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Integrated Programs for Science and Mathematics: Review of Related Literature

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Abstract

This study presents a review of literature on the integration of science and mathematics, focusing on the dominant trends in the related studies. Majority of the studies conclude that the concept of the integration between science and mathematics is still vogue. On the other hand, there are various methods, techniques and models to achieve this integration. Although these distinct models, methods and techniques are employed in the integration efforts, the results are the same. The integration improves the student achievement. However, there are also some barriers in these efforts. One of such problems is the lack of teachers' and pre-service teachers' content knowledge and pedagogical content knowledge. The other deficiency is about the fact that teachers do not have sufficient experience for delivering integration programs since their pre-service education do not provide them with the opportunity to use it.

Key words: Integration, Integration of Science and Mathematics, Integrated Curriculum.

Introduction

Interdisciplinary practices are emphasized increasingly in recent years (Rutherford & Ahlgren, 1990; NCTM, 2000; MEB, 2004; Kıray & Kaptan, 2012). One of such relations is between science and mathematics. These two fields are similar and interrelated, making them more suitable for integrated programs. The relations between these two fields are natural, rather than forced. The content knowledge of the fields is resulted from their interaction or cooperation. Additionally, the relationship of both fields has a long period of time (Hurley, 2001).

Integration of science and mathematics has a long history. However, early integration lacked instructional dimension; instead, it attempted to make use of mathematics. The acceptance of education as a discipline by positivist philosopher started at the beginning of the 20th century and then the bonds between science and mathematics attracted the attention of educators. Various studies were made with regard to the integration between these two disciplines. Later, instead of the term integration, other terms began to be used such as blended, connected, correlated, core, cooperation, coordinated, cross-disciplinary, fused, immersed, integrated, integrative, interactions, interdependent, interdisciplinary, linked, multidisciplinary, nested, networked, thematic, threaded, trans-disciplinary, sequenced, shared, unified and webbed (Berlin, 1991; Berlin & White, 1994; Lederman & Niess, 1997; Mathison & Freeman, 1997; Gehrke, 1998; Czerniak, 2007, Deveci, 2010; Kıray, 2012). Some of these terms are used interchangeable. However, some of these terms have distinct meanings. Kıray (2012) argues that if these terms refer to research in science and mathematics, then they should be grouped under the heading of "integrated science and mathematics". On the other hand, such variety of terms has led to different definitions for the integrated science and mathematics.

Definitions of the integrated science and mathematics

Berlin and White (1992) defined the integrated science and mathematics as the mixture of two courses in a way that they cannot be separated each other. They argued that this integration can be achieved through the use of methods in science in the other course and vice versa. Lederman and Niess (1997, 1998), Roebuck and Warden

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(1998) and Huntly (1999) defined this integration as a blended case. Lehman (1994), Frykholm and Glasson (2005) and Furner and Kumar (2007) regarded the integrated science and math as the expansion of two disciplines. Kıray (2012) suggests that after identifying the objectives of the integrated science and math, all possible interactions between two disciplines may be part of this integration ranging from simple connections to blended practice. A similar approach was adopted by Berlin and Lee (2005). In addition to various definitions, there are also various methods and models with regard to the integrated science and math.

Methods and models with regard to the integrated science and math

Berlin and White (1994) developed a model called BWISM that is the first one in the field. BWISM is add-up of six steps as follows: 1- ways of learning, emphasizing the active participation of students in the learning process, 2- ways of knowing, using both induction and deduction and qualitative and quantitative data to reach new information, 3- process and thinking skills, recognition that the math skills are also that of science and that scientific process skills are also employed in mathematics, 4- content/conceptual knowledge, recognition that the integrated science and math refers to similar concepts, 5- attitudes and perceptions, emphasizing that some attitudes, values and perceptions are common in mathematics and science and 6- teaching strategies, emphasizing that there are methods that can be used for the instruction of science and mathematics.

Davison, Miller and Metheny (1995) argued that the integrated science and math includes five principles as follows: 1- discipline specific integration in which two or more subcategories of science and mathematics are combined through an instructional activity, 2- content specific integration, in which some objectives from the existing objectives of the science and math programs are chosen and combined, 3- process integration, in which skills of science and math are combined, 4- methodological integration, in which teaching-learning techniques, methods and strategies of discovery and learning cycle are employed, and 5- thematic integration, in which science and mathematics are integrated around a theme. Therefore, Davison, Miller and Metheny (1995) suggested that the use of at least of the above options refers to as the integrated science and math.

Lonning and DeFranco (1997) divided the interaction of science and math into five subcategories: 1- independent mathematics, which is the instruction of pure mathematics, 2- mathematics focus, in which the concepts of science are employed to support the math concepts, 3- balanced mathematics and science, in which the concepts and activities of science and math are integrated 4- science focus, in which the concepts of math are employed to support the science concepts, 5- independent science, which is the instruction of pure science.
A similar approach was also adopted by Huntly (1998). Likewise, she developed five different interaction between science and math as follows: 1- math for the sake of math, referring to as math course, 2- math with science, referring to as the use of science content or methods in the math problems, 3- math and science, referring to as the use of both content and methods of science and math together to give explanations, 4- science with math, referring to as the use of math to solve science problems, and 5- science for the sake of science, referring to as science course.

Hurley (2001), on the other hand, developed five distinct types of integration as follows: 1- sequenced integration, involves the sequential instruction of science and math, 2- partial integration, involves both combined and separate instruction of science and math, 3- enhanced integration, involves the use of either of the disciplines as a major one and the other as a dependent one, 4- total integration, involves the simultaneous and equal instruction of science and math and 5- parallel integration, involves separate but simultaneous instruction of science and mathematics. The types developed by Hurley are independent. Each emphasized a distinct integration option.

Kıray (2012) focused on the development of an instructional program for the integrated science and math. He suggested that the content knowledge of science and math can be organized and the related objectives can be identified. However, he also argued that the integration of science and math cannot be always possible or suitable. Based on these suggestions, he developed a model called balanced model for the integrated science and math. In this model, the organization of the content knowledge is at the center and it is combined with skills, the process of teaching and learning, affective characteristics, measurement and assessment. Kıray's (2012) balanced model involves five steps as follows;

1- Content knowledge: The content knowledge in this model is similar to the models developed by Lonning and DeFranco (1997) and Huntly (1998). These scholars also refer to balance model in their accounts of the integrated science and math, suggesting that content of science and math should be represented equally in the program for the integrated science and math. There are seven dimensions with regard to the content knowledge:

a) Mathematics: At this dimension, only the objectives of the math course is taken into consideration, b) Math-centered science-assisted integration: Either content knowledge or the objectives of science is included in the objectives determined for math, c) Math-intensive science-connected integration: Math is much more emphasized in the topics in which both science and math are taught and the objectives identified for math are correlated with science, d) Total integration: The objectives are developed in what that science and math are completely blended, e) Science-intensive mathematics-connected integration: Science is much more emphasized in the topics in which both science and math are taught and the objectives identified for science are correlated with math, f) Science-centered mathematics-assisted integration: Either content knowledge or the objectives of math is included in the objectives determined for science, and g) Science: At this dimension, only the objectives of the science course is taken into consideration. These dimensions are also called the types of the integrated science and math.

2- Skills: The step of skills states that math skills such as problem solving, reasoning, communication, connections and representation are also common skills for science in all types of the integrated science and math. Process skills of science are divided into two subcategories: Common skills that are regarded as primary and common skills that are regarded as secondary. Primary common skills are connections, problem solving, reasoning, reaching conclusions and interpreting, organizing the data and formulating models, comparison-classification, measurement, collecting information and data, estimation, making inference, prediction, recording the data, communication, observation. Secondary common skills are those of math and science. Of them, those skills regarded as primary are used the types of Science, Mathematics, Science-centered mathematics-assisted integration and Mathematics-centered science-assisted integration. Secondary common skills are used at the remaining types, namely Science-intensive mathematics-connected integration, Mathematics-intensive science-connected integration and Total integration.

3- The processes of teaching and learning: It predicts that both science and math are taught and learned based on the constructivist approach. It recommends inquiry-based processes for both courses.

4- Affective characteristics: In the model, it is stated that when the program for the integrated science and math begins to be used, the affective characteristics defined separately for each will affect student achievement. Such an effect may be mostly seen at the integration type of total integration. It will be less in the following types in which integration is limited to simple connections, such as mathematics-centered science-assisted integration and science-centered mathematics-assisted integration.

5- Measurement and assessment: At this step, the objectives of the program should be consistent with the measurement and assessment attempts. The attempts of measurement and assessment will be shaped by the integration type preferred. However, both outcome and process should be assessed.

Research about the integrated science and math

Berlin and Lee (2005) compared the number of published articles on the integrated science and math in two periods, namely the period of 1901-1989 and of 1990-2001. They found that a total of 401 researches were published in the period of 1901-1989 and that 449 research was published in the period of 1990-2001. The findings clearly show that the studies on the integrated science and math have increased in the last 20 years.

Bütüner and Uzun (2011) found that science teachers have complaints about the lack of connections between science and math in the existing programs of science and technology and math courses. They also stated that they have to deal with math topics before certain science units such as physical science since prior math knowledge is required for the learning of such topics. Watanabe and Huntly (1998) found that science teachers mostly regard math as a tool for science or the language of science.

Kıray, Gök, Çalışkan and Kaptan (2008) concluded that math teachers are not aware of the necessity of math knowledge for the course of science and technology. However, both science teachers and math teachers believe that student achievement in either of these courses affects the achievement in other course. Frykholm and Glasson (2005) found that pre-service teachers are aware of the blending nature of science and math and of the significance of the connections between these two courses. However, the participants were found to have the fear of using the program for the integrated science and math. The reasons for this fear included the lack of teaching experience and deficiency of content knowledge.

Lehman (1994) found that more than half of the teachers participated in the study did not believe that they had necessary background knowledge to use the program for the integrated science and math. Similarly, Başkan, Alev and Karal (2010) concluded that although the teachers have positive attitudes about the integration of science and math, they do not have necessary knowledge to integrate these two courses. Mason (1996) also concluded that secondary teachers have deficit content knowledge and pedagogical content knowledge for the other courses and do not know how to integrate the programs of such courses. Kıray and Kaptan (2012) also reached a similar finding. The lack of necessary content knowledge and pedagogical content knowledge to integrate science and mathematics is one of the most important barriers of the successful integration.

Huntly (1999) argued that although integrated science and mathematics courses are much more effective, the success of the integration is based on the teachers' content knowledge. Since the understanding of teachers with regard to science and mathematics is limited, connections to be developed between science and mathematics will also be limited. The teachers participated in Huntly's study argued that the lack of instructional materials and models for the programs for the integrated science and mathematics do not allow them to use this program. Huntly further suggested that teachers' pedagogical content knowledge should be improved in order to have successful integration and teachers should know the objectives of the integrated program. Meisel (2005) suggested that teachers should be offered in-service training concerning the integrated programs for science and mathematics, since such training activities have positive effects on the implementation of the integrated programs.

Kıray (2010) concluded that the integrated science and mathematics program should not involve all topics. Instead, only the most suitable ones should be covered in the integrated program. The teachers participated in Kıray's study stated that they do not endorse the total integration, but they prefer those integration attempts in which some knowledge and skills are transferred to the other course. All participants also argued that science teachers do not know mathematics well and mathematics teachers do not know science well. Therefore, they objected to integration attempts between these two courses. Additionally, each category of teachers seemed to claim that their field is superior to the other field.

James, Lamb, Householder and Bailey (2000) found that mathematics teachers experience difficulties in the implementation of the integrated program for science and mathematics. They also found that mathematics teachers less tend to use the integrated program in contrast to science teachers. Berlin and White (2010) concluded that student teachers are also not willing to use the integrated science and the math program due to its difficulty.

Hurley (2001) analyzed 31 studies on student achievement using effect size. It was found that the integrated science and mathematics has positive effect on student achievement in two courses, but its effects are much higher in science. Ross and Hogaboam-Gray (1998) also found the integrated students are much more successful than those in control group. Hill (2002) found the similar findings for the sixth grade students. Kaya, Akpınar and Gökkurt (2006) also determined higher levels of achievement for the students who are given the integrated instruction. Kıray (2010) evaluated the effects of the integrated science and math program on student achievement. He found that the students of the integrated science and mathematics program could more easily solve the problems in the category of "science-math". However, in other categories there were no differences between the integrated instruction group and the control group. Deveci (2010), on the other hand, found that the program for the integration of science-centered mathematics-assisted did not lead to any significant difference in terms of student achievement. However, the program contributed to the permanence of knowledge. Kıray and Kaptan (2012) who tested the effects of science-centered mathematics-assisted integration program found that those students in the integrated group were much more successful than those in the control group.

Conclusions and Implications

There are numerous studies indicating the significance of the interaction between science and math. However, there is still uncertainty over how to reflect this interaction into the program and classroom environment. On the other hand, the definition of the integrated science and math is not clear-cut. The efficiency of the integrated science and math programs has not been evaluated extensively. Those studies dealing with the efficiency of these programs employ distinct models or methods.

Emprical studies analyzing the efficiency of the integrated science and math program show that the integrated programs have positive effects. However, these studies also document the deficiency in the implementation of these programs. Studies on pre-service teachers show that the most significant barrier to implement the integrated programs is the lack of teachers' and pre-service teachers' content knowledge and pedagogical content knowledge. The lack of experience is cited as another barrier. Science teachers seem to need and be volunteer to use the integrated science and mathematics programs.

Therefore, it can be suggested that the integrated programs should be developed for long period of time in order to provide an effective program for the integrated science and mathematics. Additionally, teacher-training programs should be reorganized in order to improve the content knowledge and the pedagogical content knowledge of the pre-service teachers.

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