Supporting Targeted Connections: A Call for Cross-Curricular Design

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Abstract

Current efforts by the National Governor's Association's Common Core Standards Initiative seek to articulate expectations for what students should know and be able to do grade-level by grade-level within a content area (NGS, 2009). There is no indication, however, that any attempt is being made to correlate topic placement between content areas. Close examination of mathematics and science concepts to identify supporting ideas, processes, and skills would allow the design of parallel curricula that would take advantage of "targeted connections" that arise naturally within the study of a unit. Such parallel programs expand the definitions of integrated curricula and correlated lessons to include the idea of correlated conceptual explorations. (Berlin & White, 1994; Offer & Vasquez-Mireles, 2009). The supporting connections that exist between mathematics and science would be made explicit through the process of aligning the sequence of topics for each grade level across the content areas.

This paper will look at the differences between integrated curricula and correlated lessons and the challenges each face. Targeted connections and parallel curricula will be defined and an example of the type of connections that could be exploited to enhance student exploration and understanding of each content area will be given.

Introduction

In 1990 the authors of <u>Reshaping school mathematics: A philosophy and framework for curriculum</u>, stated "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 methods a focus on exploration, investigation, conjecture, evidence, and reasoning. Firmer school ties between science and mathematics should especially help students' grasp of both fields" (NRC, 1990, pp. 44-45). Similarities in the perceived nature of the disciplines highlight the interrelated aspects of the curricula and suggest obvious links between them (AAAS, 1989; NCTM, 2000). Leveraging the science curriculum to give a context for understanding mathematical concepts and the mathematics curriculum to provide the skills and critical thinking skills needed to conduct scientific inquiry should enhance student comprehension and achievement in both areas. There have been several attempts to coordinate the study of mathematics and science. Integrated curricula often exhibit a mathematics or science focus as the content areas are coordinated at different levels. Classifying integrated curricula according to the area of primary importance creates a continuum depicting the different levels of this coordination (Berlin & White, 1994; Lonning & Defranco, 1997; Pang & Good, 2000). Correlated lessons seek to connect the study of mathematics and science while insuring both mathematics and science learning objectives direct the instruction (Offer & Vasquez-Mireles, 2009). Targeted connections occur naturally in the course of well-sequenced, parallel programs that have been aligned to connect supporting conceptual understandings. All attempts to coordinate study of these disciplines, however, suffer from a lack of coherence in curriculum structures. The challenge to designing effective cross-discipline studies is in determining when topics should be introduced (i.e. at what grade level), the sequence in which topics should be introduced, and the depth of understanding expected as a student progresses from grade-level to grade-level.

Integrated Curricula

Integrated curricula are designed as single courses of study, usually taught by a single teacher. Because these curricula are either taught by a mathematics-trained or a science-trained teacher, the perception of the nature of these course vary from mathematics courses that incorporate science applications to science courses that utilize appropriate mathematics models. Continuum models have been devised to characterize the relationships between the mathematics and science included in integrated curricula. The models classify the activities, lessons, and/or entire integrated curricula along a continuum that ranges from independent mathematics lessons (i.e. math for the sake of math), to mathematics-focused lessons with supporting science content to provide a context, to "balanced lessons" in which the mathematics and science is of equal importance, to science-focused lessons with supporting mathematical content as a tool, to independent science lessons (i.e. science for the sake of science) (Berlin & White, 1994; Lonning & Defranco, 1997). Most integrated curricula seem to fall into the categories of math-focused or science-focused. Berlin (1991) found that science activities with related mathematics concepts were the dominant approach. The argument can be made, however, that mathematics-focused curricula would be more powerful as the mathematics curriculum has an inherent, logical structure (Isaacs, Wagreich & Gartzman, 1997). While integrated curricula would seem to be an efficient use of instructional time, a lack of common understandings and weaknesses in content knowledge are obstacles to the effectiveness of this approach (Stinson et al., 2009).

Correlated Lessons

Correlated lessons extend the definition of integration, striving to achieve "balanced" integration in which the mathematics and science content is of equal importance (Berlin & White, 1994; Lonning & Defranco, 1997). Parallel mathematics and science lessons are developed by a team of teachers, each a content specialist in their own discipline. This allows the concepts from both disciplines to be almost equally taught (Vasques-Mireles & West, 2007). A strength to the team-teaching approach is that conversations occur around the language and the parallel relationships that are being taught. There are, however, challenges to developing and implementing <u>correlated</u> lessons that range from lack of planning time and difficulties in coordinating team taught lessons to lack of materials and difficulties identifying appropriate connections (Vasques-Mireles & West, 2007).

Targeted Connections

Targeted connections expand the definition of correlated lessons to encompass correlated units of study. Rather than selecting a mathematics or science topic and then attempting to identify the pertinent topics from the other discipline, parallel programs would be designed in mathematics and science that would connect underlying, supporting conceptual understandings as well as appropriate skills and applications. These programs, designed to be taught simultaneously, would each develop the connected conceptual understanding within the context of the separate discipline. Correlated lessons would be utilized within the units to take advantage of the naturally occurring connections in processes, skills, and applications.

Lynn Steen, in a paper presented at the Wingspread Conference (NSF- SSMA, 1991), suggested that such an ideal situation "employs mathematical methods thoroughly in science, and scientific methods thoroughly in mathematics, coordinating both subjects sufficiently to make this feasible. Each discipline, science and mathematics, would accrue benefits from an infusion of methods of the other, but neither would lose its identity or distinguishing features in an artificial effort at union" (Steen, 1991). It must be acknowledged that some mathematics and science concepts are discipline-specific and should be studied as such. However, it is possible that within coordinated units of study there would be instances of naturally occurring connections that could be explored from both a mathematics and science perspective. In order to take advantage of these naturally occurring connections, the mathematics and science curricula must be closely aligned and taught simultaneously. Thus the lack of coherence in topic placement is perhaps the greatest challenge to designing parallel courses of study.

Topic Placement

There is very little consensus on what topics in mathematics and science should be presented at each grade level in the elementary setting (Reys et al., 2006; Schmidt, Wang & McKnight, 2005). While there is agreement in some areas on the sequence of topics in elementary mathematics (work with whole numbers and operations prior to computations with fractions, for instance), the placement of other strands are less defined. And it is not only the sequence of the topics that is in question. There are also differences as to when each topic is introduced, i.e. which topics are included at a grade level.

In 2000, NCTM released the Principles and Standards for School Mathematics (NCTM, 2000). The Curriculum Principle states, "a curriculum is more than a collection of activities: it must be coherent, focused on important mathematics, and well-articulated across the grades" (p. 14). NCTM's latest publication regarding topic placement offers an approach that focuses on a small number of significant concepts that should be presented at each grade level (NCTM, 2006).

In science, the strand maps featured in the Atlas volumes build a coherent content hierarchy across different grade levels in terms of science, mathematics, technology and society (AAAS, 2001). The Project 2061 staff believed, "If we invest our energies in selecting or inventing activities and pacing them intuitively at different grade levels, we will fall short of the quality of innovation that Project 2061 intends. The job is rather to think through the entire flow of learning, including major connections among ideas, so as to identify the kinds of learning experiences that would optimally contribute to students growing along those lines" (AAAS, 2001, p. 137).

There are three strand maps for the nature of mathematics and ten strand maps for the mathematical world. The strand maps suggest ways to link or integration mathematics with science.

Regardless of the placement of topics, specific correlated lesson can be designed by an individual teacher or a team of teachers (Vasquez-Mireles & West, 2007). Selecting either a mathematics or science concept as the starting point, teachers can attempt to identify the supporting concepts appropriate to the exploration of the ideas. However, a well-designed cross-content curricular design that strives to coordinate topics that naturally support each other and place their study at the same grade level would greatly facilitate this process. Identifying the crucial mathematics skills needed to explore a given science topic and/or the appropriate science application to give context for understanding a particular mathematics concept becomes the first step, then, in creating parallel curricula that can take advantage of the targeted connections that naturally occur. Once these supportive ideas are identified, discussion of the appropriate grade-level placement within the elementary curriculum can take place.

An Example

One example of coordinating conceptual understandings in parallel units would be in coordinating the mathematical ideas of three-dimensional geometry and spatial visualization and an exploration of the phases of the moon. A research project conducted by Cabe Trundle, et al. (2007) examined students' conceptual understanding of the causes of the moon phases. During specialized instruction, students examined and created drawings representing what the moon looks like during each of the phases, i.e. the "view" of the moon. They also worked with three-dimensional models and a light source to help them explain what causes the phases of the moon to appear. Results from pre- and post-tests indicated students were successful in creating and sequencing illustrations of the lunar phases and in explaining the causes for these phases.

The specialized instruction described in the above study is often found in elementary mathematics curricula during spatial visualization explorations. For instance, in the elementary mathematics curriculum, Investigations in Number, Data, and Space, fourth-grade students work on developing spatial visualization skills in the unit Seeing Solids and Silhouettes (3-D Geometry). They work with geometric perspective and explore the different pictures one gets of a three-dimensional "building" depending on their point-of-view. Using an overhead projector as a light source, they also explore the silhouettes that can be formed by different polygons. Given that understanding the phases of the moon includes locating the light source (the sun) and determining your location relative to the moon and the sun (your point-of-view), working with these concepts simultaneously in mathematics and science would expand students' understanding in both areas. There is difficulty with topic placement, however, when using existing curricula to teach these topics. The FOSS science unit that explores phases of the moon is used as part of the seventh-grade sequence, not the fourth-grade where this math unit is used. Given the "fit" of these ideas, it would be advantageous to teach these units at the same time.

Could the phases of the moon be explored equally well at the fourth-grade level, or are the additional scientific concepts associated with this unit more developmentally appropriate for the middle-school? Could exploring spatial visualization as easily be done in the middle-school curriculum as at the elementary level, or is there evidence to support the need to introduce these concepts earlier? The discussion on the appropriate placement within the elementary or middle-school educational sequence should take place after the supporting conceptual understandings that exist between the content areas have been identified.

Conclusion

The work with fourth-grade students to discover the causes of the lunar phases indicate that appropriately designed instruction is key to building students' conceptual understanding (Cabe Trundle, et al., 2007). If this is the case, then coordinating instruction on correlated concepts should further enhance student understanding. Mapping the underlying conceptual ideas inherent in science and mathematics units is necessary to identify the connections between the content areas. Coordinated, parallel programs could then be utilized to provide the type of specialized instruction shown in this study to be effective. While additional research testing to determine if the connections identified are appropriate and the correlated instruction effective, the case for cross-curricular sequencing which allows the use of targeted connections and supporting specialized instruction seems strong. Such discussions should be included in the current work on core standards and topic placement for elementary and middle school curricula.

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