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Teaching elementary science and technology in Ontario

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Abstract

In 1998 the Ontario Ministry of Education and Training mandated a science and technology curriculum for all Grade 1-8 students. Its purpose is to provide students with the scientific and technological knowledge and skills that will enable them to be productive members of society, with the ability to identify and analyze problems, and with the ability to explore and test solutions in a wide variety of contexts.

This paper describes an approach to teaching elementary science and technology developed through a partnership between a Faculty of Education and three local school boards. The approach has at its centre the concept of a Big Task, a significant activity which requires the use of knowledge, understanding and skill that has been taught in an integrated and holistic way. For students to be successful in a Big Task they need particular and appropriate knowledge, skill and understanding. These are taught through a series of Support Tasks: short, highly structured and focused activities.

Keywords: elementary, D&T, science, professional development

Introduction

This paper describes the first year of a three-year project in which elementary school teachers with minimal science and technology subject expertise work with five Queen’s University faculty and a graduate student to meet the needs of the newly introduced Ontario curriculum in science and technology for Grades 1 – 8. In the first year, 20 teachers have developed a common approach to teaching both science and technology at the elementary level and are writing curriculum materials.

Elementary science and technology in Ontario

In September 1998, the Ontario Ministry of Education and Training (MET) introduced a new science and technology curriculum for all Grade 1-8 students (Ministry of Education & Training, 1998). Its intended purpose is wide-ranging, including providing:

- The scientific and technological knowledge and skills that will enable [students] to be productive members of society.... To develop attitudes that will motivate them to use their knowledge and skills in a responsible manner.... [To]... develop ... skills that are ... important for effective functioning in the world of work ... [and] learn to identify and analyse problems and to explore and test solutions in a wide variety of contexts. (p 3)

The three goals of the curriculum are:
- To understand the basic concepts of science and technology;
- To develop the skills, strategies, and habits of mind required for scientific inquiry and technological design; and
- To relate scientific and technological knowledge to each other and to the world outside the school.

The learning expectations for science and technology are organized into five strands, defined as “the major areas of knowledge and skills” (MET, 1998:7). These are (a) Life Systems, (b) Matter and Materials, (c) Energy and Control, (d) Structures and Mechanisms, and (e) Earth and Space Systems. Table 1 shows the 40 topics for the five strands in Grades 1 to 8. In the curriculum document
the content to be covered in each of the topics is described at three levels; (a) in an overview, (b) in three overall expectations (goals) that “describe in general terms the knowledge and skills that students are expected to achieve” (MET, 1998:7) and (c) in a list of specific expectations that “describe the expected knowledge and skills in greater detail” (MET, 1998:7). Students’ learning is assessed using a rubric containing four levels of achievement (Barlex et al, 2000).

Issues arising from the Ontario elementary science and technology curriculum

Combining science and technology education into a single curriculum area gives rise to a number of philosophical, conceptual and practical issues. From a philosophical perspective it is clear that whilst science and technology are becoming increasingly interdependent they are fundamentally different in terms of purpose (Sparkes, 1993). Numerous writers have examined the relationship between science and technology, and the implications of that relationship for curriculum (Fensham, 1991; Fensham and Gardner, 1994; Gardner, 1994, 1995). There appears to be general agreement that the purpose of science education is largely explanatory, to provide the student with an understanding of the way the natural world operates and the contribution this understanding makes to the world in which we live. The purpose of technology education is often seen as largely interventionist. Students are invited to make a difference to the world through designing and making products and systems in response to needs, wants and opportunities. This does not deny the connections and overlap between the two subjects; indeed the contribution of each to the other is usually acknowledged. Clearly any approach to teaching a curriculum that includes both science and technology will need to take account of the different purposes of these two disciplines.

The organization of the expectations into the five chosen strands creates a number of conceptual problems. For example, the combination of structures with mechanisms, energy with control, and matter with materials is less logical than combining structures with matter and materials, mechanisms within a strand called control and having energy as an underlying theme in all strands. The

<table>
<thead>
<tr>
<th>Grade</th>
<th>Strand</th>
<th>(a) Life systems</th>
<th>(b) Matter and materials</th>
<th>(c) Energy and control</th>
<th>(d) Structures and mechanisms</th>
<th>(e) Earth and space systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 1</td>
<td>Characteristics &amp; needs of living things</td>
<td>Characteristics of objects &amp; properties of materials</td>
<td>Energy in our lives</td>
<td>Everyday structures</td>
<td>Daily &amp; seasonal cycles</td>
<td></td>
</tr>
<tr>
<td>Grade 2</td>
<td>Growth &amp; change in animals</td>
<td>Properties of liquids &amp; solids</td>
<td>Energy from wind and moving water</td>
<td>Movement</td>
<td>Air &amp; water in the environment</td>
<td></td>
</tr>
<tr>
<td>Grade 3</td>
<td>Growth &amp; change in plants</td>
<td>Magnetic &amp; charged materials</td>
<td>Forces &amp; movement</td>
<td>Stability</td>
<td>Soils in the environment</td>
<td></td>
</tr>
<tr>
<td>Grade 4</td>
<td>Habitats &amp; communities</td>
<td>Materials that transmit, reflect or absorb light or sound</td>
<td>Light &amp; sound energy</td>
<td>Pulleys and gears</td>
<td>Rocks, minerals, erosion</td>
<td></td>
</tr>
<tr>
<td>Grade 5</td>
<td>Human organ systems</td>
<td>Properties of and changes in matter</td>
<td>Conservation of energy</td>
<td>Forces acting on structures &amp; mechanisms</td>
<td>Weather</td>
<td></td>
</tr>
<tr>
<td>Grade 6</td>
<td>Diversity of living things</td>
<td>Properties of air &amp; characteristics of flight</td>
<td>Electricity</td>
<td>Motion</td>
<td>Space</td>
<td></td>
</tr>
<tr>
<td>Grade 7</td>
<td>Interactions within ecosystems</td>
<td>Pure substances &amp; mixtures</td>
<td>Heat</td>
<td>Structural strength &amp; stability</td>
<td>The Earth’s crust</td>
<td></td>
</tr>
<tr>
<td>Grade 8</td>
<td>Cells, tissues, organs &amp; systems</td>
<td>Fluids</td>
<td>Optics</td>
<td>Mechanical efficiency</td>
<td>Water systems</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 Strands and topics in the Ontario science and technology curriculum
conceptual problems are compounded by the way in which some strands are divided into topics and the content specified for particular topics.

The major practical problem with the curriculum arises from the diversity of the specific expectations within a particular topic. This can easily lead to the teaching of a sequence of lessons in which connections between the content are not evident to students. In addition, the curriculum provides great challenges to the majority of elementary school teachers, who do not have a science or technology background and who are unfamiliar with the equipment, tools and materials required to teach the subjects. One can reasonably ask, therefore, how elementary school teachers might begin.

A partnership to address the issues
While there are numerous collections of materials, units, and lesson plans already available for the new curriculum, simply copying and distributing materials to teachers is unlikely to provide them with the intellectual and practical support they need to use such materials effectively. This simplistic approach does not acknowledge the realities of teaching elementary school science and technology. An alternative approach involves helping teachers to acquire both subject and pedagogic expertise in science and technology developed through participating in the writing and piloting of classroom activities and the associated curriculum materials.

In early 1999, five members of the Faculty of Education at Queen’s University proposed to three local school boards the establishment of a three-year partnership to support teaching the new MET science and technology curriculum. The project, now underway, involves a small number of teachers (20 in Year 1, 20 more in Year 2, and 40 more in Year 3) who, through in-service work initiated by faculty, develop the expertise to answer questions for themselves about teaching and learning elementary science and technology. These innovators will then share their experience and understanding with other teachers. In this way the partner school boards will develop a significant group of teachers with expertise in teaching science and technology. This approach also provides teachers with opportunities to learn about science and technology that are closely tied to their immediate experiences and needs. As teachers become adept in particular areas of science and technology at the elementary level they can, in turn, act as resources to colleagues. The in-service work of the Elementary Science and Technology (EST) Partnership is built on the development of units, and on the novel conceptual model for EST manifested in the units, as described below.

The EST Partnership’s approach to teaching elementary science and technology
The approach to teaching developed by the EST Partnership has, at its centre, the concept of a Big Task (BT). A BT is a significant activity in which students have to use the knowledge, understanding and skill they have been taught in an integrated and holistic way. It forms a focal point in a teaching sequence and enables students to reveal what they have learned through what they can do. For students to be successful in a BT they will need particular and appropriate knowledge, skill and understanding. These are taught through a series of Support Tasks: short, highly structured and focused activities. The effectiveness of this teaching and learning is evidenced through the quality of response to the BT. This is a development of the Capability Task/Resource Task approach developed by the Nuffield Design and Technology Project in England (Barlex, 1995). This approach informed the inclusion of designing and making assignments (DMAs) and focussed practical tasks (FTPs) in the 1995 national Curriculum for Design and technology (School Curriculum & Assessment Authority, 1995).

In an EST unit that focuses on science, the Big Task is called a Big Question (BQ). Answering a BQ will require students to use knowledge of science processes and concepts to collect, organise and analyse data in order to produce a reasoned argument. Students may use data from their own investigations or
from secondary sources. They may present their answers in a variety of ways, for example, log book, individual or group presentations, formal report or multimedia presentations. For the topic Rocks and Minerals in the Grade 4 strand Earth and Space Systems students must answer the BQ: How do the properties of rocks and minerals affect the landscape? Support Tasks for this BQ include:

1. "What am I?" explores the difference between rocks and minerals.
2. "Where do I belong?" is intended to teach a student about classification.
3. "Test time" is intended to teach a student how to classify objects according to criteria.
4. "Do you know your rock groups?" is intended to teach a student how to recognise rocks types.
5. "Life long ago" is intended to teach a student about fossils.
6. "Make me!" is intended to teach a student about how soil is formed.
7. "How does it move?" is intended to teach a student about the effects of erosion on the landscape.
8. "Was it us?" investigates the effects of humans on the landscape.
9. "Rocks in our house" investigates the use of rocks and minerals in the manufacture of household items.

In an EST unit that focuses on technology, the Big Task is called a Design and Make Activity (DMA). A DMA requires students to intervene in, and make improvements to, the made world by designing something that they themselves can make and then making the product they have designed. Both the product and the processes by which it is conceived, developed and realised are significant in this activity. For the topic Everyday Structures in the Grade 1 Structures and Mechanisms strand students must respond to the following design brief: Design and make a home for a living creature that meets all of its needs. Support Tasks for this DMA include:

1. "Eye Spy a structure" has the student investigate the function of various structures.
2. "Types of structures" is intended to teach a student about box, frame and solid structures.
3. "Shapes and structures" has the student investigate the relationship between shape and structure.
4. "Fastening materials" is intended to teach a student ways of joining materials.
5. "How stable is it?" is intended to teach a student about stability.
6. "Building a box for a toy" is intended to teach a student the relationship between function and shape.
7. "Testing materials against the elements" is intended to teach a student about the properties of materials.
8. "Animals and their environments" requires a student to investigate the natural environment of a favourite animal.

The nature of the topic in the curriculum determines whether or not the focus of a curriculum materials unit is a BQ or a DMA. If the curriculum content in a topic is primarily scientific then the student will engage with one or more BQs. Similarly, if the content is primarily technological then the student will tackle one or more DMAs. In a few topics students may need to tackle both BQs and DMAs. Big Questions and Design and Make Activities allow teachers to cover the MET science and technology expectations in an innovative way, and motivate students to meet the expectations in a coherent and meaningful way.

Discussion

There is anecdotal evidence to suggest that the approach to elementary science and technology adopted by the Partnership is accessible to teachers, and that by using this approach to plan and teach the curriculum they develop ownership of it and become more autonomous as professional educators. Comments collected from teachers at the end of the second in-service session indicate that the EST approach is having an impact on four areas of their professional growth.

First, the teachers identified the importance of working with colleagues in overcoming the apprehension many teachers feel when faced with a new curriculum.

"I got here on Tuesday, quite apprehensive about what was going to happen."
“With the sense of team work and high degree of support I feel I have the confidence to begin the ‘Big Task’ that now awaits me!"

“The availability of colleagues and faculty helped me with the process.”

Two teachers, unable to maintain contact with their teacher partners, reported on how isolated they felt. Interestingly, over the first term these two teachers made significantly less progress in writing curriculum materials for their chosen topic.

A second impact of the in-service was to how some teachers thought about science and technology in the curriculum.

“The model you have introduced me to during these three days has really changed the way I think about teaching science and technology.”

“I am now looking at science and technology from a far different perspective.”

Third, many teachers began to appreciate the Project’s task-based approach to teaching elementary science and technology.

“I’m beginning with some very strong ideas about how my Big Question and Support Tasks are going to go.”

“I have a much clearer idea about what Big Questions and Design and Make Activities are.”

“I am able to change and modify (and reconstruct) my strand to meet the needs of my classroom, my science curriculum and School Board expectations based on the Big Task model.”

Finally, there is evidence of teachers understanding the implications of the Partnership’s approach for their teaching in the future.

“There is now a reason for all the ‘little activities’ we have always done: to design and make something for a purpose, not just because we have to. And to answer a Big Question for a reason, not just because we have to cover the curriculum.”

This same teacher reported how in introducing a topic on sound he used the pedagogic model with his class in the following way. He began by asking children what they wanted to know about sound. Having listed those questions on the board he told them about his question, that is, the BQ: “How do we and other animals hear?” He structured the Support Tasks to help the children answer not only his BQ but their own particular questions.

Planning for Year 2 of the partnership

In the second year of the partnership the units written in Year 1 will be further piloted by Year 1 teachers, with a particular emphasis on the collection of exemplars to illustrate attainment at particular achievement levels. This will inform the development of assessment instruments. Another 20 teachers will be brought into the Partnership to work with faculty members in developing curriculum materials for the remaining 20 topics. Faculty partners, working in consultation with both Year 1 and Year 2 teachers, will begin development of a Teacher’s Guide in preparation for the wider dissemination of all 40 units developed by the partnership.

Finally, faculty partners will extend the programme of research associated with the Project to include investigations into the following:

- The impact of the partnership approach on children’s learning in science and technology.
- The effectiveness of the partnership model of collaborative working between teachers and teacher educators in developing effective approaches to teaching and learning elementary science and technology.
- The impact of the partnership approach to elementary science and technology on the effectiveness of pre-service teacher education.

Conclusion

The introduction of new curricula
unsupported by in-service and professional development opportunities for teachers, and without the provision of related classroom materials, unduly burdens teachers and can lead to subjects being taught inauthentically.

The EST Partnership provides teachers with a professional development activity that supports their efforts to implement a new curriculum. Evidence suggests that the partnership has assisted teachers interpret curriculum expectations, and develop the expertise to answer questions for themselves about teaching elementary science and technology. At the same time teachers have been introduced to a model for teaching science and technology that reflects the integrity of the two disciplines.

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