in the analysis. Articles in over 70 journals and ERIC documents were examined. After selecting all articles that addressed both science and mathematics education, a content analysis was used to determine the major theme and content of each article. The investigators read all selected articles repeatedly and used a process of dialogue and consensus to place each article, ultimately, in one of the five sections of the bibliography. As a final step, all articles were subjected to another review with regard to section classification.

For consistency, both volumes of the bibliography of integrated science and mathematics teaching and learning literature used the same process of analysis and delineation of categories or sections. The integrated science and mathematics teaching and learning literature was divided into five categories: (a) Curriculum, (b) Instruction, (c) Research, (d) Curriculum-Instruction, and (e) Curriculum-Evaluation. A narrow definition of curriculum was used. Curriculum relates to intended learning or the outcomes of being educated. Citations in the Curriculum Section primarily deal with the content in a course or group of courses or, simply put, "what students are taught." For example, an article entitled "Achieving Science Literacy Through a Curriculum Connected With Mathematics and Technology" (Hamm,

1992) is listed in the Curriculum Section.

Instruction is the process of implementing the curriculum. It refers to the structuring of the learning environment to coordinate elements of time, space, materials, equipment, and personnel. Simply put, citations in the Instruction Section primarily relate to "how students are taught." Although it is recognized that the instruction literature must initially deal with the curriculum, those documents that have been placed in this category primarily deal with the instructional elements. School Science and Mathematics Integrated Lessons (SSMILes) published in *School Science and Mathematics*, such as "Thinking Small: Milligrams, Micrograms and Counting Atoms" (Whitmer, 1992), are documents that are classified in the Instruction Section.

The Research Section includes both theoretical and empirical research documents. The theoretical research documents are comprised of theoretical models and frameworks related to the integration of science and mathematics teaching and learning. Empirical research includes research documents that are data based and generate new knowledge and understandings from both qualitative and quantitative inquiry. Empirical research also includes reviews of research. An example of a theoretical model included in the Research Section is "The Berlin -White Integrated Science and Mathematics Model" (Berlin & White, 1994).

Two additional sections were used in order to classify documents that include both curriculum and instructional activities (Curriculum-Instruction Section) and curriculum and evaluation of that curriculum (Curriculum-Evaluation Section). Documents such as "Technological Problem-Solving Activities as a Means of Instruction: The TSM Integration Program (Sanders, 1994) and "A Look at Project AIMS" (Deal, 1994) are examples of documents classified in the Curriculum-Instruction and Curriculum-Evaluation Sections, respectively. It should be noted that although most of the citations can be distinctly placed in one of the bibliography sections there are some that cannot, and placement decisions were based upon the primary focus of the document.

Analysis and Discussion

The first bibliography (from 1901 until the first half of 1991) includes 555 documents. The second volume of the bibliography of integrated science and mathematics teaching and learning literature includes 402 documents published from the second half of 1991 through 2001. Combining the documents from the two bibliographic volumes results in a total of 957 citations. However, two modifications were made to the initial data source from Volume 1.

During the compilation of the second volume of the bibliography, 13 additional citations were identified for the years 1901-1991. The revised total for documents in Volume 1 increased to 568.

In 1992, the Department of Education funded the Eisenhower National Clearinghouse (ENC) to develop a database of all K-12 mathematics and science resources. A recent search of the ENC database resulted in the identification of 1,165 integrated science and mathematics curriculum-instruction resources. Consequently, the second bibliography does not include the vast number of integrated curriculum-instruction resources now available in the ENC database.

In order to analyze the Curriculum-Instruction Section literature from 1901-2001, it was necessary to modify the numbers reported in this section in the first bibliography. The first bibliography includes documents that describe the integrated science and mathematics curriculum along with instructional methods and activities, as well as a substantial number of curriculum-instructional programs such as Activities Integrating Mathematics and Science, Great Explorations in Math and Science, Minnesota Mathematics and Science Teaching Project, and Unified Science and Mathematics for Elementary Schools. Designed as total programs or as supplements to the established curricula, these curriculum-instruction programs and their corresponding documents/books were included in the first bibliography because, at the time, there was no other cataloging of these resources. Consequently, the numbers in the first volume of the bibliography have been adjusted to subtract curriculum-instruction programs/books that are now catalogued by ENC (n = 120). Accordingly, the adjusted total number of citations in the first volume of the bibliography is 448. The historical analysis is based upon a total of 850 documents (adjusted total of 448 from Volume 1 plus 402 from Volume 2) related to integrated science and mathematics teaching and learning.

Historical Analysis 1901-2001

The topic of integrated science and mathematics teaching and learning is not new. The earliest document referenced in the first bibliography of integrated science and mathematics teaching and learning literature was published in 1905 in *School Science and Mathematics*. Publishing since 1901, numerous articles appeared in this same journal published by the Central Association of Science and Mathematics Teachers. In

1970, this association was renamed the School Science and Mathematics Association (SSMA) and their journal, *School Science and Mathematics*, continues to be a principal source for integrated science and mathematics articles. National funding agencies have also been involved in integration efforts.

A cursory look at the integrated science and mathematics teaching and learning literature reveals that there has been a plethora of terms being used to refer to "integration"; for example, connections, cooperation, coordinated, correlated, cross-disciplinary, fused, interactions, interdependent, interdisciplinary, interrelated, linked, multidisciplinary, transdisciplinary, and unified. These terms represent various degrees of integration, including mathematics taught as a prerequisite tool for science, mathematics applied to science problems, science phenomena translated into mathematical terms, and science and mathematics taught in concert in a real-world, problem-solving context.

Figure 1 displays the number of documents by decade published in the 20th century. The graphical display of all the documents related to the integration of science and mathematics teaching and learning that have been published each decade through 1999 yields an impressive and revealing trend. There is a noticeable pattern of growth in the number of integrated science and mathematics documents since the 1970s that may reflect increased federal funding, recommendations from national reform documents, and teacher education programs related to integrated science and mathematics education. For example, the National Science Foundation funded a number of integrated programs in the 1970s (e.g., Minnesota Mathematics and Science Teaching Project and Unified Science and Mathematics for Elementary Schools). Integrated science and mathematics education was further advanced in both science and mathematics education reform documents published in the 1980s and 1990s, leading to standards-based documents in the late 1980s and throughout the 1990s. Consequently, a number of integrated science and mathematics preservice and in-service programs were designed and described in the literature of the 1990s.

A conservative approach was used to predict the number of publications in the first decade in the 2000s. A linear line of best fit was calculated using the number of publications in the 1970s, 1980s, and 1990s. Applying the resultant algebraic formula, $y = 119.1x - 106$, yields

Figure 1. *Integration of science and mathematics teaching and learning literature by decade.*

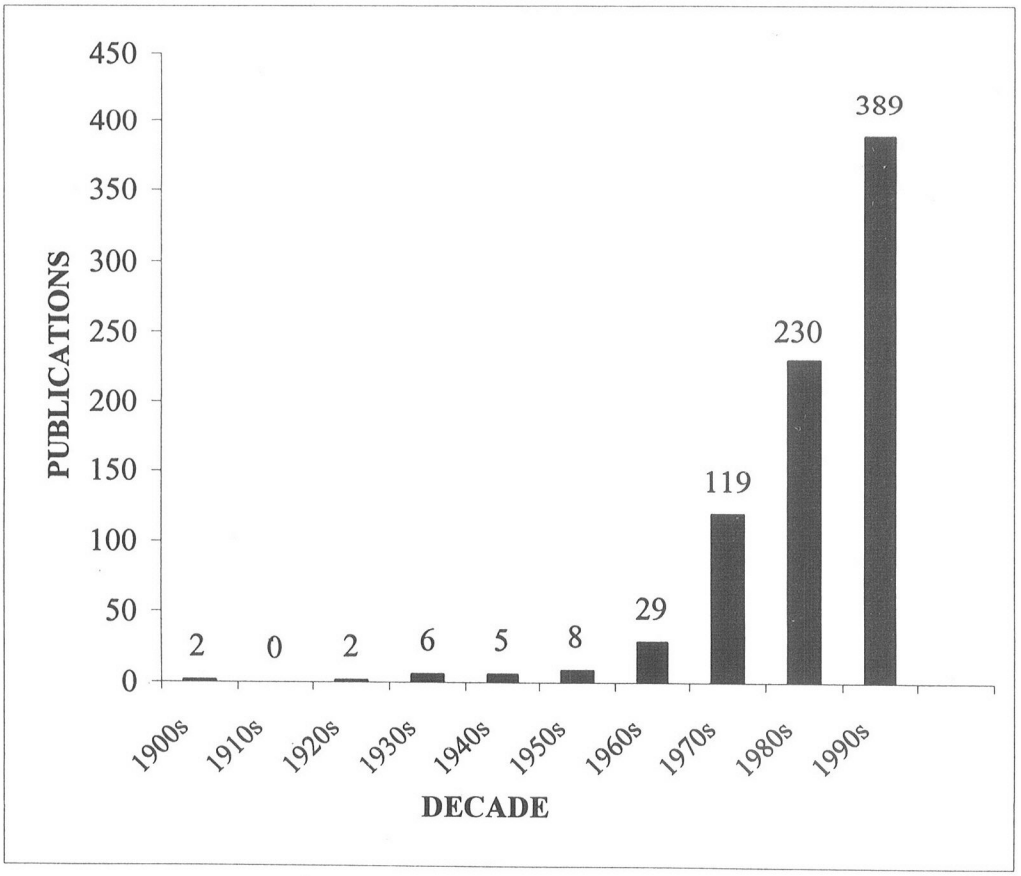
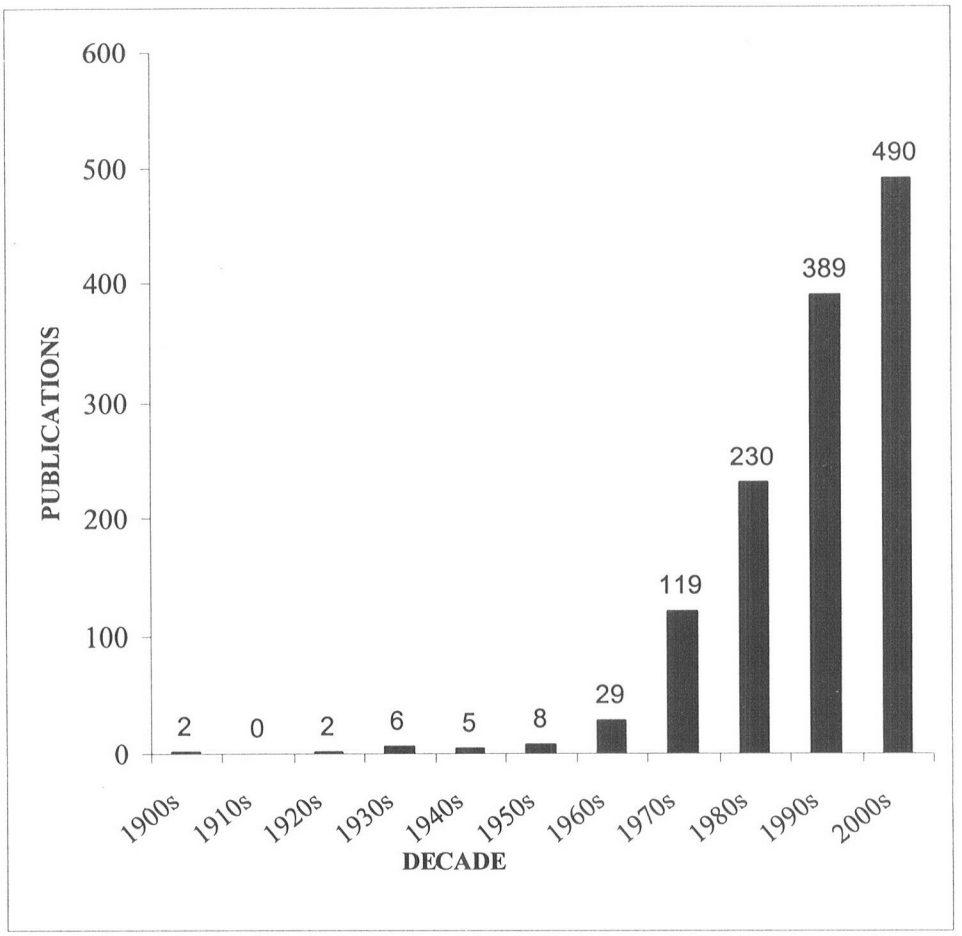


Figure 2. *Projected integration of science and mathematics teaching and learning literature for the 2000s.*



approximately 490 documents related to the integration of science and mathematics education projected for the next decade, 2000-2009 (see Figure 2).

Clearly, there has been a tremendous proliferation in the number of documents related to the topic of integrated science and mathematics education from the 1970s through the 1990s that can be predicted to continue into and through the 21st century.

Categorical Analysis

The next analysis examined the literature patterns according to the five categories of curriculum, instruction, research, curriculum-instruction, and curriculum-evaluation. The researchers decided to divide the literature data into two parts: 1901-1989 (401 documents) and 1990-2001 (449 documents). This decision was based upon two reasons: (a) an interest in the last full decade (1990s) impacted by the era of standards-based reform and (b) an attempt to divide the number of documents into robust time frames to facilitate the identification of trends and patterns. Table 1 provides the totals for each of the five categories, along with the number of articles by year, 1901 through 1989. Similarly, Table 2 provides the totals for each of the five categories, along with the number of articles by year, 1990 through 2001.

Overall, a comparison between Table 1 (1901-1989) and Table 2 (1990-2001) reveals a dramatic increase in the number of documents related to the integration of science and mathematics teaching and learning. For the years 1901-1989 or for a period of 89 years, 401 citations were identified. In contrast, for the years 1990-2001, a period of only 12 years, 449 citations were identified. This is a remarkable statistic; more documents were published in the last 12 years than in the preceding 89 years.

Categorical Integration Literature: 1990-2001 Compared to 1901-1989

During the years 1990 through 2001, 449 documents

Table 1

Integrated Science and Mathematics Teaching and Learning Literature by Category and by Year 1901-1989

Year	Instruction	Curriculum	Research	Curriculum-Instruction	Curriculum-Evaluation	Total
1901-1904						0
1905	2					2
1926	1					1
1929	1					1
1930	1					1
1931	1					1
1935	1					1
1936	1					1
1937	1					1
1939	1					1
1941	1					1
1942		2				2
1943			1			1
1945	1					1
1950		1				1
1952	1					1
1957		2				2
1958	1					1
1959	1		1		1	3
1961	4	1				5
1962	3	1				4
1963	1	1	1			3
1964				1		1
1965	1					1
1966	3		1			4
1967			1	1		2
1968		1		2	1	4
1969	1	1	1	2		5
1970	2	2		3		7
1971	1	5	1	1		8
1972	4	5		4		13
1973	1	3	1	2		7
1974	2	3		1		6
1975	10	11		4	3	28
1976	1	3	2	4	2	12
1977		3	3	0	2	8
1978	2	3	1	?	1	10
1979	4	16				20
1980	2	6		3		11
1981	2	5	2	2		11
1982		6		1		7
1983	2	5	2	0		9
1984	1	3	7	2		13
1985	2	19	5	5		31
1986	4	11	3	2		20
1987	5	39	4	2	1	51
1988	4	20	3	0		27
1989	3	42	4	1		50
Total	80	220	44	46	11	401

Table 2
Integrated Science and Mathematics Teaching and Learning Literature by Category and Year (1990-2001)

Year	Curriculum	Instruction	Curriculum-Research	Curriculum-Instruction	Evaluation	Total
1990	5	31	2	1		39
1991	8	15	9	1	3	36
1992	5	14	8	2	0	29
1993	8	43	7	5	1	64
1994	8	46	7	4	1	66
1995	1	23	8	1	1	34
1996	2	21	1	3	0	27
1997	1	23	7	1	0	32
1998	2	20	16	0	0	38
1999	0	17	6	1	0	24
2000	3	25	7	1	0	36
2001	2	13	8	1	0	24
Total	45	291	86	21	6	449

related to integrated science and mathematics teaching and learning literature were published. A comparison of the literature by categories indicates that the documents related to instruction permeate the literature. Specifically, there are 291 documents in the Instruction category, as compared to 45 in the Curriculum category, 86 in the Research category, 21 in the Curriculum-Instruction category, and 6 in the Curriculum-Evaluation category (see Table 2). As in the preceding 89 years (1901-1989), the greatest number of citations appears in the Instruction Section ($n = 291$).

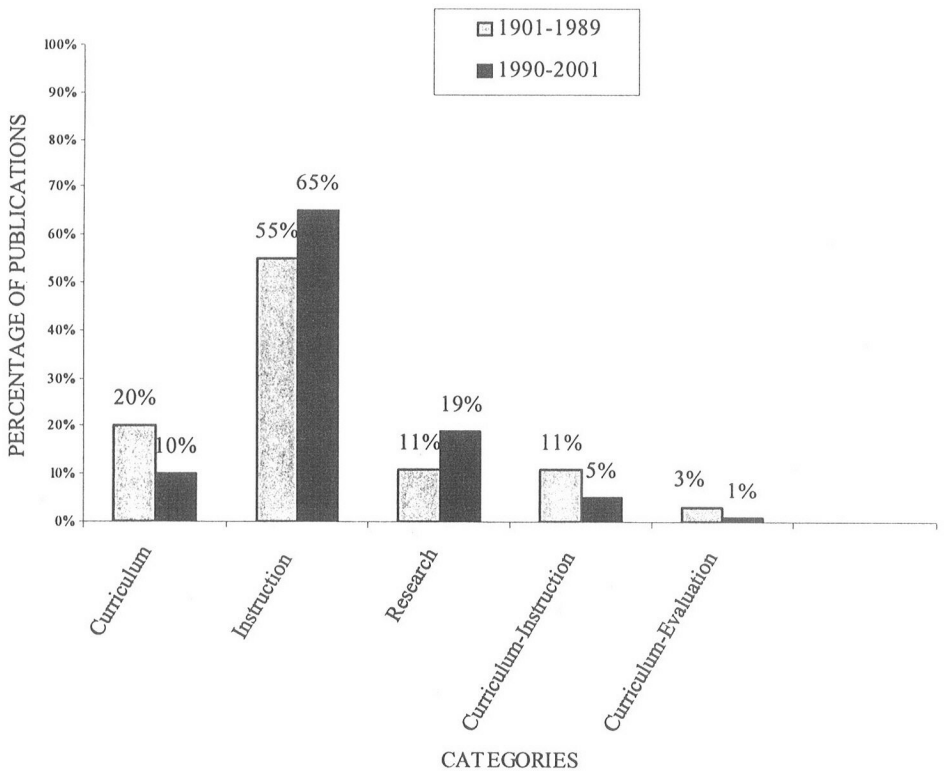
The science concepts and processes and mathematics concepts and skills that emerged in the analysis of the instructional documents in the first 89 years were also apparent in the past 12 years. The science processes of classifying, collecting and organizing data, communicating, controlling variables, developing models, experimenting, inferring, interpreting data, measuring, observing, predicting, and space-time relationships were most frequently cited in the instruction literature. The most frequent mathematics concepts/skills mentioned or implied include angular measurement, estimation, formulas and equations, fractions, function, geometry, graphs, modeling, patterns, percentage, probability and statistics, problem solving, ratio and proportion, and variable. Analysis of this literature reveals that most of the documents are basically science instructional activities or lessons for middle and secondary school students that include mathematics-related concepts.

During the years 1993 and 1994, there was a noticeable increase in the number of integrated science and mathematics instructional documents. Perhaps the numerous meetings and preliminary documents related to the development of the national standards for science education, along with implementation of the national standards for mathematics education, encouraged individuals to explore instructional connections between these two disciplines.

Figure 3 illustrates the percentage of documents in each of the five categories published from 1901-1989 compared to the percentage published in 1990-2001. Comparing the Curriculum category for these two time periods indicates that the percentage of articles devoted to curriculum is 20% and 10%, respectively. Perhaps, with the advent of national standards in both science and mathematics education, there is less need to discuss the role of integrated science and mathematics within the curriculum. However, recent curriculum documents (1990-2001), though fewer in relative number, include many more documents related to teacher education programs for both preservice and in-service teachers designed to integrate science and mathematics education.

What is rather startling is that the number of integrated science and mathematics instructional documents in the past 12 years ($n = 291$) is somewhat higher than the number in the preceding 89 years ($n = 220$). However, the percentage of integrated science and mathematics instructional documents in the first bibliography compared to the second bibliography has increased from 55% to 65%. Surprisingly, the largest percentage of integrated science and mathematics instructional activities published in the last 12 years appeared in journals that targeted secondary science

Figure 3. *Percentage of publications 1901-1989 and 1990-2001 by category.*



teachers (27.3%), middle school science teachers (25.3%), and secondary mathematics teachers (24.2%). Journals published for elementary mathematics teachers accounted for 10.3% of the integrated instructional articles, while 6.7% and 6.2% of the integrated documents appeared in journals for elementary science teachers and middle school mathematics teachers, respectively.

The publication of integrated science and mathematics instructional activities in journals for secondary science and mathematics teachers in departmentalized classrooms is in stark contrast to the publication pattern in the previous 89 years, when most of the instructional documents were published in journals targeting elementary science teachers in self-contained classrooms and middle school science teachers (Berlin, 1991). The percentage of articles in journals for middle school science teachers has been consistently high over the last 100 years. The attention to integrated instructional activities for secondary science and secondary mathematics classrooms is clearly a dramatic, unanticipated finding in the last 12 years.

The review of the first 89 years of integrated science and mathematics literature revealed a profound lack of research documents. Out of 401 citations, only 44 or 11% of the documents relate to research over a period of 89 years. In contrast, the last 12 years of integrated science and mathematics teaching and learning literature includes 86 or 19% devoted to research, nearly double the number of articles devoted to research in a mere 12 years. It should be noted that there was nearly a balance between theoretical and empirical research and that there was considerable attention to the development of theoretical models for the integration of science and mathematics education during the last 12 years.

Similar to the trend noted in the Curriculum Section, theoretical models and empirical research related to integrated science and mathematics courses, projects, and programs for preservice and in-service teachers have emerged in the last 12 years. As previously noted, the terminology and definition of integration is not at all consistent within the literature, precluding reliable and valid comparisons among research studies. Clearly, there remains a critical need for careful conceptualization and additional research on integrated science and mathematics teaching and learning for all grade levels and teacher education preparation and enhancement programs.

The percentage of documents focused on curriculum-instruction has dropped from 11% (1901-1989) to 5% (1990-2001). Although there are many more current integrated curriculum-instruction resources, the percentage of articles describing both curriculum and instruction appears to be diminishing. It should be noted again that many of these curriculum-instruction resources are now catalogued in the database of the Eisenhower National Clearinghouse and not included in this analysis. This would account for much of the decrease in the percentage of documents in this category in the past 12 years.

A similar diminishing pattern appears in the Curriculum-Evaluation Section comparison. The percentage of articles in this category reported in the literature published from 1901-1989 is 3%, and the percentage of articles published from 1990-2001 is 1%.

Conclusions

Based upon the historical analysis of the integrated science and mathematics teaching and learning literature published from 1990 through 2001 compared to the literature published from 1901-1989, the following three conclusions have emerged:

1. Reform documents such as *Science for All Americans* (Rutherford & Ahlgren, 1990) and *Reshaping School Mathematics: A Philosophy and Framework for Curriculum* (National Research Council, 1990), followed by standards-based documents such as the *National Science Education Standards* (National Research Council, 1996), *Curriculum and Evaluation Standards for School Mathematics* (National Council of Teachers of Mathematics, 1989), and *Principles and Standards for School Mathematics* (National Council of Teachers of Mathematics, 2000) have clearly recommended integration or connections between school science and mathematics. These standards-based documents have guided the development of state frameworks that have been further supported through state mandated high-stakes tests aligned with the standards-based documents. Moreover, national and state standards in science and mathematics education proposed by the professional learned societies have led to changes in licensure requirements and teacher education programs. This standards trail seems to have resulted in greater attention to integrated science and mathematics education, as evidenced by the proliferation of documents on this topic published from 1990-2001.

2. It appears that integrated science and mathematics instructional activities were initially designed for elementary school and middle school science teachers during the years 1901-1989. This is not unexpected, as the integration of science and mathematics education may be easier within a self-contained classroom with one teacher (Steen, 1994) or within a middle school science classroom that traditionally applies or uses mathematics to develop science concepts. The historical comparison between the time periods of 1901-1989 versus 1990-2001 reveals a grade-level shift in integrated instructional documents. Middle school science continues to be highlighted in integrated instructional documents, but surprisingly, a greater emphasis upon secondary mathematics and science education is apparent in the integration literature published from 1990-2001.

3. Although there continues to be support for integrated science and mathematics education in the reform documents and several theoretical integration models have been posited in the literature published from 1990-2001, more empirical research grounded in these theoretical models is clearly needed as we enter the 21st century.

It is hoped that historical analysis will generate additional dialogue, development, and research in order to gain a better understanding of integrated science and mathematics teaching and learning. These efforts may lead to enriched classroom experiences, promote student engagement in learning, and improve student attitude toward and achievement in both science and mathematics.

References

American Association for the Advancement of Science. (1989). *Project 2061. Science for all Americans. Summary*. Washington, DC: Author.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

American Association for the Advancement of Science. (1998). *Blueprints for reform*. New York: Oxford University Press.

Berlin, D. F. (1991). *Integrating science and mathematics in teaching and learning. A bibliography* (School Science and Mathematics Association Topics for Teachers Series No. 6). Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

Berlin, D. F., & Lee, H. (2003). *A bibliography of integrated science and mathematics teaching and learning literature. Vol. 2: 1991-2001* (School Science and Mathematics Association Topics for Teachers

Series No. 7). Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

Berlin, D. F., & White, A. L. (1994). The Berlin - White Integrated Science and Mathematics model. *School Science and Mathematics, 94*(1), 2-4.

Berlin, D. F., & White, A. L. (1998). Integrated science and mathematics education: Evolution and implications of a theoretical model. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 499-512). Dordrecht, Netherlands: Kluwer Academic Publishers.

Deal, D. (1994). A look at project AIMS. *School Science and Mathematics, 94*(1), 11-14.

Hamm, M. (1992). Achieving science literacy through a curriculum connected with mathematics and technology. *School Science and Mathematics, 92*(1), 6-9.

International Technology Education Association. (1996). *Technology for all Americans: A rationale and structure for the study of technology*. Reston, VA: Author.

International Technology Education Association. (2000). *Standards for technological literacy: Content for the study of technology*. Reston, VA: Author.

Lee, H. (2000). Integrating science with other subjects. In D. L. Haury & W. S. McCann (Eds.), *Trends in science education research-1998: Taking the annual pulse of the science education research community* (pp. 138-140). Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: Author.

National Council of Teachers of Mathematics. (1991). *Professional standards for teaching mathematics*. Reston, VA: Author.

National Council of Teachers of Mathematics. (1995). *Assessment standards for school mathematics*. Reston, VA: Author.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author.

National Research Council. (1989). *Everybody counts. A report to the nation on the future of mathematics education*. Washington, DC: National Academy Press.

National Research Council. (1990). *Reshaping school mathematics. A philosophy and framework for curriculum*. Washington, DC: National Academy Press.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

National Science Teachers Association. (1992). *Scope, sequence and coordination of secondary school science. Vol. 1. The content core: A guide for curriculum developers*. Washington, DC: Author.

National Science Teachers Association. (1997). *NSTA pathways to the science standards: Guidelines for moving the vision into practice, Elementary school edition*. Arlington, VA: Author.

Pang, J., & Good, R. (2000). A review of the integration of science and mathematics: Implications for further research. *School Science and Mathematics, 100*(2), 73-81.

Rutherford, F. J., & Ahlgren, A. (1990). *Science for All Americans*. New York: Oxford University Press.

Sanders, M. (1994). Technological problem-solving activities as a means of instruction: The TSM integration program. *School Science and Mathematics, 94*(1), 36-43.

Steen, L. A. (1994). Integrating school science and mathematics: Fad or folly? In D. F. Berlin, *NSF/SSMA Wingspread Conference: A Network for Integrated Science and Mathematics Teaching and Learning. Conference plenary papers* (pp. 7-12). Columbus, OH: National Center for Science Teaching and Learning.

Whitmer, J. C. (1992). SSMILes: Thinking small: Milligrams, micrograms and counting atoms. *School Science and Mathematics, 92*(1), 40-44.

Editors' Note: Donna F. Berlin, School of Teaching and Learning, The Ohio State University; Hyonyong Lee, Department of Earth Science Education, Kyungpook National University.

Correspondence concerning this article should be addressed to Donna F. Berlin, The Ohio State University, School of Teaching and Learning, 333 Arps Hall, 1945 North High Street, Columbus, OH 43210.

Electronic mail may be sent via Internet to berlin.1@osu.edu