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ABSTRACT

Current reform in mathematics and science education advocates the integration of science and mathematics teaching and learning as a means of improving achievement and attitudes within both disciplines. This bibliography is a collaborative effort involving the ERIC Clearinghouse for Science, Mathematics, and Environmental Education; the National Center for Science Teaching and Learning; the National Science Foundation; and the School Science and Mathematics Association. It is prepared for classroom teachers, teacher educators, curriculum reformers and developers, and educational researchers interested in the integration of science and mathematics teaching and learning. The bibliography of 555 citations is divided into five sections. The "Curriculum Literature" section lists 84 citations dealing with what students are taught. The "Instruction Literature" section lists 251 citations related to how the students are taught. The "Research Literature" section includes 41 citations of research documents from both qualitative and quantitative perspectives of inquiry and reviews of research. The "Curriculum-Instruction" section of 166 citations is used to classify curriculum programs that include instructional activities. The "Curriculum-Evaluation" section of 13 citations is used to classify curriculum programs that include evaluation of curriculum programs. The introduction compares the different sections by number and content and discusses the nature and significance of that content. (MDH)

Science Mathematics

Integrating Science and Mathematics in Teaching and Learning

A Bibliography

Donna F. Berlin

National Center for Science Teaching and Learning
The Ohio State University
August 1991

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ERIC® Clearinghouse for Science, Mathematics and Environmental Education
The Ohio State University
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Preface

This bibliography represents a pioneering attempt to identify and categorize the substantive literature related to the integration of science and mathematics teaching and learning. It is a timely document intended for classroom teachers, teacher educators, curriculum specialists, and researchers who are interested in studying or promoting integration of science and mathematics in schools. It is also intended that this bibliography will be periodically updated as theory and practice related to integration evolve.

This document is the product of a collaborative effort involving the ERIC Clearinghouse for Science, Mathematics, and Environmental Education; the National Center for Science Teaching and Learning; the National Science Foundation; and the School Science and Mathematics Association. These agencies have joined in developing this bibliography to aid educators in the ongoing quest to promote increased understanding of the connections among science, mathematics, and technology in our everyday affairs. A fundamental idea of this quest is that the disciplines of science and mathematics share a common core, the search for understanding through inquiry.

Readers are invited to submit recommendations and comments regarding this bibliography to the ERIC Clearinghouse for Science, Mathematics, and Environmental Education (ERIC/CSMEE), Room 310, 1200 Chambers Road, Columbus, OH 43212. With your help this bibliography will serve as a vehicle to advance scholarship in the area of integrating science and mathematics teaching and learning.

David L. Haury, Director
ERIC/CSMEE

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Introduction

As one goal in the *America 2000* education strategy, U.S. President George Bush has proclaimed that, "U. S. students will be first in the world in science and mathematics achievement." (Bush, 1990, p. 9) Current literature related to reform in science and mathematics education endorses the integration of science and mathematics teaching and learning as a means of improving achievement and attitudes within both disciplines.

The significance and timeliness of this compilation of the literature related to integrated science and mathematics teaching and learning is established by the following excerpts from five recent education reform documents. These documents address the interrelated nature of science and mathematics along with implications for curricula and instructional practice.

Science for all Americans suggests a symbiotic relationship between science and mathematics:

> 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 data....Science and mathematics are both trying to discover general patterns and relationships, and in this sense they are part of the same endeavor. (Rutherford & Ahlgren, 1990, pp. 16-17)

In *Project 2061. Science for all Americans. Summary* (American Association for the Advancement of Science, 1989), this perspective is translated into curricula recommendations:

> The national council's recommendations include some topics that are not common in school curricula. Among those topics are the nature of the scientific enterprise, and how science, mathematics, and technology relate to one another and to the social system in general. (p. 5) The school curricula—from kindergarten through twelfth grade —[among other things]... must be changed...to weaken or eliminate rigid disciplinary boundaries, to pay more attention to the connections among science, mathematics, and technology... (p. 10)

A similar position is reflected in the mathematics education reform document, *Reshaping School Mathematics. A Philosophy and Framework for Curriculum* (National Research Council, 1990):

> Since mathematics is both the language of science and a science of patterns, the special links between mathematics and science are far more than just those between theory and applications. The methodology of mathematical inquiry

> shares with the scientific method a focus on exploration, investigation, conjecture, evidence, and reasoning. Firmer school ties between science and mathematics should especially help students' grasp of both fields. (pp. 44-45)

In *Everybody Counts. A Report to the Nation on the Future of Mathematics Education* (National Research Council, 1989), the curricular relationship between science and mathematics is discussed:

> Now much more than arithmetic and geometry, mathematics today is a diverse discipline that deals with data, measurements, and observations from science; with inference, deduction, and proof; and with mathematical models of natural phenomena, of human behavior, and of social systems. (p. 31)

Recommendations for instructional practice related to integrated science and mathematics teaching permeate the National Council of Teachers of Mathematics' *Curriculum and Evaluation Standards for School Mathematics* (1989). For grades K-4, 5-8, and 9-12 respectively, the standards recommend "instructional practices characterized by content integration" (p.20), "connecting mathematics to other subjects and to the world outside the classroom" (p.70), and "the use of real-world problems to motivate and apply theory" (p.126).

Philosophically and theoretically, there is strong support for the integration of science and mathematics teaching and learning as a way to improve and enrich the science and mathematics learning experiences. This bibliography 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.

This bibliography of integrated science and mathematics teaching and learning literature has been divided into five sections: Curriculum, Instruction, Research, Curriculum—Instruction, and Curriculum—Evaluation. A narrow definition of curriculum has been used. The curriculum relates to intended learnings 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". 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". While 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. The Research section of the bibliography includes research documents that generate new knowledge and understandings from both qualitative and quantitative perspectives of inquiry. The Research section also includes reviews of research. Two additional sections were used in order to classify curriculum programs that include instructional activities (Curriculum—Instruction section) and evaluation of curriculum programs (Curriculum—Evaluation section). It should be noted that while most of the citations can be distinctly placed in one of the bibliography sections, there are some that cannot, and these placement decisions were based upon the primary focus

of the document.

Although there are 555 citations in the bibliography, this listing is not intended to be exhaustive. The editor apologizes to any author whose work in this area has been inadvertently omitted, and communication as to any omissions would be appreciated. This bibliography is not intended as a final product, but will be periodically updated. Copies of the documents referenced in the bibliography are housed in the library of the National Center for Science Teaching and Learning at The Ohio State University, Columbus, Ohio.

The topic of integrated science and mathematics teaching and learning is not new. The earliest document referenced in the bibliography was published in 1905 in *School Science and Mathematics*. At the turn of the century, numerous articles appeared in this same journal published by the Central Association of Science and Mathematics Teachers (CASMT). 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. The National Science Foundation has funded various curriculum projects and sponsored two national level integration conferences: The Cambridge Conference on the Correlation of Science and Mathematics in the Schools (1967), and most recently The Wingspread Conference for A Network for Integrated Science and Mathematics Teaching and Learning (1991).

A cursory look at the bibliography reveals that there is a plethora of terms being used to refer to *integration* (e.g., 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.

A comparison of the separate sections of the bibliography indicates that the documents related to instruction permeate the literature. Specifically, there are 251 documents in the Instruction section as compared to 84 in the Curriculum section, 41 in the Research section, 166 in the Curriculum—Instruction section, and 13 in the Curriculum—Evaluation section. Science-related areas such as consumer education, energy education, engineering, environmental education, marine education, nutrition education, science career education, technical education, and vocational education naturally provide experiences and activities related to both science and mathematics. The integration of science and mathematics often develops from the nature of the topics rather than by thoughtful intent. Consequently, there are many instructional documents in the bibliography that are associated with these areas of science education.

The instruction literature was reviewed in terms of science concepts and processes, mathematics concepts and skills, and grade level distribution. Analysis of this literature reveals that most of the documents are basically science instructional activities or lessons which include mathematics-related concepts. 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. The mathematics concepts are sometimes, but not often, recognized or stated as objectives in the activities. These same science and mathematics concepts/processes/skills are most often suggested as appropriate content for integrated science and mathematics curricula and are more frequently associated with the physical sciences as compared to the life and earth sciences. (See the Curriculum section.) Most of the activities/lessons are designed for upper elementary and middle school grades (3 through 8). Surprisingly, there are about the same number of instructional documents related to the primary grades (kindergarten through 2) as compared to the secondary school grades (9 through 12). One would have hypothesized more instructional activities designed for the early grades as these classrooms are often characterized as self-contained, holistic, integrated learning environments. There are very few documents related to post-secondary instruction.

Some notable curriculum—instructional programs designed as total programs or as supplements to the established curricula appear in the literature. Some were developed in the 1970s, such as the Minnesota Mathematics and Science Teaching Project (MINNEMAST) and Unified Science and Mathematics for Elementary Schools (USMES). During the last five years, there has been a resurgence in the development of programs that integrate science and mathematics. Recent programs include Activities Integrating Math and Science (AIMS), Great Explorations in Math and Science (GEMS), the Jasper Series, Teaching Integrated Mathematics and Science (TIMS), The Voyage of the Mimi, and the Second Voyage of the Mimi. Inspection of the Curriculum—Evaluation section, reveals that there is a critical need for more attention to the assessment of the effects of these programs as related to student science and mathematics achievement and attitude.

The bibliography reveals a profound lack of research documents. Out of 555 citations, only 41 or 7% relate to research. Some of the research documents are only tangentially related to integrated science and mathematics teaching and learning. A number of research studies relate conservation and seriation skills, graphing ability, problem solving ability, proportional reasoning, and spatial ability to mathematics and/or science achievement. These studies relate specific abilities to both science and mathematics achievement and consequently infer a rationale for the integration of science and mathematics education. As previously noted, the terminology and definition of integration is not at all consistent within the literature which precludes reliable and valid comparisons among research studies. Furthermore, many of the research studies were designed only to examine the effect of integration on achievement or attitude in science or mathematics, but not the effect on achievement and attitude related to both disciplines. There is clearly a need for careful conceptualization and additional research on integrated science and mathematics teaching and learning.

It is hoped that this bibliography will generate additional thought and research in order to gain a better understanding of integrated science and mathematics teaching

and learning and possibilities for improving and enriching the teaching and learning of these two disciplines. Some areas for exploration include: the development of a hierarchical arrangement or continuum for the definitions of integration, the development of a theoretical and research-based rationale for integrated teaching and learning of science and mathematics, the specification of guidelines for infusion of integrated teaching and learning of science and mathematics into school practice, and the identification of high priority research questions related to integrated teaching and learning of science and mathematics. The expressed goals and objectives of the National Center for Science Teaching and Learning (NCSTL) Focus Area 5: Integration Across Content Areas reflect an effort to spearhead the exploration. NCSTL, funded by the Office of Educational Research and Improvement, has been instrumental in and supportive of The Wingspread Conference and the publication of this bibliography. Future projects include dissemination of the Instruction section of this bibliography as a computer database, publication of the Wingspread Conference Proceedings, Literature Synthesis Reports, an Integration Writers Conference, and the coordination of various integration research projects. As coordinator of the integration focus area, it is my intention to establish and promote a national, coordinated effort to explore the role of integrated science and mathematics teaching and learning related to today's science and mathematics education reform movements.

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Curriculum

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