Teaching Mathematics & Science through Integrated Approach

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Abstract

Kothari Commission (1964-66) recommended that teaching of science and mathematics, up to class X must be made compulsory. 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). 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). In defining how to integrate math and science, White and Berlin (1992), and Sunal and Furner (1995) made the following recommendations: (1) base integration on how students experience, organize, and think about science and math; (2) take advantage of patterns as children from the day they are born are looking at patterns and trying to make sense of the world; (3) collect and use data in problem-based integrated activities that invoke process skills; (4) integrate where there is an overlapping content in math and science; (5) 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; (6) use instructional strategies that would bridge the gap between students’ classroom experiences and real-life experiences outside the classroom.

In science, geometric principles such as symmetry, reflection, shape, and structure reach down to the atomic levels. In science, algebraic balance is required in chemical formulas, growth ratios, and genetic matrices. In science, math is used to analyse nature, discover its secrets and explain its existence and this is the big problem. In math class one of the biggest needs is relevance. Why not use science to teach math? Since one of the biggest uses of mathematics in science is data gathering and analysis, that is the best place to start. When a teacher gives students a real science problem to solve -- one that requires math tools -- the
teacher is giving the students a reason to use math. Mathematics then becomes meaningful for the learners.

This paper emphasizes use of integrated approach in teaching math and science and substantiates use of this approach by selecting and discussing some topics from math and science.

**Introduction**

It is a common experience for all of us who are devoted to the cause of school education that while studying mathematics children wonder and ask their teachers, when will we use it? where? Then in science classes, again children struggle as they are expected to apply mathematical principles to solve scientific problems. There is an inherent relationship between the two. During the past century, sincere efforts have been made for improving science and mathematics education. There is a natural and logical relationship between science and mathematics. Teaching-learning of these two disciplines can be effectively integrated by using real-world problem solving situations.

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 method a focus on exploration, investigation, conjecture, evidence, and reasoning. Firmer school ties between science and mathematics should especially help students' grasp of both fields (National Research Council, 1990; pp.44-45).

**Review of Related Literature**

Although the area of integrated mathematics and science education is not new as evidenced by writings dating back to 1905, it is complex, not well defined, and inadequately studied. The literature in the last decade has increasingly focused on defining integrated mathematics and science education through theoretical models. An earlier theoretical model, posited by the participants of the Cambridge Conference on Integration of Mathematics and Science Education held in 1967 (Education Development Center, 1970), defined five categories of interaction between mathematics and science. These categories include:

1. math for math,
2. math for science,
3. math and science,
4. science for math, and
5. science for science
Brown and Wall (1976) fashioned these categories into a continuum consisting of mathematics for the sake of mathematics, mathematics for the sake of science, mathematics and science in concert, science for the sake of mathematics, and science for the sake of science. Recent theoretical models have used this same continuum with minor changes. For example, Lonning and DeFranco (1997) describe their continuum as independent mathematics, mathematics focus, balanced mathematics and science, science focus, and independent science. Similarly, Huntley (1998), using an interesting foreground/background analogy, suggests a continuum from mathematics for the sake of mathematics, mathematics with science, mathematics and science, science with mathematics, and science for the sake of science. Finally, Roebuck and Warden (1998) modify the Brown and Wall continuum to include math for math’s sake, science-driven math, mathematics and science in concert, math-driven science, and science for science’s sake. Only one recent theoretical model, the Berlin-White Integrated Science and Mathematics (BWISM) Model (Berlin & White, 1994), uniquely describes the center of the continuum, mathematics and science.

**Figure 1: Math and science linear integration continuum**
Berlin-White Integrated Science and Mathematics Model (BWISM)

The Berlin-White Integrated Science and Mathematics Model has been recognized in both the mathematics and science education communities (Berlin & White, 1994, 1995, 1998). Evolving over a period of 15 years, it reflects and combines multiple perspectives and endeavors, including empirical research, a comprehensive review of the literature, the perspectives of the mathematics and science communities, curriculum research and development projects, and valued classroom practice. With National Science Foundation support, a 1991 national level conference on the integration of mathematics and science education (Berlin, 1994; Berlin & White, 1992) further helped to delineate the multiple aspects of the BWISM model. The Berlin-White Integrated Science and Mathematics Model includes six aspects:

1. Ways of learning: Integration can be based on how students experience, organize, and think about science and mathematics. Based on a constructivist/ neuropsychological perspective or rationale, students must do science and mathematics and be actively involved in the learning process.

2. Ways of knowing: Integrated school science and mathematics can reinforce the cyclical relationships between inductive-deductive and qualitative-quantitative views of the world. In science and mathematics, new knowledge is often produced through a combination of induction and deduction. For this discussion, induction means looking at numerous examples to find a pattern (qualitative) that can be translated into a rule (quantitative). The application of this rule in a new context is deduction.

3. Content knowledge: Science and mathematics can be integrated in terms of content that is overlapping or analogous. Big ideas or themes such as change, conservation, models, patterns, scale, symmetry, and systems can be found in both science and mathematics. The examination of concepts, principles, laws, and theories of science and mathematics reveal ideas that are unique to each discipline and ideas that overlap or are analogous (e.g., the fulcrum of a lever and the mean of a distribution).

4. Process and Thinking skills: Integrated science and mathematics can develop processes and skills related to inquiry, problem-solving, and higher-order thinking skills. Integration of science and mathematics can focus on ways of collecting and
using information gathered by investigation, exploration, experimentation, and problem solving. Skills such as classifying, collecting and organizing data, communicating, controlling variables, developing models, estimating, experimenting, graphing, hypothesizing, inferring, interpreting data, measuring, observing, predicting, and recognizing patterns are representative of this aspect.

5. **Attitudes and Perceptions**: Integration can be viewed from what children believe about science and mathematics, their involvement, and their confidence in their ability to do science and mathematics. Similarities and differences related to scientific and mathematical attitudes/perceptions or 'habits of mind' can be identified. The values, attitudes, and ways of thinking shared between science and mathematics education include accepting the changing nature of science and mathematics; basing decisions and actions on data; a desire for knowledge; a healthy degree of skepticism, honesty, and objectivity; relying on logical reasoning; willingness to consider other explanations; and working together to achieve better understanding.

6. **Teaching Strategies**: Integration can be viewed from the teaching methods valued by both science and mathematics educators. Integrated science and mathematics teaching should include a broad range of content, provide time for inquiry-based learning and problem solving, provide opportunities to use laboratory instruments and other tools, provide appropriate uses of technology (e.g., calculators and computers), encourage cooperative learning, embed assessment within instruction, and maximize opportunities for successful connections between science and mathematics

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**Figure 3**: Contextualizing science and mathematics integration
Classroom Examples based on BWISM Model

Teachers do not realize how important it is to appreciate that pupils often have a fear of mathematics and an inbuilt barrier when anything mathematical is proposed, or when calculations are expected during science lessons. Numeracy is defined by the National Numeracy Strategy as more than knowing about numbers and number operations. It includes an ability or inclination to solve numerical problems, and familiarity with the ways in which numerical information is gathered and is presented in graphs, charts and tables (DfEE 1999b). Numerate pupils should be confident enough to solve problems without going to others to seek advice or help; they should also have a sense of size of number; be able to calculate accurately, both mentally and on paper; have strategies to check if their answers are reasonable, and be able to suggest suitable units for measuring. They should also be able to estimate to a reasonable degree of accuracy.

Ratios & Percentages

1. NCERT Class X Science Book
   
   Chapter 4: Carbon and its Compounds

   Anthracite is composed of the elements carbon, hydrogen, nitrogen and oxygen in the following proportion by mass: Carbon = 93.3%; hydrogen = 3%; nitrogen = 1.0%, oxygen = 2.7%.

   If teacher asks questions:
   
   - What mass of carbon is contained in 100g of anthracite?
   - What mass of oxygen was contained in 200g of anthracite?
   - How many grams of anthracite contained a combined mass of 12g of hydrogen and nitrogen?

   Children face lot of difficulty in solving these problems.

2. NCERT Class X Science Book

   Chapter 10: Reaching the Age of Adolescence

   During puberty there is a sudden increase in height. At this time the long bones, that is, the bones of the arms and the legs elongate and make a person tall. A table is given showing the expected full height of both boys & girls (age 8 years to 18 years).
Calculation for full height (cm) = \[
\frac{\text{Present height (cm)}}{\text{Present height (cm)}} \times 100
\]
% of full height at this age
(as given in the chart)

For Example: If a boy is 9 years old and 120 cm tall. At the end of the growth period he is likely to be

\[
\frac{120}{75} \times 100 = 160 \text{ cm tall}
\]

If students have no clarity of the concept of % or ratio then they are like likely to face a problem in calculating full height in this particular case.

3. In an exercise using small plastic construction blocks, students were asked to construct a model aeroplane twice the size of the one demonstrated by the teacher. A wide variety of models were produced, some doubling the width, others doubling the width and depth, others doubling width, depth and length. What do we mean by double the size? We are often not clear in our language, but it is not always easy to be clear.

4. Dilution of solutions in science can produce difficulties. For example if a 10cm³ solutions needs to be diluted ten times, pupils are likely to add 100cm³ rather than 90 cm³. An understanding of how dilutions are formed is an important concept for pupils to grasp. Practically mixing, measuring and discussing the dilutions could help consolidate the concept and the calculations required.

**Graphs**

1. In a lesson on ‘Heart Beat Rate’, students were divided into small groups and were given a task to check and record their pulse readings before and after exercise. They had taken readings at two-minute intervals after exercise and recorded the pulse rate for about 15 minutes, until the heart had returned to the normal rate. They were asked to plot their results on a graph (no mean feat, in view of having to place the records at the appropriate point on the time axis).

Students faced a lot of problem in plotting these pulse rate values on time scale.
Students had a difficulty when they were shown two graphs with the same information but on different scaled axes (one graph showed a greater gradient than the other).

Statistics

All pupils need to be able to use everyday statistics and to interpret common representations of statistics in their daily lives. Some of the basic statistics, such as averages and means, median and modes, are less understood and can be used to misinform unless the reader is fully aware of the differences. A manager might use the most favourable average wage of the work force by selecting from the median or mean to demonstrate what people earn in a company, while the union representative would almost certainly use the mode company wage (a lower figure) if a pay rise was requested. Both could be said to be average wages, but could be very different figures. Bar charts are commonly used in daily newspapers and by financial institutions selling investments. These can often misrepresent data if the reader misreads the vertical axis, the axis starts above zero or a large scale is used for an axis. In science, pupils often find the terms discrete and continuous difficult to apply to variables. If the terms ‘measurement’ and ‘counting’ are applied to the two terms respectively then there is usually no problem, but it is important for teachers to help and direct in these matters.

Summing Up....

As science teachers it is important to clarify to pupils: what needs to be remembered by them (facts, conventions); what they must practice (skills); what they can come to understand for
themselves (concepts); when they have to make decisions about the approaches to use (strategies). So, facts and conventions need to be learned and remembered. It is necessary to make sure that they have the skills of how to manipulate formulae, for example, and give them practice for fluency. Pupils need to experience the concepts in order to come to an understanding of them (for example, with a unit such as force) and also to be given opportunities to use their skills in solving problems, for example in using units of force. Moving between both they can then make decisions and learn which strategies are best to employ. If pupils are given time and opportunities to estimate, calculate, interpret, discuss with each other and with the teacher, then they will really gain a full understanding of the numerical and other mathematical concepts within science.

References


