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The Mathematics and Science Integration Argument: A Stand for Teacher Education

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This paper explores the question, should we integrate mathematics and science in reforming science education? As science, especially physical science involves mathematics, and both subjects involve process skills, integrating science and mathematics methods courses might be a way to improve science education. Considerations and recommendations for mathematics and science integration are addressed.

Keywords: Mathematics, Science, Integration, Teacher Preparation, Policy, Interdisciplinary, Standards, Technology

INTRODUCTION

The quality of education that teachers provide to student is highly dependent upon what teachers do in the classroom. Thus, in preparing the students of today to become successful individuals of tomorrow, science and mathematics teachers need to ensure that their teaching is effective. Teachers should have the knowledge of how students learn science and mathematics and how best to teach. Changing the way we teach and what we teach in science and mathematics is a continuing professional concern. Efforts should be taken now to direct the presentation of science and mathematics lessons away from the traditional methods to a more student centered approach.

In an era dominated by mathematics, science, and technology, it is essential that science and mathematics be taught in K-12 and that classroom teachers are equipped with the knowledge and skills to teach both science and mathematics meaningfully to students. However, in a test driven curriculum where students and teachers are evaluated on student performance based on reading and mathematics standardized test scores, teaching meaningful science remains a challenge.

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A young person's ability and confidence to do mathematics and science is critical for their future success in our high-tech globally competitive age. In this context, this paper will explore integrating science with, not at the expense of mathematics in reforming science education.

According to the Report of the 2000 National Survey of Science and Mathematics (Weiss, Banilower, McMahon, and Smith, 2001), the condition of science and mathematics in pre-college education follows. At K-4, mathematics (95%) is taught more frequently than science (69%). About 67% of K-4, 42% 5-8 and 37% 9-12 teachers are "not at all familiar" with the National Science Education Standards, where as in mathematics about 38%, 27% and 15% of teachers in respective grade levels are not familiar with the National Council of Teachers of Mathematics Standards.

While 1% of mathematics teachers at the elementary level do not feel well qualified to teach mathematics, 21% physical science, 11% earth science and 10% life science teachers feel the same. At K-4, 20% of science teachers and twice as many mathematics teachers perceive themselves as "master" teachers. This gap is smaller at grades 5-8 (39% science, 57% mathematics) and at 9-12 (64% science, 69% mathematics). On the other hand, 77% K-4, 78% 5-8 and 89% 9-12 science teachers consider well qualified to make connections between science and other disciplines. Mathematics teachers considering the same about integration of content include 83% K-4, 78% 5-8 and 68% 9-12. Interestingly, a far lesser number of teachers, that is

20% K-4, 27% 5-8, and 19% 9-12 in science classes, and 23% K-4, 17% 5-8, and 12% 9-12 in mathematics classes reported that they help students see connections between science and other disciplines on a daily basis. How to successfully integrate science and mathematics remains a critical question.

Integration

Research indicates that using an interdisciplinary or integrated curriculum provides opportunities for more relevant, less fragmented, and more stimulating experiences for learners (Frykholm & Glasson, 2005; Koirala & Bowman, 2003;Jacobs, 1989). Interdisciplinary teaching depends on the way students best acquire knowledge, the important role of not only reaching students during their developmental stage but influencing the teaching of subjects, and (c) the cooperative involvement of both students and teachers planning and learning together to modify the instruction of the end product-the students (Jacobs, 1989; Antonellis & James, 1973). More and more educators are coming to realize that one of the fundamental problems in schools today is the "separate subject" or "layer cake" approach to knowledge and skills. Often students cannot solve problems because they do not understand the context in which the problems are embedded (Frykholm & Glasson, 2005). The separate subject curriculum can be viewed as a jigsaw puzzle without any picture. If done properly, integration of math and science could bring together overlapping concepts and principles in a meaningful way and enrich the learning context. Learning situated in such enriched (macro) contexts often lead to meaningful learning experiences. Carefully designed interactive videos are suitable for creating real-life contexts for problem-based learning in mathematics integrated with science (Kumar and Sherwood, 1997).

Integrating mathematics and science in the schools has become a central issue by such organizations as School Science and Mathematics Association (SSMA), the National Council of Teachers of Mathematics (NCTM), the American Association for the Advancement of Science (AAAS), and the National Research Council (NRC). These organizations strongly support the integration of math and science, which is reflected in the recommended national standards documents, such as *National Science Education Standards* (NRC, 1996) and the NCTM *Standards* (1989 & 2000). NCTM (2000) makes "Connections" one of its process standards and advocates the use of integrating subjects like mathematics and science. Berlin & Kyungpook (2005) state how more integration is now taking place in teacher education programs in mathematics and science methods courses, making these connections results in implementing this approach at the middle and secondary levels when in the classroom. Koirala & Bowman (2003) found in a three year study of preservice middle school integrated math and science methods course that preservice teachers appreciated the emphasis on integration used in the course, but at the same time when concepts did not integrate easily thy were frustrated and despite the frustration, it was found that the preservice teachers' understanding of integration was enhanced as a result of the integrated course. Pyke & Lynch (2005) found in a study of mathematics and science teachers' doing preparation for the National Board for Professional Teaching Standards (NBPTS) certification enrolled in an integrated prep course clearly indicated that a collaborative approach produced higher scores and higher passing rates for most respondents. The data from the study indicated that the collaborative preparation is highly valued for motivational and instrumental support. In a study by Utley, Moseley, & Bryant (2005) a relationship between science and mathematics teaching efficacy of preservice elementary teachers was found. Data revealed that as science and mathematics teacher education in a methods course progressed, science and math teaching efficacy significantly increased. So, where should the implementation cycle begin? Hence, research indicates that methods courses profoundly impact how a teacher will teach (Haigh, 1985); therefore, it is essential to introduce preservice teachers to a contextual way of understanding the curriculum when learning how to teach mathematics and science (Frykholm & Glasson, 2005).

Beane (1992) suggests moving away from the straight subject area approach to involve the identification of a central theme and to ask what each subject area can contribute to it. Also, the involvement of students in an integrated science and math unit lends itself to motivating students (Friend, 1985; Wolfe, 1990) and increases student achievement in both disciplines (McBride & Silverman, 1991). This idea relates directly to the constructivist approach of hands-on minds-on learning. Recent technological advances in user-friendly software, such as SimCity, and ArcView--Geographic Information Systems (GIS) are two excellent programs, which connect math, science and social science concepts (Furner & Ramirez, 1999). There are a number of resources for teachers that provide curricula and activities to integrate math and science. Berlin and White (1992) provide a CD-ROM database of integrated science and math curriculum materials and lessons. Great Explorations in Math and Science (GEMS) is a series of activity books for students in grades pre-school through high school integrating math with life, earth, and physical sciences. Activities in Math and Science (AIMS) is another well know resource of activities for grades K-9 with specific themes. Also, the use of Internet Field Trips/Webquests where the educators

can connect the math, science and technology is critical in this day and age at all school levels (Furner, Doan-Holbein, & Scullion-Jackson, 2000). Although the research and resources are available to support the integration of math and science, in many classrooms neither of them is actively used. This could be based on the fact that teachers do not know how.

Considerations and Recommendations

In defining how to integrate math and science, White and Berlin (1992), and Sunal and Furner (1995) made the following recommendations.

- •Base integration on how students experience, organize, and think about science and math.
- •Take advantage of patterns as children from the day they are born are looking at patterns and trying to make sense of the world.
- •Collect and use data in problem-based integrated activities that invoke process skills.
- •Integrate where there is an overlapping content in math and science.
- •Be sensitive to what students believe and feel about math and science, their involvement and the confidence in their ability to do science and math.
- •Use instructional strategies that would bridge the gap between students' classroom experiences and real-life experiences outside the classroom.

The integration of math and science encompasses a number of considerations, for example, teaching math entirely as a part of science, math as a language and tool for teaching science, or teaching science entirely as a part of math. Also, teachers' confidence level in teaching math and science needs to be addressed. In some instances, a math teacher may not feel prepared to teach science or vice versa. Also science teachers may not feel confident teaching all science disciplines. Beane (1995) defines curriculum integration as a way of thinking about the purpose of schools, the sources of curriculum, and the basis of knowledge. Beane believes in order to define curriculum integration; there must be a reference to knowledge.

According to Jacobs (1989) and the Association for Supervision and Curriculum Development (1989), planning and teaching interdisciplinary lessons involve two or more teachers, common planning time, the same students, teachers skilled in professional collaboration, consensus building, and curriculum development. As Robinson (1994) pointed out, the following considerations are necessary for the preparation of interdisciplinary instruction.

- •An understanding of the nature of subject field and the need for teachers, for example, single subject field/single teacher; single subject field/multiple teachers; multiple subject fields/single teacher; or multiple subject fields/multiple teachers.
- •A deeper knowledge of methods of interdisciplinary subject matter correlation (unified subject field, theme, topic, problem-based, etc.)
- •Strategies for motivating students to use process skills, such as reading, writing, reporting, research, problem solving, mathematical application, data collection, data analysis, an drawing conclusions.

The following set of conditions is essential for interdisciplinary instruction (Robinson, 1994).

- •The lesson or unit should complement or support some aspect of instruction in the subject area.
- •The lesson or unit should complement or support the content and/or learning skills in at least one other subject field.
- •The lesson or unit should be constructed in a manner that encourages students to integrate and use the new knowledge and skills from several areas of competence.

Zemelman, Daniels, and Hyde (2005), have arrived at the following research-based list of "best practices" for teaching math and science: (a) use manipulatives/hands-on (make learning concrete and active); (b) use cooperative group work; (c) use discussion and inquiry; (d) use questioning and making conjectures; (e) use justification of thinking; (f) use writing for thinking, feelings, and problem solving; (g) use problem-solving approach to instruction, making content integration a part of instruction; (h) use technologies such as calculators and personal computers; (i) promote the role of the teacher to that of a facilitator of learning; and (j) use assessment as a part of instruction. As noted above, problem solving is an area where frequently math and science are integrated, and problem-based learning might be a successful instructional strategy for integration.

Problem-based learning invoking process skills instead of rote learning must become a classroom norm in integrated science and mathematics. Teachers should be able to incorporate more problem solving/inquiry approaches to instruction as well as assessment rubrics that take into account processes. NCTM (2000, 1995, & 1989) and NRC (1996) suggest that the methods and tasks for assessing students' learning should be aligned with the curriculum's goals, math and science content, instructional approaches, and hands-on activities including manipulatives. Also, appropriate assessment must be practiced based on the type of information sought, how the information will be used, and the developmental level and maturity of each student. Teachers need to employ alternative forms of assessment such as observations, interviews, performance tasks, self-assessments of students, portfolios, and standardized tests. Students must be

given multiple opportunities to demonstrate their understanding of mathematics and science aligning assessment with curriculum and instruction. Teachers benefit children most when they encourage them to share their thinking process and justify their answers out loud as they engage on problem-based learning.

End Note

There is optimism for improving science teaching through integration with mathematics. Yes, we should integrate mathematics and science wherever it is possible in the curriculum. Problem-based learning is an area where successful integration of mathematics and science could be achieved. The critical role of mathematics in understanding the relationships between scientific concepts especially in the physical sciences cannot be underestimated. In this context, student success depends on the degree to which math and science are integrated in order to motivate and engage students in meaningful learning. In today's high-tech world, it is important that our young people grow to become confident in their ability to do mathematics and science in an ever-increasingly high-tech globally competitive society.

Educators who help students develop their confidence and ability in mathematics and science would have a positive impact on students' lives in the long term. Our students' careers, and ultimately most of their decisions in life, could rest upon how we decide to teach mathematics and the sciences. It really is our obligation as an educational community to make the difference for the future of our students in an ever-growing competitive global environment, which depends so heavily on mathematics, technology, and the sciences. If schools do more in terms of integrating mathematics and the sciences they may impact the lives of their students forever. In the near future, when asking our students how they feel about math and science, we will hope they will say things like: "I love math" or "Science was my favorite subject" or " I am a good problem solver" or " I got first place at the county-wide science fair" or "Mathematics is the tool I use as a scientist."

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