Linking mathematics, science and technology in the elementary classroom

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Abstract

Teacher candidates at Queen's University participated in a two-week integration project that de-emphasised subject-specific tasks and instead focused on subject integration across mathematics, science and technology (MST). The project was grounded in technology, with the associated mathematics and science concepts being discussed as they emerged.

The project highlighted a number of issues related to teaching MST. Many participants were unaware that technological education focuses on both designing and making. They did not have the knowledge or the skills to model with three-dimensional materials. Participants were unable to invoke relevant mathematics and science principles while designing and making. Some were enthused, others claimed the project was not worthwhile, reflecting the typical classroom in which some students will respond positively to a particular learning experience while others will not. The project also raised questions about the most effective ways to ensure that students not only use but also understand relevant concepts from design and technology, mathematics and science.

CURRICULUM DEVELOPMENT

Introduction

What do dinosaurs, rabbits, elephants and spiders have in common? During a Mathematics, Science and Technology (MST) Integration Project held at the Queen's Faculty of Education, each was the inspiration for a puppet controlled by levers and linkages. Over the past two years, instructors at the Faculty have explored various methods of providing all pre-service junior-intermediate teachers with background experience in the integration of subjects. Five classes, totalling 150 teacher candidates, participated in a two-week integration project that de-emphasised subject-specific tasks and focused on subject integration.

The Common Curriculum (Ontario Ministry of Education and Training, 1995), which now determines the curriculum in Ontario schools for grades one to nine, organises subjects into four clusters, one of which is mathematics, science and technology. The document states that "mathematics, science and technology are related disciplines that enable us to understand and live in harmony with the natural world and to contribute to responsible development of the human-made world" (p. 70).

We decided that the project would be grounded in technology, with the associated mathematics and science concepts being discussed as they emerged. *The Common Curriculum* outcomes for Grade 6 were reviewed and the following chosen as a focus: "Safely use tools, equipment and materials in designing and building structures, mechanisms and systems that include control devices" (p. 75). From this focus, the use of levers and linkages was selected as a specific topic which could be successfully explored and developed by participants within a two-week period.

Planning the activity

Participants met twice with instructors during regular mathematics and science curriculum course times, once at the beginning and again at the end of the project. Self-selected teams of 2 to 4 met and worked both during and between these scheduled times. Upon return to regular classes, participants were asked to reflect on their experience.

A classroom was organised and equipped to demonstrate that the project could be run in any elementary school. This was critical if the project was to be accepted by pre-service teachers as one which could be used with their students, since most elementary schools do not have purpose-built technological education facilities. Flat tables were arranged in groups to provide large work surfaces. Each work area was supplied with a "tool kit" containing equipment appropriate for young students and consumable materials readily available in an elementary school.

At the first meeting the logistics of the project were described. This was followed by an introduction to the underlying philosophy of technological education, and a discussion of its role in the curriculum. Although skills-based industrial arts would have been available during their high school days, few of the participants had completed these courses. Fewer yet had any

Teacher candidates demonstrate levers and linkages in puppets designed as part of an MST integration project held at the Queen's Faculty of Education

experience of contemporary technological education, with its focus on both designing and making.

Material was presented to illustrate that designing and making lies at the heart of all technological activity. The steps in a simple design process were described, emphasising that all designing and making derives from a context. From this context a specific need is identified and described, which in turn leads to the generation and building of a solution. The first meeting also included an introduction to related technical knowledge, that is, the six simple machines and levers. Discussions and demonstrations illustrated the three classes of levers, how levers may be combined into linkages, and how motion and linkages are connected.

In the first year of the pilot, participants were given the following context: "During a recent visit to a day care centre one of the teachers commented that very young children like to play with animated toys. Unfortunately, the school has no money for extra toys and the teachers do not have the time or facilities to make them. Your own teacher has told you that in the near future you will be studying how simple machines work and has suggested that we combine this new learning with an attempt to help the children and teachers at the day care centre." From this context the following design brief was derived: "Design and make an animated toy for children age two to five years. The toy must have moving parts operated by levers and linkages."

In the second year of the project links were made between MST and drama. As part of their drama programme participants were asked to create a legend based on the origin of some natural phenomenon. For example, one group chose to explain the origin of rainbows. They developed a narrative and a set of characters, isolated the movements of each, and then designed and built appropriate puppets.

Once designing and making began, participants were required to identify where the mathematics and science occurred. A chart was provided in which they could describe when and where relevant concepts were invoked. As pre-service teachers, they were asked to think about how they would make the connections with elementary school students.

Making the puppets

While design process theory proposes that designers sketch several possible solutions before moving to modelling with three-dimensional materials, instructors found that participants, as novices, did not do this. They moved quickly, and frequently directly, from problem identification to manipulating

"Designing and making" were new experiences for most teacher candidates involved in the MST integration project

materials, often generating solutions and manipulating three-dimensional materials simultaneously. For example, one reported "my partner and I worked on a trial and error basis. We didn't think about what we wanted before we started. We merrily barrelled along until we ran into a problem. When [this happened] we were forced to step back and reconsider [our ideas]". This approach to designing is supported by research on expert/novice problem solving, which has shown that at the beginning of a problem-solving episode experts spend more time attempting to "understand" the problem, whereas novices move more quickly to solution generation (Chi, Glaser, & Farr, 1988). This was an important element of follow-up at the project's conclusion, for it has implications for the way in which elementary students are required to explore and represent ideas.

As modelling with paper and cardboard continued, participants explored both the shape and form of the puppets, and the mechanisms that would operate their moving parts. Instructors worked with individual teams during this phase of the project, helping with but not giving the answers. This was much appreciated, for as one participant reported "we felt like the ideas were ours, and they were"

Cooperative learning also added to the success of the project. According to one participant, this "fostered learning ... [and provided] the opportunity to discover our own knowledge". Another reported "because we were all involved in the same task a real sense of togetherness evolved". Providing a friendly atmosphere where participants were encouraged to attempt new things and risk being wrong was reported as crucial to learning.

Rich discussions evolved as the puppets took shape. Some participants noted the difficulties involved in designing simple linkages. They had a very clear idea of what they wanted puppets to do: jaws of animals to open and close; tails to wag; or arms and legs to move simultaneously. Yet some were unable to design a linkage that would allow their puppet to move in the desired way. As a result they often compromised by simplifying the movements. This was a valuable learning experience, for not only were participants developing an understanding of the complexities of designing linkages, they were also experiencing the difficulties that elementary students might have translating ideas in the "mind's eye" into three-dimensional models. One participant wrote "when my students are struggling with a concept that I find extremely simple, [I'll] think back to my puppet-making experience. This [will help] me to understand what they are going

The linkages and levers integration project highlighted a number of issues related to the integration of mathematics, science and technology

through". At the same time, participants agreed that it was fun and that a huge amount of learning was going on. As one reported "learning about ... levers was much easier and much more interesting in the context of puppets and our legends than if the concept was introduced in a traditional, abstract way".

Reflecting on integration

The pilot project highlighted a number of issues related to the integration of mathematics, science and technology. First, many participants were unaware that technological education focuses on designing and making: that designing precedes making. Neither did they have the knowledge or the skills to model with three-dimensional materials. What emerged was the need for time to experience the technology, that is, designing and making.

Second, many participants were unable to invoke relevant mathematics and science principles while designing and making. It was evident that while building the puppets the focus was on solving immediate problems in a pragmatic way by manipulating materials. Use was made of a design process, technical knowledge and skills, principles of force and balance, measurement, and ratios. Yet neither the mathematical or scientific principles were identified or consciously called upon as designing and making continued. As a result they were not used to their full potential. While reflecting on the project, one participant said "trial and error was the strategy we employed to arrive ...at ... a puppet. The trial method did not mean that I understood [the science and mathematics of levers and linkages]". The focus was on "How do I do it?" and not on "Why does it work?"

It appears that the underlying mathematics and science principles were not "caught" while the puppets were being built. Hence, the essential ideas may have to be taught and the connection between the nature of the technological process and the mathematics and scientific concepts made evident. There are a variety of ways to do this, raising questions about the most effective approach to teaching in an integrated classroom.

For example, one could teach relevant concepts prior to setting a technological context and addressing design issues. This approach would mean that they are initially treated in an abstract way. While a few participants commented that they would have preferred the theory before the practice, the vast majority highlighted the importance of "learning by doing". However, as described above, there is reason to

doubt that they were learning the mathematics and the science.

It is also possible to provide mini-lessons as relevant issues arise in class. In this, a balance must be struck between the time devoted to exploring the mathematics and science issues while maintaining continuity of effort on the designing and making. The complexity and newness of the project may be critical to this approach. In the linkages and levers project most participants were able to meet with success without ever being concerned with mathematical or scientific concepts revealed by the exercise. Participants were shown examples of puppets operated by levers and therefore were not designing a solution in a knowledge vacuum. This may have reduced their need to learn and apply the underlying concepts.

Another possibility is to design and make a technological project and then, upon its completion, analyse it from a mathematics and science perspective. This may be the least effective approach for stimulating thought. For many, there may no longer be a "need to know".

The relevance of the project to participants' future classroom practice was the third issue to emerge. Some were enthused: one reported "I learned a great deal from this project and intend on using a similar activity in my own classroom one day". Others incorporated their learning from the experience into a subsequent student teaching round. On the other hand, some claimed they learned little and did not find it worthwhile. Consequently they did not intend to replicate the experience with their own elementary students. This divergence of view itself provided a source of discussion, for it mirrors the reality of the classroom where some students will respond positively to a particular learning experience while others will not.

Fourth, and finally, participants' became aware of the need to use correct terminology. This was prompted by, on one occasion, use of the term "thing". In attempting to describe to her group the way in which she had designed a particular linkage, she said "... and I had to put an extra thing here". When asked by an instructor what was meant by "thing", she said "a lever". This led to a discussion about the domain-specific language that should be introduced and used in an MST classroom. It was agreed that teachers must set an example by using appropriate terms and insist that students do the same.

Conclusion

What has been learned from this pilot MST integration project? Pre-service teachers and instructors acknowledged that the experience of designing and making puppets demonstrated the value of both placing a task in context and learning by doing. They witnessed that mathematics, science and technology can be integrated and taught in a regular elementary classroom using simple tools and materials. At the same time the project has raised questions about the most effective way to ensure that students not only use but also understand mathematics and science concepts.

References

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