Integrating Curriculum in Mathematics and Science: A Global Perspective

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In this article integrating math and science curricula is promoted as well as examining how the role of professional learning communities (PLCs) can assist in this endeavor. This strategy will lead to numerous benefits such as closing the minority achievement gap and advancing the United States' rank in global measures. Although barriers exist to this implementation, the authors believe these can be overcome. The importance of "teacher buy-in" is examined as well as strategies for allowing teacher preparation time.

Introduction

Carl Frederick Gauss, a German Mathematician, astronomer, and physicist said, “Mathematics is the queen of sciences.” Integrating science and mathematics is a natural fit as a means for improving student achievement, but how do we go about making this happen? Educational leaders, department chairpersons, team leaders, and instructional specialists should be working together to support faculty in their endeavors to collaborate about best practices for teaching mathematics and science and where possible, integrate these key subjects.

For the purposes of this article our working definition for integration comes from Wiles and Bondi (2007) who define integration of disciplines as “The organization of objectives under a disciplinary topic that allows students to use skills and knowledge from more than one content area within a given instructional activity or unit of study” (p. 349).

Conceptual Framework

The conceptual framework presented is intended to initiate conversation regarding the benefits of integration of mathematics and science instruction as well as focus on collaboration of educators who teach these disciplines. This conceptual framework recognizes that integration of mathematics and science as well as collaboration is relevant and should be used by educators to facilitate improvement in their teaching abilities in the classroom which ultimately leads to students' successes in the classroom. Focusing on a conceptual framework that recognizes that integration and collaboration are important is relevant to educators in order to provide a powerful lens to observe, identify and analyze aspects of collaboration and integration which will improve classroom practices.

Educator collaboration forms partnerships which in turn benefit students' achievement. Collaborative partnerships are strongly encouraged in an effort to improve instruction for science, technology, engineering, and mathematics students at all levels (Schneider & Pickett, 2006). Research has shown that collaboration among different disciplines enhances learning and creates a higher quality of curriculum development and research (Clark, Moss, Goering, Herter, Leonard, Robbins, 1996; Eisenhart & Borko, 1991; Krajcik, Blumenfeld, Marx, Soloway, & Fishman, 2000).

The National Research Council (2012) aligned the K-12 science, mathematics, technology and engineering standards in education to focus on the integration. According to the National Research Council (2012) the conceptual framework presented in the report was designed to articulate the committee's vision. The vision of the committee was to educate students using a global perspective while incorporating 21st century learning. It is necessary to provide courses for mathematics and science teachers through which they can learn subject knowledge in Science, Technology, Engineering, and Mathematics (STEM) contexts, as well as have the opportunity to explore the connections within the disciplines (Norman, Moore, Kern, 2009).

Performance of United States Minority Students

White students in the United States have been outperforming minorities in the areas of mathematics and science for decades. In nearly all of the nation's states there is a 30 to 50 percentage-point difference between White students and the largest minority group in the percentage of students scoring at the basic level on the eighth-grade National Assessment of Educational Progress (NAEP) exam (Blank & Langesen, 1999). High –poverty students enter kindergarten with the most basic mathematical knowledge at hand; they can count and recognize basic shapes (West, Denton, & Reaney, 2000).

There is not a perfect solution that may be used to eradicate the achievement gap but the integration of mathematics and science as well as active engagement with minority students in the classrooms is a start. Measures should be taken to ensure underrepresented minorities and special needs students have improved opportunities and greater encouragement to participate fully in mathematics and science education (Clark, 1999). Research has shown that a number of positive effects happen when minorities are enrolled in STEM fields. One positive effect includes increased retention of students from underrepresented groups in STEM fields.

Global Student Comparison in Mathematics and Science

The Organization for Economic Co-operation and Development (OECD) conducts surveys every 3 years measuring student performance in international education systems. The Program for International Student Assessment (PISA) is the assessment system that the OECD coordinates when conducting international surveys. A survey in 2012 was given, evaluating the world's 15-year-olds knowledge and skills in mathematics, science, and reading (Kelly, Xie, Nord, Jenkins, Chan, & Kastberg, 2013). The survey assessed the knowledge of students from 65 countries and economies 34 of which are members of the development organization OECD; this organization includes the United States (Chew, 2012). Figures 1 and 2 below shows the top 5 countries and Finland's average scores in mathematics and science literacy.

Figure 1: PISA 2012 - Mathematics Literacy Average Scores

Education System	Average Score	Ranking
OECD average	494	
Shanghai-China	613	1
Singapore	573	2
Hong Kong-China	561	3
Chinese Taipei	560	4
Korea, Republic of	554	5
Finland	519	12
United States · **Massachusetts (514)** · **Connecticut (506)** · **Florida (467)**	**481**	**36**

Figure 2: PISA 2012 - Science Literacy Average Scores

Education System	Average Score	Ranking
OECD average	501	
Shanghai-China	580	1
Hong Kong-China	555	2
Singapore	551	3
Japan	547	4
Finland	545	5
United States · **Massachusetts (527)** · **Connecticut (521)** · **Florida (485)**	**497**	**28**

The data is indicating that the United States is substantially behind other countries in mathematics and science. The OECD average score for mathematics literacy was 494 and the average score for science literacy was 501. The United States even fell below both the mathematics and science averages. The students from Asian countries outperformed all other countries as they hold the top 4 positions. The teachers in many of the Asian countries spend a large amount of time working together collaboratively to prepare the most engaging lessons for their students. Students from Finland scored above average on these surveys. According to Chew (2012), Finland's National Core Curriculum is premised on the idea "that learning is a result of a student's active and focused actions aimed to process and interpret received information in interaction with other students, teachers and the environment and on the basis of his or her existing knowledge structures" (p.1).

The integration of science, technology, engineering and mathematics (STEM) education is argued to be beneficial to the global economy, teachers and education institutions have been working to provide the best package of integrated education

(David & Sharon, 2006). Research has shown that collaboration and integration have proven to be beneficial in education. With the United States lagging behind other countries in mathematics and science this leaves educators working to find solutions to become more globally competitive. One such solution is working together collaboratively in professional learning communities to improve mathematics and science curriculum through integration.

Benefits of Mathematics and Science Integration

Traditionally, the school principal makes most of the curricular decisions while the classroom teacher is expected to carry out the decisions. Cultivating teachers to become leaders and assist with curricular decisions will enhance the academic program. Many teachers have a desire to collaborate and integrate science and mathematics instruction but lack the authority to implement an integrated curriculum. The support for an integrated curriculum is backed by many professional organizations such as the National Council of Teachers of Mathematics (NCTM), the National Science Teachers Association (NSTA), National Council for the Social Studies (NCSS), the National Research Council (NRC), the National Association for Core Curriculum (NACC), and the National Middle School Association (NMSA).

There has been a long history of literature review to support the idea of curriculum integration (Berlin & White, 1992; Brooks & Brooks, 1993; Cohen, 1995; Beane, 1996; Kim, Andrews, & Carr, 2004; McDonald & Fisher, 2006; Ward, 2009). The plethora of literature is qualitative in nature and supports the idea of integration as a means for improving critical thinking skills, practical applications, cognitive development, and student attitudes in science and mathematics. Ward (2009) states, “Gaining equal momentum is the movement by preK-8 teachers to integrate their teaching across content areas with the goal of building connections between and among the various subject matters taught in school" (p. 3). In recent years, many university researchers have concentrated on the benefits of an integrated curriculum. Goldin (2003), Seymour and Hewitt (2000); Singh, Granvile, and Dika (2002), discovered the subjects of science, technology, engineering and mathematics are closely related to each other and when integrated provides meaningful learning through integrating knowledge and concepts and skills.

While there is much qualitative research there is a shortage of current quantitative data linking integration with student achievement. However, Stevenson and Carr (1993) reported increased student interests and achievement in integrated instruction. Vars (1991) found that interdisciplinary programs produced higher standardized achievement scores. Quantitative studies to explore the relationship between integrated science and mathematics programs and student achievement are needed.

Barriers of Mathematics and Science Integration

Science and mathematics integration has become a focus for many educators. The question then becomes, what are the barriers preventing teachers from integrating? And how can the barriers be lessened?

There are many challenges that prevent science and mathematics teachers from integrating. While many educators desire to integrate there are challenges preventing successful implementation; such as "territorial" concerns, aligning state standards, and time for planning and implementing. School leaders should examine these challenges preventing teachers from integrating and discover how they can remove these barriers.

The three key barriers for science and mathematics integration include “territorial “concerns, aligning state standards, and time for planning and implementing.

The barriers are defined as follows:

- “Territorial” Concerns
    - The science teacher believes the mathematics teacher should be responsible for integrating, whereas; the mathematics teacher believes the science teacher should be responsible for integrating.
- Aligning state standards
    - Recognize science and mathematics state standards are a natural fit and can easily be aligned.
- Time for Planning and Implementing
    - There are not enough days to bring in another subject into my curriculum. Teachers feel they do not have enough time to teach their own curriculum much less teach state standards from another curriculum.
    - When do I have time to work with another teacher on integrating science and mathematics?

Solutions

By educating faculty on the benefits of integrating not only will territorial concerns be alleviated but teachers will “buy into” the need for collaboration and integration. Teachers should be empowered to make the decision to collaborate and integrate with another content expert and not be made to feel as if this is a “top-down” mandate.

According to Jacobsen (2014) “It is time for top-down approaches to schooling to give way to the active, engaged, and collaborative teaching and learning relationships made possible by new educational technologies” (p. 1). As leaders we must dispel the myth that the science teacher does not need to become the mathematics teacher and the mathematics teacher does not need to become the science teacher. Part of the benefits of integrating is the fact that when a science teacher reinforces what the mathematics teacher has taught and the mathematics teacher reinforces what the science teacher has taught the benefactors become the students. Integration becomes a partnership between the teachers.

When the science teacher enhances their program by reinforcing concepts taught by the mathematics teacher and vice versa then time becomes a moot point. When two teachers are focusing on similar concepts but in different environments in essence, time is gained. Teachers will then be able to work with students at a higher level of cognition because they have more time to explore concepts in depth.

In Texas, the science and mathematics state standards fit naturally together. For example, in 5th grade science, students are expected to learn about scientific investigation and reasoning by describing, planning, and implementing investigations and analyzing and interpreting information. In 5th grade mathematics, students are expected to learn how to solve problems connected to everyday experiences by making a plan, carrying out the plan and evaluating the plan for reasonableness along with explaining and recording observations. These two standards can easily be aligned. The science teacher’s role is to teach scientific investigation and the mathematics teacher’s role reinforces this concept via practical applications. Many other examples of natural fits are prevalent within the science and mathematics state standards.

Administrators play a central role in providing time for teaching teams to collaborate. The leadership team should be creative in planning the master schedule in such a way that teachers who wish to integrate have time during the day to collaborate and plan integrated lessons. Once administrators show they believe in integration by carefully designing a master schedule to support this concept, the teachers will be more inclined to carry out this vision. In other words, administrators should “walk the walk.”

Professional Learning Communities a Global Perspective

One method for providing teachers an opportunity to collaborate is through Professional Learning Communities (PLC). Professional Learning Communities originated in the United States in the 1990s and forms of PLCs can be found abroad in international education systems. DuFour, DuFour, Eaker, & Many (2006) describe three important elements of a successful PLC: focus on learning, collaborative culture, and results-oriented thinking. The Glossary of Education Reform (2014) defines a PLC as “a group of educators that meets regularly, shares expertise, and works collaboratively to improve teaching skills and the academic performance of students” (professional learning community, 2014, p. 1). Some researchers believe that teachers should be spending more time working with their colleagues to improve instruction and this can be accomplished through implementation of a PLC. Further, research has also demonstrated when teachers have more opportunities to collaborate with colleagues and professional development experts, engaging in professional discourse about teaching and learning, and making their work public (digitally) the more engaged the teacher becomes in strengthening their own practice (Jacobsen, 2014).

Many countries have designed their instructional day so teachers have an opportunity to collaborate with their peers. “International commentators have identified many ways in which schools can develop collaborative learning spaces for their teachers that contribute to the mandates of ongoing training and respect for teachers as professionals” (Hanover Research, 2013, p. 21). International educational leaders are recognizing the need to provide teachers with more autonomy and trust with regards to instructional decisions. Traditionally, in the United States teachers will plan lessons independent of one another. The OECD *Education at a Glance* Report (2012) discusses net teaching time in the classroom and compares the participating OECD participating countries. The following table reflects net teaching time in hours at each level for various countries compared to the United States.

Figure 3: Organization of Teachers’ Working Time, 2010

Country/Region	**Net Teaching Time in Hours**		
	Primary Education	Lower Secondary Education	Upper Secondary Education, General Programs
Finland	680	595	553
South Korea	807	627	616
England	684	703	703
OECD average*	**782**	**704**	**658**
Canada	799	740	744
Australia	868	819	803
United States	**1,097**	**1,068**	**1,051**

Source: OECD
*NB: Average inclusive of countries included in this table and those not reproduced here; total n=36

Based on the above data teachers in the United States are spending more time teaching students in the classroom; however, the mathematics and science literacy scores are below the OECD averages. While teachers in other high performing countries are spending less time teaching students the data might indicate they are spending more time planning lessons and collaborating in preparation for teaching the students.

Hamlett (n.d.), in a professional learning community blog, posted different models of teacher collaboration and professional learning as he reviewed school systems in Australia, Tasmania, and Canada. The models Hamlett included are (1) Professional Learning Cycles – Ontario Model; (2) Co-operative learning; (3) School planning teams; (4) Timperley cycle; (5) Richard DuFour PLC model; and (5) Classroom Observation and Feedback.

In a Status Report on Teacher Development in the United States and Abroad, the authors found that in countries with high achievement the teachers had four advantages over the teachers in the United States (Darling-Hammond, Wei, Abdree, Richardson, & Orphanos, 2009). One such advantage is the fact that professional learning is planned into the teachers' work schedule. Darling-Hammond et al (2009) state that "In most European and Asian countries, instruction takes up less than half of a teacher's working time. The rest…is spent on tasks related to teaching, such as preparing lessons…and working with colleagues" (p. 15). Furthermore, Darling-Hammond et al (2009) note that "Schools in European nations—including Denmark, Finland, Hungary, Italy, Norway, and Switzerland—dedicate time for regular collaboration" (p. 15). "Among OECD nations, more than 85 percent of schools in Belgium, Denmark, Finland, Hungary, Ireland, Norway, Sweden, and Switzerland provide time for professional development as part of teachers' average work day or week" (p. 15). For educational leaders to provide professional learning during the work day demonstrates the importance and commitment to maintaining high student achievement. It also demonstrates an understanding that teacher collaboration and learning has long lasting impacts on their own pedagogical and content knowledge. In addition, "Similar practices are common in Japan, Singapore, and other Asian nations, as well" (p. 15). Teachers can be found dedicating non-teaching time to planning collaboratively, lesson studies and peer observations.

The Japanese lesson study model has gained some popularity in the United States. Lesson study is a comprehensive look at an individual lesson with colleagues providing feedback. A teacher teaches a lesson and a team of colleagues observe the lesson. Afterwards, they all come together to redesign the lesson. Soon thereafter another teacher from the team presents the redesigned lesson to a different group of students and the other colleagues observe. The process of planning, teaching, observing, reflecting, revising, and re-teaching a lesson is the lesson study (Lewis, C., Perry, R., & Hurd, J., 2004). According to Doig and Groves (2011), "While Lesson Study takes place across all curriculum areas in Japan, it is perhaps most commonly practiced in mathematics, and this has tended to be the case in other countries too" (p. 77).

Amid OCED countries, educators who implement professional learning communities have seen exceptional improvement in student achievement in mathematics and science. Educators' collaboration has proven to be advantageous to many countries in the global community. Why is collaboration so important? Collaboration provides a cyclical stream of improvement for educators and students.

Conclusion

As the above discussion shows, in the United States educators are working together collaboratively to integrate mathematics and science curriculum, however, this was not found globally. The commonality globally was the concept of creating collaboration similar to a professional learning community. Globally teachers are spending more time collaborating regarding pedagogy and content to further increase their own knowledge and their students are benefiting from this academically.

While certain barriers to teachers' participation in implementing integration exist in the United States, many of these barriers can be overcome through common planning times, aligned mathematics and science standards, and school administrators who are proponents of integration. When mathematics and science teachers actively participate and create some form of collaborative learning environment integration and improved student achievement happens naturally.

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