Teaching and Learning in Integrated Settings

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Abstract

This study describes two examples of curriculum integration in mathematics, science and technology involving technology-based projects and Year 8 students. The projects incorporated differing degrees of integration and cooperation between teachers from the respective subject areas and were met with varying levels of enthusiasm by the students who participated. The scope of the study was to look beyond whether the students enjoyed the projects and investigate what learning took place in these integrated settings. A variety of data collection methods was employed, including field notes, interviews, photographs and the collection of artefacts such as teaching notes and work samples. Students' concept maps and learning journals provided valuable insights about the learning that took place in each project. The study theorises on the factors that may have influenced the success or otherwise of each project.

Introduction

In a world facing increasingly complex social and political problems there is a growing need for interdisciplinary collaboration between people of differing professional backgrounds and with this has come an emergence of new professions that are at the cusp of previously separate disciplines. Societal changes are being mirrored in our school system with moves towards greater integration of the disciplines that make up the traditional curriculum. The momentum for integration has been driven by a vision that it can bring into being a learning that is connective, transmissible and motivating. It is seen as a means of reengaging young people, many of whom are alienated from school, in learning that is both purposeful and accessible (Barab & Landa, 1997; Cumming, 1994; Perkins, 1991; Yager 1999).

Integration takes many forms and the word conjures different meanings to different people. Much research has been done that describes the different forms of integration, how they are implemented and how they might be sustained (Hargreaves, Earl & Ryan 1996; Vars & Beane, 200; Wallace, Rennie, Malone & Venville 2001). There are abundant and sometimes extravagant claims for the success of integration that seek to persuade us that integration is the panacea of an ailing education system. These claims tend to be testimonial in nature, written by teachers inspired by the excitement, effort and cooperation of their students while working on integrated projects but they fail to provide empirical evidence of what learning is taking place in these settings and the factors that facilitate that learning. This is a point not lost on the critics of integration or its supporting literature (Czerniak, Weber, Sandmann & Ahern, 1999; George, 1996; Panaritis, 1995) who point to the need for further research in order to establish what is gained and what is lost through integration and how this might be measured.

One approach that has produced promising results is that of the integrated technology-based project. (LaPorte & Sanders, 1993; Sanders, 1994; Ross & Hogaboam-Gray, 1998; Venville, Wallace, Rennie & Malone 2000). Technology, in this instance, is the study of the development of technological solutions to specific problems. These projects involve the integration of mathematics, science and technology through the vehicle of a technology project. The case studies described in this paper involved a school that had adopted this particular approach.

The study school had a history of integrated technology-based projects that were first introduced with academic extension groups. The success of these projects led teachers to develop modified projects to motivate and encourage groups of low achievers. Once again, this approach proved successful and was the catalyst for the development of a series of projects to suit mainstream Year 8 groups. The research tracked a mainstream Year 8 class and a group of Year 10 students in an academic extension program. It examined the context, teaching strategies, student engagement and learning that took place during these projects. Two of the Year 8 projects are presented here for comparative purposes. They produced contrasting levels of success in the classroom and illustrate both advantages and pitfalls in this kind of curriculum approach.

The Research

Each case study was conducted over a full school term with the opportunity for prolonged engagement and persistent observation (Guba & Lincoln, 1998) in order to describe in detail the structural, pedagogical and learning characteristics of each setting. Several complementary monitoring tools were employed including direct observation of performance tasks, field notes, interviews, concept mapping, audio taping, photographs, learning journals and analysis of artefacts such as student portfolios and teaching notes. The focus was to utilise research and assessment techniques that were primarily based on actual classroom tasks and to provide sufficient data to ensure a rich description (Denzin & Lincoln, 2000) of the events that unfolded in each group. The projects described in each case study were completed by the same class, under the direction of the same two teachers. One teacher was responsible for the mathematics and science and the other was the technology teacher.

Project 1: Rocket Racers

This project took place during the second school term and involved students in designing and building model rocket cars powered by compressed air. The technology teacher assigned students the brief to design and build a vehicle powered by compressed air. The vehicle had to be capable of travelling along a 33 metre guide-track with the aim being to produce the fastest vehicle over the distance. The vehicle needed to follow the track, and a sample of the track material (made from 25 mm wide u-shaped plastic channel) was put on display so that students could take measurements and consider suitable guidance systems. The class was then shown a selection of possible construction materials and tools at their disposal. The only item that the students were asked to supply was a clean, empty 600 mL plastic soft-drink bottle.

For this project students were expected to follow a design→ make→ evaluate→change process. After some discussion about the design, a few factors that would require consideration were established and listed on the whiteboard. These included:

- Aerodynamics: What shapes can lessen wind resistance?
- Materials to be used: How can the vehicle be made lightweight without compromising its strength?
- The track: What do you need to know about the track before you build your vehicle?
- Guidance system: How will the vehicle follow the track?

Meanwhile, the science/mathematics teacher began introducing the science topics relating to this project. Students began exploring concepts related to energy transfer, including force, work, power and efficiency. Tasks included naming and describing three forces acting on the rocket racer and drawing a diagram to show the direction in which these forces are acting. Students also had to explain why all the potential energy from the compressed air was not transferred to the kinetic energy of the rocket racer and describe how factors affecting friction would influence the design of the vehicle.

The process of building the vehicle required students to use mathematics in the measurement of heights, widths, lengths and diameters. The science/mathematics teacher ensured that students could recall the definitions of radius, diameter and circumference; that they remembered how to draw a net of a cone and were aware of the relationship between mass and volume of water. She also revised scale with the class as all designs had to be drawn on a scale of 1:2. The main mathematical learning involved planning for the collection of data during the testing phase. Discussion with the class established that three variables were to be considered during the trials: the mass of the vehicle, the volume of water added and the diameter of the hole in the bottle's screw cap. Each group was asked to design a table in which they could collect and record the data they would require for analysis in order to improve the performance of their vehicles. During the testing process, groups used stopwatches to time their vehicles. If the vehicles did not travel to the end of the track, the distance travelled was measured using a trundle wheel and the time recorded for that distance. These measurements were later used in the mathematics class to calculate the speeds attained by their vehicles and produce computer-generated graphs of the results.

Designing and Building the Racers

The students were anxious to begin building their vehicles, but reluctant to spend time on the design phase of the process. Their designs showed that they had given little consideration to the points that had been discussed earlier—how to lessen wind resistance, how to make the vehicle lightweight without compromising its strength, and how to make it stay on the track. The designs were very simple (Figure 1) mostly consisting of a chassis of rectangular aluminium bent to form shallow sides through which were drilled holes to accommodate the axles. The soft-drink bottles were taped to the chassis.

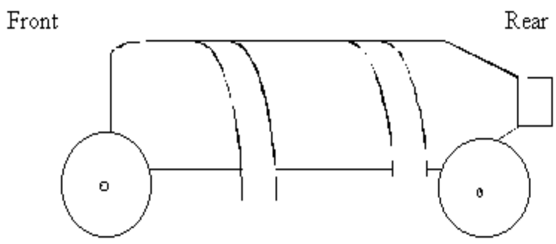

Figure 1

Testing the Rocket Racers

The testing of the first prototypes revealed the many design problems. Most vehicles only travelled a short distance and then either stopped or left the track. The students began to realise that this project was more complex than they had first thought. Some of the problems they encountered included:

- Vehicles rubbing on the track or becoming suspended on it. This problem occurred because students had not checked the height measurements that would be required for the vehicle to clear the track. They had either chosen wheels that were too small or had not considered the consequences of where they drilled the holes on the chassis for the axles.
- Chassis and wheels contacting each other. The teacher pointed out to most groups that this was causing friction and there was a need to insert a spacer on the axles between the wheels and chassis.
- Inadequate guidance system. Some groups tried setting the wheels on one side of the vehicle into the channel of the guide track, but this did not produce good results. Others attached a system that created too much friction while others found that their system was too fragile to withstand the testing procedure.

It had been planned for the science/mathematics teacher to be present during the vehicle trials, but on each occasion she was called upon to cover for teachers who were absent. This left the technology teacher to deal single-handedly with the emerging problems of vehicle design and performance. After the second day of trials, students appeared to have exhausted their ideas about how to improve their vehicles. None of the groups produced a vehicle that would reach the end of the track or even perform consistently.

After this session the technology teacher built a vehicle of his own. He produced it at the beginning of the third day of trials and the students instantly started asking questions such as, "Is that the winning car? Is that the right car?" They appeared to believe that there was one correct design solution and, before they saw the vehicle being tested, began to modify their own vehicles to match this design. They frantically drilled holes in the chassis to make it lighter. Four groups attached plastic nose cones to their cars, but only two could explain that the purpose was to improve the aerodynamics of the vehicle. Everyone came to watch the teacher’s vehicle being tested, but the car only travelled a short distance along the track then came to a stop. The teacher measured the distance (about 5 metres) then picked up his car and told the students, "I think it might be too heavy. I added 300 mL of water so I’ll try it with 200 mL next time and see what happens." He continued to systematically change a variable then test the car, each time recording the results on the whiteboard. This produced the desired impact on the students and they stopped making random changes to their own vehicles and began to work methodically. By the end of the lesson, all of the vehicles had improved and several were consistently reaching the end of the track and would have gone much further if there hadn't been a buffer to stop them.

Assessment

Student assessment was based on the quality of their record keeping as well as the finished vehicle's performance. On completion of the project each group was asked to create a concept map using a number of given terms or concepts related to the rocket-car task. Each group was given a photocopied list of key terms to be linked in the concept map. The words in the list were cut out and the groups discussed, arranged and rearranged the layout of the words on the page until they were satisfied that the best layout had been achieved. Only then did they paste the words onto the page and write in the linking constructs. The students were told that the purpose of the activity was to demonstrate how much they had learned from working on the rocket racer project and the list of key terms was only intended to get them started on the process. They were encouraged to add in any other key terms that were necessary to make their concept maps complete. The concept maps were used to further inform judgements about the quality and depth of learning that had taken place.

The students who produced the winning car also produced a well organised and well-linked concept map. One student, who had worked individually, produced a car that performed reasonably well to begin with but, as she made changes, the vehicle's performance deteriorated and she seemed unable to make the modifications that would result in improvement. Her concept map revealed that she had a very limited understanding of what she was doing and it seems likely that her early successes were more by luck than design. One group had added an animal-shaped superstructure to their car, which did not enhance its aerodynamic qualities and added considerably to its mass, yet they produced an excellent concept map showing a sophisticated understanding of the relationships between the given terms (Figure 2). They clearly understood the concepts involved in the task, but that level of understanding had not been apparent at any time when they were experimenting with their vehicle.

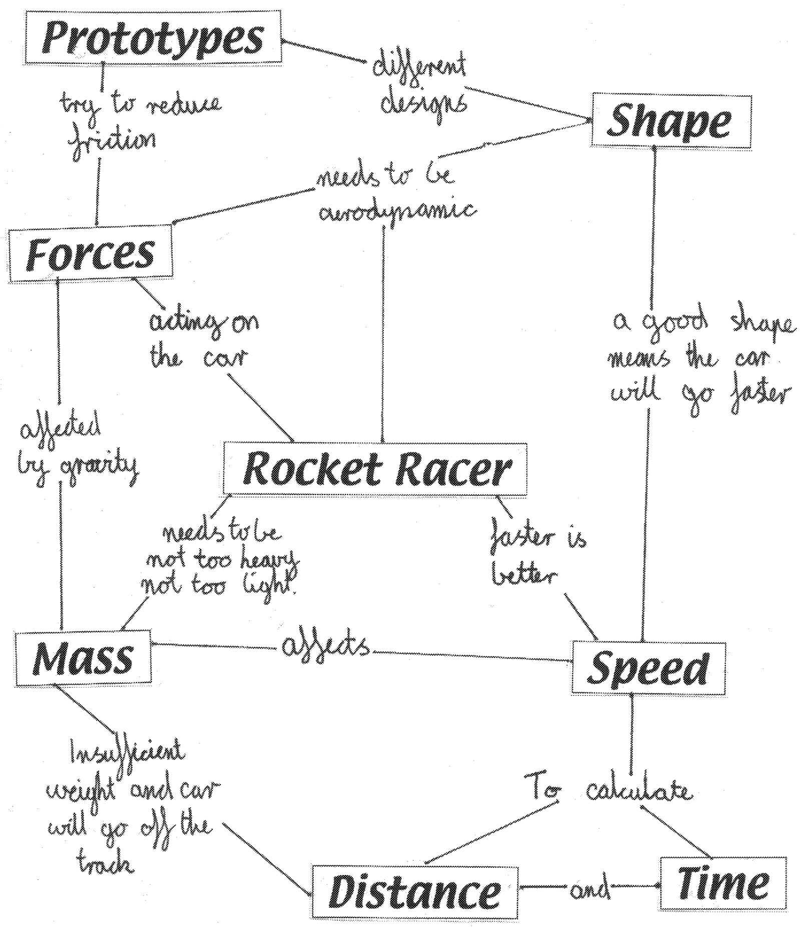

Figure 2

Discussion

Learning Outcomes

Given the time and effort put into this project by the teachers, the level of learning revealed by the concept mapping activity was not encouraging. Although there was some evidence of learning and a few of the students showed a robust understanding of the concepts involved, for many of the students the outcomes were disappointing. Eight groups and one individual completed a concept map. Two groups failed to note a connection between the speed and shape, and three groups failed to note a connection between mass and speed. Only two groups noted the effects of friction anywhere in their concept maps and three groups were unable to link any of the forces acting on the vehicle. None of the groups added to the key terms supplied by the teacher.

Motivation

This lack of learning was especially apparent for the two or three behaviourally difficult students in the class. These students described the task as boring. Their levels of motivation remained low throughout the project and little was achieved. In fact, the levels of motivation were generally quite disappointing from all students, given the nature of the project, the enthusiasm and patience of the teachers, the materials and equipment at their disposal and the opportunity that the project presented to work on a collaborative, practical activity. One example of this lack of motivation came when the students were asked to supply the empty soft-drink bottle for their vehicles. None were supplied.

Application of Knowledge

Students seemed to have difficulty in making connections between what they were learning in science and mathematics and the problems they had to solve in technology. They seemed unwilling or unable to recognise the usefulness of their knowledge or to apply it. For example, while investigating variables was a major component of the science and mathematics teaching, it was not until the third day of testing, when the technology teacher modelled the process, that the students applied this skill. Students measured the dimensions of the track but failed to recognise the implications of these measurements for the vehicle's design. The fact that none of the students attempted to give their vehicle a more aerodynamic shape or that many had failed to consider the effect of friction in spite of these topic being explicitly covered during the science lessons also indicates that the connections to the science and mathematics taught had not been made. The claimed advantages of integration—that it results in learning rich with connection making, and students who are more cooperative, involved and excited—were not evident during this project.

Project 2: Submarines

This project took place later in the year, during the fourth school term, and involved the same group of students in building and testing model submarines that had been devised and designed by the technology teacher. Unlike the previous project, the students were not required to design their vessels, however, the initial reaction to the project was one of resistance from a number of students. The teacher had to strive to hold their attention during the introductory lesson. Students were first shown the submarine design by the technology teacher, who provided a full sized cut-away model in order that they could see all the operating parts and how they worked. Figure 3 illustrates what the students were able to see on this model.

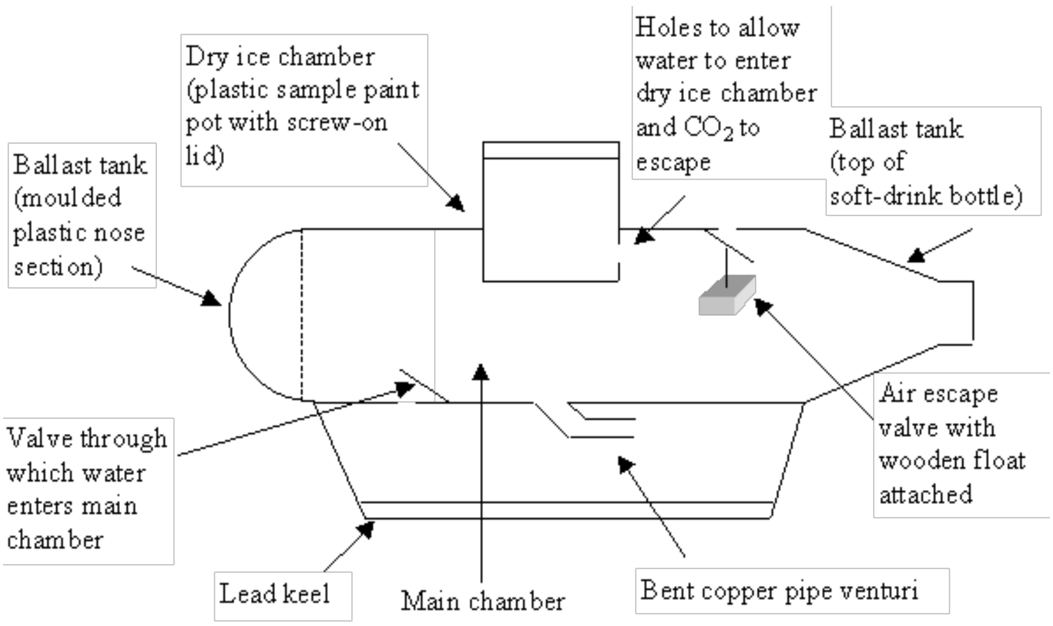

Figure 3

The operation of the submarine involves water entering through the lower valve and air escaping through the top valve, which is held open by a wooden float. As the water level rises, the submarine sinks. The float holding the top valve open rises with the water, eventually allowing the valve to close. When water enters the dry ice canister, the dry ice starts to vaporise more quickly, filling the main chamber with carbon dioxide gas and forcing the water out through the copper pipe, which propels the submarine forward. The submarine's buoyancy increases because the water has been displaced by CO_2, and it returns to the surface for the cycle to repeat.

The building of the submarines took place under the supervision of the technology teacher, while in science, students covered topics such as floating, sinking, buoyancy, Archimedes' Principle, density, states of matter, air pressure and jet propulsion. Students also researched the history of submarines and the parts of a submarine. There were two major mathematics components to this project. The first required students to examine units and instruments available for measuring things and to investigate how much measurement error is tolerable in various circumstances. The importance of accuracy in measurement quickly became apparent during the building process because components that did not fit well together created gaps that were a difficult and messy to seal. The second mathematics component was to read from scale drawings, a skill that would be required to follow the instruction sheets for each of the submarine's components—the keel, the conning tower, the valves and the fore and aft ballast tanks—prepared by the technology teacher. Students were also asked to solve the problem of how to rule two lines equidistant from each other along the upper and lower surface of the submarine's cylindrical hull.

As a result of previous experiences in running this project, the science/mathematics teacher also dedicated an entire lesson to trouble-shooting: "What can you do if . . . happens?" Past experiences had taught staff that, in spite of doing a number of projects where the model of *make ® evaluate ® change* was used, many of the students gave up very quickly if they didn't have immediate success.

Testing the Vessels

Testing was conducted at a nearby swimming pool. Before starting, the students were reminded of the variables (ballast in fore and aft tanks and mass of lead on the keel) that they would have to measure and trim in order to get the submarine to work correctly. These measurements had to be taken and recorded before the submarines entered the water. The first tests were done without dry ice and were conducted to ensure that the submarine would sink nose-first all the way to the bottom of the pool then sit level when it settled there. Once the students were sure that their submarines were correctly trimmed, they were allowed to proceed with the test using dry ice. Most groups had to solve a few problems to begin with, but once they were operating successfully, the submarines would porpoise through the water, diving and resurfacing about four or five times before having to be refuelled.

Assessment

Part of the assessment was based on the finished product. However, students also completed an activity booklet for science and mathematics incorporating independent research activities and classroom activities. The technology report allowed the teacher to evaluate how accurately each group had set the variables, observed what happened, recorded the results and made changes as required. During the building process the students also kept a learning journal in which questions were posed and the teachers responded to the answers given by the students. This proved to be an effective way of keeping track of the level of understanding each student had about the project and addressing any misconceptions that arose along the way.

Discussion

Learning Outcomes

The learning journals provided evidence that learning was taking place and were also a useful means of assisting that learning to occur. The questions probed the students' understandings and the teachers were quickly able to respond to any misconceptions that emerged or to help any students who had not grasped a concept. One commonly occurring misconception was that the submarine would be propelled by air escaping through the venturi. For a number of students, this misconception was dealt with through a dialogue in the learning journal, for example:

> T. What would you expect to see if air was coming out from the venturi?
>
> S. Bubbles
>
> T. The space above the venturi is filled with water so how does the air reach the venturi?
>
> S. Is it water that comes out?
>
> T. Look closely when you test your submarine. If you see bubbles then there must be air but if there are no bubbles then it must be water.

Incomplete answers could be expanded through these written dialogues but, occasionally, a student was unable to offer any answer to the question posed. In these circumstances the teacher was able to give the student some individual time to ensure the necessary understanding. A sound understanding of the process by which the submarine operated was fundamental to being able to solve problems on testing day so it was vital to ensure that the learning had taken place before the students took their submarines to the pool.

Motivation

When the project was first introduced to the class, the students appeared to show little motivation or interest. However, as the building process began, their level of involvement increased and by testing day every group had managed to produce a vessel ready to be launched.

Application of Knowledge

It is unlikely that the students would have remained focussed on their tasks or persevered to make their submarines work without the input from the lesson devoted to trouble-shooting. When problems were encountered, the teachers were able to guide students to apply their knowledge to figure out solutions for themselves by asking questions such as: Why will your submarine not resurface if you are seeing bubbles escaping from the top valve? How can you get that valve to seal?

In Conclusion

Why did these two projects produce such different outcomes in terms of student learning and motivation? The first thing that should be noted is the essential difference between the two projects—that is that the rocket racer involved a design ® make ®evaluate ® change process whereas the submarine project did not require any design input from the students. The design process was certainly an area of weakness for these students. This fact was recognised by the technology teacher and the students themselves in interviews that were conducted after completion of the rocket racer project. When asked if they would do anything differently, the majority of students interviewed commented that they would give more attention to the design and planning stage with comments such as:

> We didn't know until we put it together that we needed more planning. (Matt)
>
> We should have thought about it more. We were a bit ahead of ourselves. (Josh)
>
> Think of where things are going to be, not just parts of it. (Louise)

Students may have preferred to avoid the design phase, but it seems unlikely that this would be the only factor influencing the success or otherwise of the projects.

It could also be argued that, because the second project was carried out at the end of the year, the students were more familiar with the style of learning and were better able to respond to it. However, the manner in which the submarine project was initially received did not augur well for its future. Furthermore, conducting a project in the final term of a school year (Christmas) is fraught with setbacks. Several lessons were cancelled or rescheduled because of competing demands on the timetable and with so many other things happening, it would have been easy for the students to lose interest in the project.

Another difference between these two projects was in how the connections were made between the science, the mathematics and the technology. During the rocket racer project the science/mathematics teacher was unable to follow the work she had been covering through to the testing phase and integration was left entirely to the technology teacher. This may have obscured the interconnectedness of the subjects or even conveyed an unintended message to the students about the importance of applying the science and mathematics making it less likely that any transfer of learning would take place. During the submarine project, on the other hand, the science/mathematics teacher was able to become much more involved in the preparation of the submarines and the testing process.

The events described in the two case studies show that the success of integrated programs cannot be assumed. Students are not necessarily motivated, engaged or learning, never mind connecting learning across subject boundaries. Both projects were conceptually and pedagogically sound. They were well supported by materials and by teachers who were committed to the notion of integration. There was also good support from the school administration to enable teacher collaboration and the scheduling of mathematics, science and technology as an amalgamated unit. However, factors such as student willingness and readiness to learn, as well as their maturity may have contributed to the outcomes. The success of integrated teaching can be attributed to a complex and sometimes subtle web of factors including the supply of quality materials, a supportive culture, and qualified, committed and collaborative teachers. It is possible that students who have trouble recognising the connections between integrated subjects are helped by seeing the teachers jointly conduct some of the lessons, therefore, factors such as student receptiveness, prior experience and their perceptions must also be taken into account. Successful integration should not be a matter of chance. We must develop models that will enable teachers to find an appropriate pathway to successful integration that delivers improved outcomes for students in terms of motivation, engagement and connective learning and that are manageable and sustainable for teachers.

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