MATHEMATICS APART:
Examining the History of Subject Isolation and Its Implications for Mathematics Education

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ABSTRACT

This article offers a historical examination of the roots and consequences of subject isolation. The article first discusses calls to make mathematics a more integrated part of students' overall learning. It then explores factors, which led over time to subject isolation and, in particular, the heavy separation of mathematics from other academic disciplines. Next the article discusses the negative consequences of this isolation. Finally, the article moves to a discussion of how using writing to teach mathematics can help overcome many of the problems caused by mathematics' subject isolation.

1 Introduction

"Like language, religion, and music, mathematics is a universal part of human culture" (Mathematics Sciences Education Board [MSEB], 1989, p. 33).

Mathematics has always been a central way of knowing the world. We can see symmetry in nature and the man-made world around us. The legal and business worlds use proof everyday as a way of life. An understanding of musical sound depends on knowledge of trigonometric functions and their graphical representations. People regularly use the concepts and theories of mathematics to solve all sorts of real life problems.

Unfortunately, however, for too many students, mathematics is just a school subject they dislike, struggle to understand, think of as disconnected from all their other courses, and hope to forget about in the future. In short, most students see mathematics as an isolated subject which has nothing to do with the rest of their world. This article offers a historical examination of the roots and consequences of subject isolation. The article first discusses calls to make mathematics a more integrated part of students' overall learning. It then explores factors which led over time to subject isolation and, in particular, the heavy separation of mathematics from other academic disciplines. Next the article discusses the negative consequences of this isolation. Finally, the article moves to a discussion of how using writing to teach mathematics can help overcome many of the problems caused by mathematics' subject isolation.

2 The Problem of Isolated Mathematics Learning

In his paper, "Understanding Reality Through Mathematical Modeling," The noted mathematics education researcher Thomas Romberg (1997) discusses the many applications mathematics has in every day life. According to Romberg, “in too many mathematics classes students are taught only the formal properties of the various mathematical domains, and the applications of mathematics derived via mathematical modeling are overlooked” (p. 2). Romberg analyzes modeling and explains how a simple model can lead to much more complex understanding:

> Although a mathematical model starts as a simple conceptual tool, it often becomes highly sophisticated as greater understanding of the problem situation is observed. [Therefore] it seems obvious that all students must have numerous experiences in school mathematics to explore problem situations as novice applied mathematicians. Only through such experiences will they come to mathematically understand both their everyday reality and the real rapidly changing world they are growing into (p. 7).

Romberg’s work encourages mathematics teachers to link their disciplines to other areas of study and to real life experiences.

Unfortunately the academic disciplines remain largely isolated from each other. In a recent statement on integrative learning, the Association of American Colleges and Universities in conjunction with the Carnegie Foundation for the Advancement of Teaching (2004) made this claim:

> Fostering students’ abilities to integrate learning—across courses, over time, and between campus and community life—is one of the most important goals and challenges of higher education. The undergraduate experience can be a fragmented landscape of general education courses, preparation for major, co-curricular activities, and ‘the real world’ beyond the campus. But an emphasis on integrative learning can help undergraduates put the pieces together and develop habits of mind that prepare them to make informed judgments in the conduct of personal, professional, and civic life.

A range of other scholars have also highlighted the need to make students’ learning and curricula more integrated (Bean, 1996; Fink, 2003; Huber & Hutchings, 2004; Wiggins & McTighe, 2005). Yet despite these on-going calls for integrated learning, subject isolation remains an entrenched part of the United States educational system. And mathematics, as a discipline, is perhaps the most cut off subject of all. In fact, the problem of connecting students’ mathematical knowledge to their other learning has become a major concern for the field of mathematics education:

> One of the four cornerstones of the NCTM [National Council to Teachers of Mathematics] Curriculum and Evaluation Standards for School Mathematics asserts that connecting mathematics to other mathematics, to other subjects of the curriculum, and to the everyday world is an important goal of school mathematics. Among recent reports calling for reform in mathematics education, there is widespread consensus that mathematics must be made accessible to all students, that it must be presented as a connected discipline rather than a set of discrete topics, and that it must be learned in meaningful contexts that connect mathematics to other subjects and to the interests and experiences of the students (House, 1995, p. vii).

While NCTM may call for promoting mathematics' connection to the rest of the school curriculum, the reality is that mathematics remains very disconnected from everything else students learn. Coxford (1995) mentions that the isolation of the field of mathematics has been a concern for professional mathematics organizations since 1923. This increasing concern by educators over the lack of integration among subjects in the curriculum continues to be discussed in the literature (Bean, 1996; Fink, 2003; Huber & Hutchings, 2004; Lehman, 1994; Wiggins & McTighe, 2005).

3 The Roots of Subject Isolation

The current United States public school system has been greatly shaped by the educational practices of the late nineteenth century. "By the time the structure of the American public high school had become crystallized around 1900, it had developed several distinctive characteristics that are familiar at the present time" (Holton, 1969, p. 127). One of the characteristics considered by Holton is departmentalization. Departmentalization "is the concept of specialization in subject matter" (Holton, p. 127). As schools grew larger through the years, the idea of specialization became very attractive: "Specialization seemed the logical approach to the staffing of a curriculum as broad as the one adopted. Furthermore, the pattern of the college had become established and specialization was becoming a part of the structure of the institution. The system of preparing teachers increased the trend" (Holton, p. 128).

These forces lead to the creation of a subject divided curriculum. Throughout United States public schools, learning became fragmented. According to Archambault (1964) the student:

> goes to school and various studies divide and fractionize the world for him. Geography selects, it abstracts and analyzes one set of facts, and from one particular point of view. Arithmetic is another division, grammar another department, and so on indefinitely. In school each of these subjects is classified (pp. 340-341).

This classification or specialization of subject areas is what I have labeled "subject isolation."

Today subject isolation is one of the main features of U. S. public schools. While each teacher may introduce his or her own material with some small consideration for what is going on in their own department, rarely do teachers consider their work in light of other departments in the school. Even though students are taught the material necessary to move on to the next course, it is only the next course in the sequence of the discipline area of which the particular teacher is a member. For example, an algebra teacher will prepare her students for the next course in the mathematics sequence, geometry, without much regard for the science, English, or art courses that students are also planning on taking. "In the traditional schemes of education, subject matter means so much material to be studied. Various branches of study represent so many independent branches, each having its principles of arrangement complete within itself" (Dewey, 1916, p. 135). All of the academic disciplines reflect this isolation of subject matter.

4 Why Did Mathematics Become So Isolated?

The problem of mathematics isolation should not come as a surprise. Most curricula are deliberately designed to isolate areas of study. The amount of information that exists in the world and the skills necessary to deal with this information both continue to grow at a rapid rate. To cope with this information explosion, school curricula are primarily designed to maximize the transfer of information to students. The problem, however, is that when knowledge is sorted into small, isolated subject containers, that knowledge quickly becomes little more than disconnected facts. The eminent educational philosopher John Dewey noted this problem as early as 1916:

> History is one such group of facts; algebra another, geography another, and so on till we have run through the entire curriculum. . . . This idea corresponds to the conventional practice in which the program of school work, for the day, month, and successive years, consists of "studies" all marked off from one to another, and each supposed to be complete by itself - for educational purposes at least (p. 134).

Current curricula are set up so that students "should have exposure to certain information and certain disciplines" (Mullin, 1991, p. 87).

In a paper entitled "Mathematics Education and Its Cultural Context in Early 19th Century Germany," Jahnke (1985) notes how mathematics, in particular, became an isolated field of study. He says that at one point mathematics instruction in 19th century Germany "served as a basis of a philosophically orientated general education and a means to develop students' ability of judgment" (p. 1). Unfortunately, says Jahnke, the "overall failure of mathematics education" (p. 32) caused the subject to loose much of its central role in this general education, particularly as mathematics education shifted from a focus on developing students' judgment to a focus on logical thinking. A further consequence of this shift in focus meant mathematics was no longer taught as a "coherent and unified organism . . . the development of mathematics had led to a state where different parts of the syllabus had different mathematical backgrounds. The subject area had disintegrated into a conglomerate of isolated techniques" (Jahnke, p. 32).

As education developed based around isolated fields of study, the role of the teacher also slowly changed. Over time, teachers ceased being masters of broad realms of learning and instead became specialists trained only in one small branch of knowledge. In his book *The Reflective Practitioner: How Professionals Think in Action*, Schon (1983) argues that this disciplinary focus has made teachers

> technical experts who impart privileged knowledge to students. These students are fed portions of knowledge, in measured doses. They are expected to digest it and to give evidence in class that they have done so. The curriculum is conceived as a menu of information and skills, each lesson plan is a serving, and the entire process is treated as a cumulative, progressive development (p. 329).

5 Negative Consequences of Mathematics Isolation

There are five main consequences to the isolation of mathematics which occurs in most schools. Probably the most serious consequence of subject isolation is *math anxiety*. Math anxiety is the clinical term for the fear of math. Sheila Tobias (1978) explains in her book, *Overcoming Math Anxiety*, that math anxiety begins in school mathematics classes where “emphasis has always been placed on getting the right answer and timed tests” (p. 38). What results from this emphasis is that students take mathematics solely because it is required in order to graduate and without ever seeing the value of mathematics study. Failure to understand mathematics concepts being discussed in the classroom leads to anxiety among students and frustration on the part of both teachers and students. In NCTM's 1990 yearbook entitled *The Teaching and Learning of Mathematics in the 1990's*, Raffaella Borasi explains that looking at mathematics as “isolated episodes” is one of the many reasons for mathematics anxiety. Borsai points out that “for the majority of students, a dualistic view of mathematics is likely to cause expectations and behaviors leading to anxiety and academic failure” (p. 177). According to Borsai, activities designed to overcome these problems should not remain “isolated episodes within a traditional mathematics curriculum. Rather, throughout the curriculum the students should experience aspects of mathematics and mathematical activity that are consistent with a nondualistic view of the discipline” (p. 180). This nondualistic view helps students understand mathematics as a whole area of knowledge rather than just thinking about mathematics as right or wrong answers to problems.

A *lack of opportunities to develop mathematical skills* is another major consequence of isolating mathematics study. Skills such as problem solving, decision making, and logical reasoning have long been the basis of most mathematics teaching. According to the *Curriculum and Evaluation Standards for School Mathematics*, learning these skills is necessary for our students to become “productive citizens” (NCTM, 1989, p. 1). However, even though these skills are important outside the mathematics curriculum, because of the isolation of mathematics, problem solving and other skills are usually not emphasized in non- mathematics classes. Students need guidance to see that the problem solving techniques they use in mathematics may also be applied for solving completely different problems in history. Students must also be taught that just as they reason out a proof in geometry class, they can also reason through ways of approaching a solid argument in literature class. Subject isolation interferes with such transfer of learning. According to Holton (1969):

> when the important formal instruction to a group of 16-year-olds is limited to subjects labeled World History, Algebra 1, Latin II, Biology, and English Grammar and Literature, many of the problems of life in modern times will be neglected. The student is more likely to be judged on his mastery of the subject matter than to be encouraged to develop those particular skills and concepts which help him to become a more effective person (p. 128).

Another result of the isolation of mathematics is that *few students ever make it to the higher levels of mathematics* in many schools. According to the Mathematics Science Education Board (1989), mathematics has become a filter in the educational system.

More students are lost from mathematics every year than from any other subject. This is because many students don’t see the need for advanced work in mathematics. Once the school requirement has been fulfilled, the majority of students cease studying mathematics. Some students are not even given a chance to take upper level mathematics classes: “Identified early as non-college material, these students are steered away from precollege mathematics and tracked into business or ‘general math.’ But algebra and geometry are not just precollege courses” (Tobias, p. 33-34). Consequently, there are many students who graduate without seeing the true value mathematics will play in their future. “Thus the study of mathematics is reserved for the privileged elite” (Romberg, 1992, p. 757).

Even students who do remain in mathematics often fail to see the usefulness of mathematics in other subjects they are studying. This is one reason why many students do not want to continue with mathematics courses. “Mathematics must become a pump rather than a filter in the pipeline of American education” (MSEB, 1983, p. 7). As I mentioned earlier, our society has become more dependent on the mathematical sciences and therefore the demand for mathematics in college has increased. However, despite the need for students to take mathematics all through high school, according to Steen, “many students who need further mathematics enter college weak in mathematics. This has diminished the quality of undergraduate mathematics. On a national scale undergraduate mathematics has been reduced from higher education to high school education” (1990, p. 133).

Mathematics isolation leads to *limited access to colleges and the workforce* for many students. Students are not well prepared for college mathematics and often fail to understand new mathematical concepts that are introduced at the college level. In fact “60 percent of college mathematics enrollments are in courses originally taught at the secondary level” (MSEB, 1983, p. 13). This underpreparation in mathematics also spills into the economy where graduates end up needing remedial mathematics courses. Industries may spend large amounts of time and money teaching their employees mathematics that is normally taught in high schools. According to Tobias (1978), there is a connection between mathematics and the job market:

> Mastery of high school algebra alone will make the difference between a low score and a high score on most standardized entry-level tests for the civil service, federal service, industry, and armed services. It has been estimated that starting salaries go up $2,000 per year for every mathematics course taken after the ninth grade (p. 34).

Also particularly troubling is the unequal racial makeup of the people likely to study in mathematics. As Steen (1990) reports, mathematics has long been dominated by white males of European descent. Only four percent of the bachelor's degrees in mathematics and fewer than two percent of the doctoral degrees go to U.S. blacks or Hispanics. This is very troubling given population trends that show large growth in the U. S. Hispanic population. Mathematics is too important a subject to have it not reach the most diverse student population.

Yet another problem for society caused by isolated mathematics study is that the number of *American students in graduate mathematics classes* has continued to decline in recent years. This affects the development of mathematical knowledge as well as mathematics education in the United States: "Fewer than half of the Ph.D. degrees in mathematics awarded by U.S. graduate schools now go to U.S. citizens" (Steen, 1990, p. 133). Many of these students return to their home countries, taking their knowledge of mathematics with them. According to Steen, this decline in the number of American mathematics graduate students is due to the low average level of undergraduate mathematics instruction. Graduate students are also often placed as teachers in undergraduate mathematics classes. If these graduates are international students, the issues of language, tradition, and background may impede student learning of mathematics (MSEB, 1989, p. 28). What is needed here is “an infusion of new Ph.D's that will reinvigorate the source of mathematics teachers: undergraduate mathematics” (Steen, 1990, p. 133).

According to Kline (1973), by teaching mathematics as isolated units, teachers are neglecting “to teach students useful knowledge, knowledge that can be applied to other fields. Since the ideas of elementary mathematics arose from physical and practical problems, these very problems can be used to motivate the study of mathematics. To isolate mathematics is to rob it of meaning. Mathematics becomes pointless and unattractive” (p. 79-80). Overall we can see that isolating the study of mathematics has a highly problematic effect on our students’ lives and has widespread implications for the future of our society.

In his book *Democracy and Education*, Dewey (1916) emphasizes that school curricula exist as “communication, which insures participation in a common understanding” (p. 4). Teachers from all classes need to be “cognizant of the common end and all have an interest in it. It is then they would form a community” (p. 5). If the school environment were turned into such a community, students might be able to see the greater value of what they are learning. To achieve this we need more integration of the curriculum. As the scholar Mike Rose travelled around the country visiting classrooms, he observed what is happening to “reading, writing, and arithmetic - these ‘basics.’ We don't see them any longer as life skills. They're ‘subjects’ to be taken, subjects outside our experience” (1995, p. 223). What is needed is a school curriculum or setting for “providing specialized and high-level instruction, yet avoiding the situation in which students can never feel more than a cog in the educational machine” (Holton, p. 129).

6 Using Writing to Reintegrate Mathematics Learning

As discussed earlier, for most of its history, the academic disciplines have remained largely isolated from each other in United States education. However, during the 1970s and 1980s, some progress was made toward breaking through these disciplinary boundaries when a movement called Writing Across the Curriculum (WAC) began to gain momentum at many United States universities. WAC, or WID (Writing in the Disciplines) as it is sometimes referred to, was built on the central beliefs that writing is a powerful pedagogical tool for developing student thinking and that this tool can be an effective teaching tool in any discipline.

Bringing writing more firmly into the mathematics classroom is the focus of this article, and the basis for this idea is grounded in the WAC movement's views about writing as a thinking tool. Langer and Applebee's *How Writing Shapes Thinking* (1987) is a seminal study on the pedagogical practice of using writing as a teaching tool. According to Langer and Applebee, writing allows students to think and reflect in a focused way on the content about which they are writing. Langer and Applebee argue that when students are asked to write about a particular concept, they gain a greater understanding of that concept because writing requires active thinking: "Thinking skills are taught best when related to some content, the argument goes, and writing provides a particularly welcome context for thinking deeply about such content" (Langer and Applebee, p. 1). Langer and Applebee also argue that writing can be an invaluable means for evaluating student understanding: Writing "can be used to diagnose students' needs and it can reflect students' ability to apply what they know" (p. 57).

Writing in the same era, Tchudi (1986) also discussed the perceived importance of writing as a teaching tool: "The claim in the 1980s is not simply that content teachers ought to include writing in their disciplines in order to teach writing, but that they should use it as a means to improve education" (p. 16). Tchudi argued that to build a strong curriculum, every content teacher should make use of writing. To some extent these recommendations have found a place in many of today's content classes: in mathematics and science, for example, students are often now asked to answer open-ended questions that involve generating detailed written explanations of a student's thought processes involved in reaching a problem's solution.

In the early stages of the WAC movement, WAC proponents argued that teachers in all disciplines should make writing a central part of their pedagogical practices. WAC usually gained ground on campuses through a series of professional development workshops in which faculty members from across the disciplines were taught basic principles for using writing in their courses. One lasting element of the WAC movement was the development of writing centers at many universities in the United States. In *Writing Centers and Writing Across the Curriculum: Building Interdisciplinary Partnerships* Barnett and Blummer (1999) have put together a collection that describes the collaboration that has taken place and continues to take place between writing centers and WAC programs in colleges and high schools across the country.

According to Stock (2001), WAC was built around the principle of language and learning: "It was meant to remind all teachers at all levels of instruction that language—written and spoken—is the most readily accessible and powerful means of learning" (p. 97). In other words, allowing students to write their own thoughts and feelings about material they are studying in any classroom can lead to students achieving a better understanding of that material. Britton, Burgess, Martin, McLoed, and Rosen (1975) describe this use of writing for learning as exploratory writing where students are asked to compose thoughts and ideas about new subjects. Knoblauch and Brannon (as cited in Stock, 2001) also discuss this idea, stating that this exploratory writing allows teachers to engage students in learning through their own language. Herrington (1981) also emphasizes that "the 'writing-to-learn' approach implies that students do have something to say and that the process of writing provides at once the way for them to discover and communicate it" (p. 379). Overall, WAC argued that using writing would help students become more effective learners of all subjects.

Today, the basic principle of WAC—using writing as a learning tool, has taken hold in many disciplines. According to Friedman (2001), teachers of content areas such as science and mathematics generally acknowledge students' need to write in order to demonstrate the students' understandings of the material being studied. Friedman also notes that many science and mathematics teachers prepare students to write responses to open-ended questions that are asked on state standardized tests. Many major universities have programs to help faculty with writing across the curriculum. There is also currently a biannual international conference on Writing Across the Curriculum that has drawn participants from as many as 16 countries and has been in place for sixteen years. Finally, *The WAC Journal* is published annually as a collection of articles by educators on their WAC ideas and experiences. "It is a journal of practical ideas and pertinent theory" (retrieved from http://wac.colostate.edu/journal/ May 28, 2007).

7 Developing Mathematics Communication Skills

In the National Council of Teachers of Mathematics (NCTM) *Curriculum and Evaluation Standards for School Mathematics* (1989) and *Principles and Standards for School Mathematics* (2000) communication is addressed as a standard for each of the four benchmark years (Grades Pre-K-2; Grades 3-5; Grades 6-8; and Grades 9-12):

> Communication is an essential part of mathematics and mathematics education. It is a way of sharing ideas and clarifying understanding. Through communication, ideas become objects of reflection, refinement, discussion, and amendment. The communication process also helps build meaning and permanence for ideas and makes them public. (NCTM, 2000, p. 60)

Since writing is a primary tool for communication, one way to achieve NCTM's goal of teaching students effective communication skills is to bring writing into the mathematics classroom.

Baxter, Woodward, and Olson (2005) discuss one approach for teaching students mathematical communication skills through writing. They argue that in order to develop mathematical proficiency, students need to learn to communicate their mathematical thinking: "Students develop a more coherent and robust understanding of mathematical ideas by expressing their thinking in writing, even if that writing is less precise than formal mathematical expressions" (p. 132). In other words, as long as students are given the opportunity to write in mathematics classes, even informally, this writing allows for student reflection and clarification of concepts. This in turn should lead to students developing a better overall understanding of mathematics.

Communication, according to Clarke, Waywood, and Stephens (1993), is the core of all classroom experiences that stimulate learning: "Mathematical meaning requires a language for its internalization within the learner's cognitive framework and for its articulation in the learner's interactions with others" (p. 235). In order to truly understand mathematics, students need not only the ability to internalize mathematical concepts but also an ability to share that understanding with others. Clarke, Waywood, and Stephens go on to say that when students write about their thinking, this activity can be both challenging and empowering.

8 Improving Mathematics Learning and Understanding

In order to really see if a student understands a concept in mathematics, the teacher needs to look beyond the right or wrong answer. In a numeric solution to a problem, a teacher can see whether or not a student solved a problem correctly, but not whether the student understands why a problem is to be solved that way or how the formula relates to an actual real-world relationship. Thus writing can offer a tool for unpacking students' thinking about and understanding of the mathematics concepts they are being taught.

According to Shield and Galbraith (1998), writing can indeed improve students' learning and understanding of mathematics: "Writing is thought to promote a personalized and constructive approach to learning" (p. 30). Shield and Galbraith reported on a study they conducted that investigates mathematical understanding of the students as reflected in their writing. Shield and Galbraith found that an analysis of the writing provided "indications of the ways students' writing may be developed in order to stimulate a deeper understanding" (p. 44). The writing tasks used in their study were categorized as journal writing (expressing feelings and thoughts about the mathematics students are learning) and expository writing (describing and explaining what the students are learning). Expository writing is the form of writing that is currently required in the open-ended writing tasks of many states' standardized tests (Pennsylvania School System Assessment, 2007). However, it should be noted that the writing that occurs in a mathematics classroom is often constrained by the style of writing that is presented to the students in their textbooks. Therefore, students often tend to use the same style of expository writing they see presented to them.

Kenyon (1989) also discusses the benefits of writing as a way to improve mathematical learning and understanding. Kenyon's work connects writing to problem solving in mathematics: "Problem solving involves application of learned knowledge and skills in order to move through a process of resolving a situation" (p. 76). When students are asked to write thoughts and procedures, Kenyon notes, this adds another dimension to the learning process, that of being able to see a possible solution for a problem.

Noted composition scholar Peter Elbow (2004) also lends support to the idea that writing can improve students' understanding of new ideas. He claims that writing can be used "to help students comprehend and clarify concepts" (p. 13). Overall, then, it seems clear that writing in mathematics classes can provide students with a powerful thinking tool not available to students who are only asked to work with numbers and formulas.

9 Conclusion

Perhaps the greatest danger of subject isolation is that over time we have come to see it as natural and, perhaps, inevitable. Yet mathematics does not have to be cut off from the rest of the world. Indeed, there are many potential benefits to be gained from linking mathematics to other subjects, particularly to English and writing. By tracing the historical roots of subject isolation, this article hopes to show that currently fractured curricula could be redesigned in ways that promote more integration. Bringing writing into the mathematics classroom is just one small step toward that larger goal of creating a more integrated and meaningful learning experience for students.

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