Integrating Science and Mathematics Concepts: A Student Teacher Perspective

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There is an emphasis in primary preservice teacher education that Key Learning Areas should be integrated. In this study primary preservice teachers' abilities to formulate mathematical links to teaching activities related to science and technology topics was investigated. Two factors seemed to affect the quality and number of links suggested by preservice teachers; their age and the amount of science, but not mathematics, they had studied in the senior secondary school. Overall, student teachers had great difficulty in perceiving and describing mathematical concepts that could be integrated with science activities.

Science and mathematics are naturally related in the real world so there have been many recommendations that the teaching of these subjects should be integrated (Lehman, 1994; McBride & Silverman, 1991; National Council of Teachers of Mathematics, 1989). At the primary school level it has been suggested that such integration would increase achievement in both disciplines and produce more positive attitudes toward both subjects. Moreover, relationships between concepts would be emphasised and, as a result, more meaningful learning would be promoted (Lehman, 1994). Since science provides students with concrete examples of abstract mathematical ideas, integrating the two subjects should improve students' learning of mathematical concepts by providing appropriate, motivating contexts. In addition, students may achieve deeper understandings of science concepts if they are encouraged to use mathematics to quantify and explain science relationships (McBride & Silverman, 1991).

Scientific knowledge is advanced through observation and manipulation of observable phenomena whereas mathematicatics often involves patterns and relationships that are not so bound (Berlin and White, 1995). Processes fundamental to both disciplines are induction, drawing general conclusions from specific instances, and deduction, conclusions or inferences obtained by arguing from the general to the particular. These authors suggest that all students should be provided with opportunities to acquire understandings of these two processes through "the increased use of mathematical modelling in science classes and the use of student-generated scientific data in mathematics classes" (p. 25).

A number of mathematics and science educators consider the constructivist approach to learning as being beneficial (Malone & Taylor,1993; Harlen 1987; Osborne & Freyberg, 1986). This approach emphasises that knowledge is built on prior understandings and experiences and is organised around concepts involving processes and situations constructed over time. Processes basic to science include classifying, measuring, inferring, analysing and interpreting data, communicating, and formulating and interpreting models. As Berlin and White (1995) point out, these processes are also emphasised in mathematical problem solving. They suggest that integration allows students to engage in challenging, real life problem-solving tasks that enable higher order thinking skills to be utilised. Co-operative learning strategies may also reinforce the collaborative nature of the two disciplines with the teacher in the role of facilitator.

Lehman (1994) surveyed practicing elementary and student teachers and found that although they perceived integration of mathematics and science to be viable and important, they did not feel it was common classroom practice. Perceived problems were a lack of background knowledge in both disciplines, the additional time required to integrate teaching, classroom management, and a lack of commercially developed resources that teachers could utilise.

To achieve integration of mathematics and science, McBride & Silverman (1991) advocated that teacher educators should implement ideas of integration in preservice training. Stuessy (1993) describes the development of an integrated course for elementary preservice teachers which she claimed resulted in "significant positive gains in students' beliefs about themselves as successful teachers of mathematics and science" as well as higher levels of analysis and synthesis skills on tasks specifically related to integrated teaching (p. 61). There seems to be little research, however, in which teachers' knowledge of links between science and mathematics concepts has been investigated.

In N.S.W. neither the primary science nor the primary mathematics curriculum documents suggest ways in which teachers might integrate specific concepts in these disciplines and teacher education programs differ in their approaches to developing student teachers' skills in integrating Key Learning Area content. The aims of this study were to investigate a method of measuring primary preservice teachers' recognition of links between mathematics and science; their identification of mathematical topics related to activities outlined in units of work from the N.S.W. K-6 Science and Technology syllabus; and factors that seemed to affect their identification of such topics. This information could be used to assist teacher educators to design approaches to integrated lesson planning for science and mathematics at the primary school level.

Method

The sample

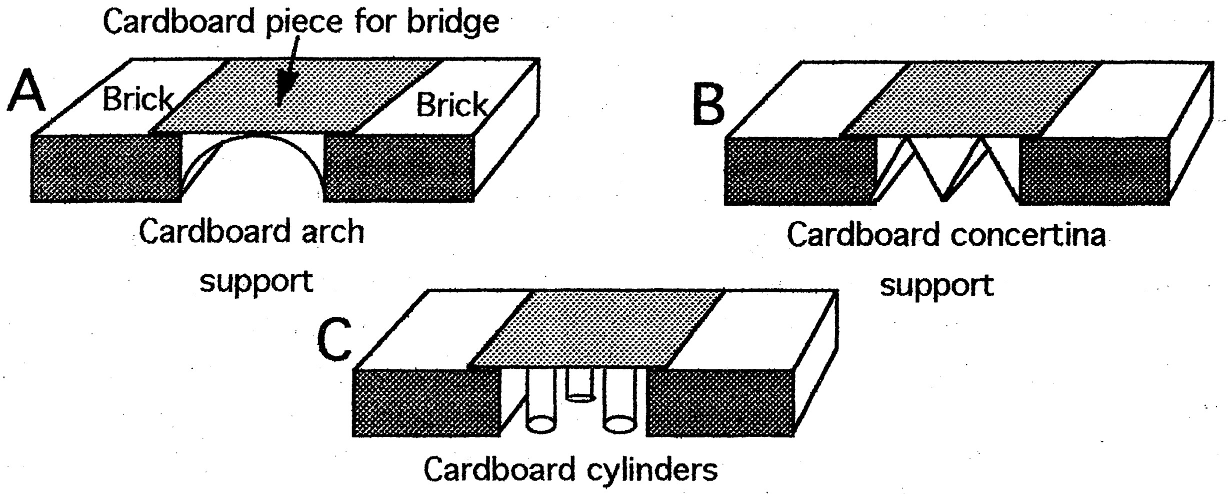
The sample consisted of 65 student teachers from teacher education programs at two N.S.W. tertiary institutions, one a concurrent Diploma in Education (Dip. Ed.) program (N=24), the other a Bachelor of Education (B.Ed.) program (N=41). The students were in the third and second years of their respective courses. The questionnaires were given to the students during workshop sessions at the end of the year.

The questionnaire

The student teachers were asked to complete a questionnaire which comprised three science design-and-make tasks (bridges, weather and semaphores) drawn from the Support Materials based on the N.S.W. K-6 Science and Technology Syllabus. The bridge task is shown in Figure 1. For each task a sequence of six teaching activities was given and students were asked to list mathematical concepts that could be linked to the activities. The students were asked to give sufficient details to show how the mathematics concepts linked to the activities. A completed example of an additional task ("Sinking and Floating") for which mathematical concepts were shown linked to the sequence of teaching activities was provided to illustrate the required responses. An indication of age, level of science and mathematics completed at the Higher School Certificate (HSC) level was also requested.

Task: Test three different supports for a bridge to determine which is the strongest.

The teacher gave each group of children six bricks (all the same size), three small sheets of cardboard, pencils, a ruler, a protractor, grid paper and scissors. They were also given a set of scales, a container and a small bucket of pebbles. The teacher then asked the children to make the bridges shown in the diagram and test which design was the strongest. The activities she planned are shown in the table below.



Activity	List maths concepts that might be necessary for or developed in each activity?
Children cut out the parts they need to make each bridge.	
Children make the three bridges shown in the diagram.	
Children test each bridge to determine which is the strongest	
Children record and then compare their results.	
Children check if the amount of cardboard used to make each bridge was the same.	

Figure 1 The bridge task from Science and technology unit Stage 2: *Indoor, Outdoor*

Scoring the questionnaires

For each task and activity the mathematical linking concepts listed by students were scored using the following criteria. "Good" linking concepts were considered to be those which related to the activity and were sufficiently detailed to give an idea of the mathematics involved (e.g. "measurement of length" rather than "measurement"). A score of four was given for one concept, five for two concepts and six for more than two concepts of this type. Connections which appeared reasonable but lacked specificity were allocated a score of either two or three, for one or more responses respectively. Such connections usually consisted of single word answers (e.g. "graphs"). Responses for which connections to the activities could only tenuously be made were scored as one. Responses which listed general processes (e.g. "investigating" or "problem solving") or no response were given a zero score and an incorrect mathematical response received a score of negative one. The maximum numerical score for each task was 30.

The background information for each student was also coded. Age was given a score from 1-6 for the following age ranges: less than 20, 20-24, 25-29, 30-34, 35-39, 40 years or over. Mathematics level (or equivalent) was scored 0-4: 0 being no mathematics studied, to 4 being 4 Unit Mathematics. Science courses were scored as follows: zero, no Science studied; one, Science for Life, two for each 2 Unit Science subject studied (Geology, Biology, Chemistry, Physics, General Science); three, 3 Unit Science; four, 4 Unit Science.

The relationship between the levels of mathematics and science studied and the total score for the tasks was investigated. An analysis of the most common mathematics concepts given for each task was also undertaken.

Results

Total scores for the three tasks ranged from 0 to 72 (mean 30, standard deviation 18) and were skewed towards lower scores. The distributions of scores for each of the tasks are shown in Table 1.

Table 1 Distributions of total scores for the three tasks (percentages)

Score range	Bridge	Weather	Semaphore
0-5	20	23	43
6-10	32	23	28
11-15	25	31	20
16-19	9	11	7
20-24	12	9	2
25-29	2	3	0
Mean (SD)	11.2 (6.3)	11.4 (7.3)	7.4 (5.9)

Since 85% of the sample were less than 25 years of age, there was not a sufficient spread of ages to be confident that there was any relationship between age and total score. However, none of the ten older students (25 years of age or older) scored less than 24 and 40% of them scored above 50 whereas 42% and 13% of the younger students fell into these categories respectively.

Table 2 A regression analysis of age, school level mathematics and science as predictors of total scores for mathematical linking concepts for the three tasks

Source	Degrees of freedom	MS	F	Probability
Regression	3	2854	15.4	0.000
Error	61	186		

Predictor	Coefficient	Standard deviation	t- ratio	Probability
Age group	5.0	1.8	2.8	.006
School maths	-.9	2.3	-.4	.709
School science	8.3	1.5	5.7	.000

A regression analysis was carried out to investigate the effect of background variables on the total score. The results of this analysis are presented in Table 2 and suggest that the most significant predictors of total score are previous school science experience ($P<0.001$) and age ($P<0.01$). These two variables accounted for 43% of the variance in the total score obtained for mathematical linking concepts. The results for the three oldest students were unusual; one student with no background in science scored far higher than would be expected while the other two scored lower than expected. None of these students had studied mathematics in senior secondary school.

An examination of the most frequent responses to each task suggested that many students were dependent on links suggested by the wording of the teaching activities. The most common mathematical concepts listed for the weather task were "measurement", "scale", "map", "speed" and "direction", all terms used to describe the teaching activities. For each task, measurement concepts were more frequently listed than number or space concepts. However, students often did not indicate what would be measured, and only one student mentioned the concept of units. For the bridge task while about half the sample mentioned area, only about half of these students also mentioned length, even though a ruler was listed among the materials provided to children.

Discussion

The questionnaire: The results of this study suggest that the questionnaire devised to assess primary preservice teachers' knowledge of links between mathematics and science was feasible for use in a group situation. Its main disadvantage was that the open-ended responses were difficult to categorise because insufficient details were given. Use of the questionnaire in an individual interview situation would overcome this problem but would increase the time required.

Identification of mathematical topics: The results are not reassuring in terms of student teachers' recognition of contexts for mathematical topics which should have been covered at primary and secondary school. Some students gave an impression of grasping at straws with suggestions such as "calculus", "trigonometry", "force". "Number" was frequently listed, presumably because measurement was suggested in all the teaching activities and measuring involves "numbers". However, the operations of addition, subtraction, multiplication, and division were mentioned only infrequently. Informal discussions with some of the students revealed that in their practice teaching experiences they were more likely to integrate science lessons with English or craft activities, rather than with mathematics.

One possible reason for not integrating mathematics with other curriculum areas may be that it is perceived to be a hierarchical and sequential subject that is difficult to program when planning thematic work. Another reason may be student teachers' lack of mathematical knowledge; the results of this study suggest that student teachers may not recognise applications of school mathematics when these are presented in unfamiliar contexts. Many student teachers may need guidance, not only in selecting worthwhile mathematical tasks, but in recognising opportunities to point out and consolidate mathematical concepts in other curriculum areas (Lappan and Theule-Lubienski, 1994).

Importance of prior knowledge: The factors that seemed to affect student teachers' identification of mathematical linking concepts appeared to be level of senior secondary science and age. The level of mathematics studied in the final years of secondary school did not seem to relate to the number or quality of the mathematical links made. Since this study was primarily exploratory, this finding needs replication, as well as explanation. It may be that science teachers build on mathematics knowledge, especially measurement, as part of their teaching, whereas the converse is less likely. However, in this study the science subjects taken at school were not considered separately; many students had taken biology in which mathematical connections are not commonly made. The effects of different science subjects also requires investigation.

There were several important limitations to this study. The first was the sample; students were at different stages in their courses and the two programs (BA Dip. Ed. and B.Ed.) have quite different approaches. The students in the BA Dip.Ed., although in their third year, were only in the first year of professional development units. A sample that included students from a wider range of tertiary institutions, and perhaps focussed on final year students, might give a clearer picture of factors that may influence effective integration.

A second limitation was that task order was the same for all students. Student teachers' responses to the last task (semaphores) were found to be least adequate. Students may have simply lost interest in this task or they may have been unfamiliar with semaphores as a system of communication. In any future study this limitation could be overcome by including only two tasks, counter balanced for order.

If teachers are expected to integrate science and mathematics instruction, integration must be included in preservice training (Lehman, 1994). The results of the present study show that preservice primary teachers did not find it easy to identify and articulate mathematical ideas in science contexts. Studies are needed to determine effective methods of assisting primary classroom teachers to integrate these two Key Learning Areas for concepts where there is a natural connection. Syllabus documents for both science and mathematics should also highlight specific links for key concepts.

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