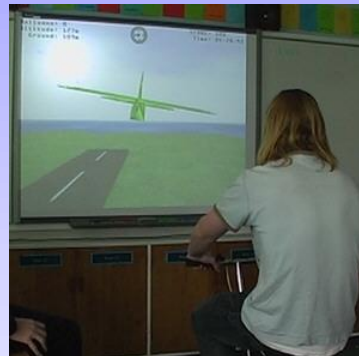


Authentic learning using mobile sensor technology with reflections on the state of science education in New Zealand



**A research project for the New Zealand
Ministry of Education**

Michael Fenton M.Sc, Dip. Tchg.
mikefentonnz.github.io

**e-Learning Fellow
2008**

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Michael Fenton M.Sc., Dip. Tchg.

Ministry of Education e-Learning Fellow 2008
Microsoft Innovative Teacher 2008

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ABSTRACT

RIGEL is a general purpose mobile technology consisting of a hand-held computer, sensors, and associated software invented by the author, Michael Fenton. During this project, RIGEL was to be tested for its suitability for two different teaching pedagogies:

- an enquiry-learning focused (constructivist) class of Year 7 & 8 students.
- an NCEA assessment focused (positivist) class of Year 13 Calculus students.

The study covered the following broad research questions:

1. How does the use of RIGEL support authentic learning?
2. How does the use of RIGEL support higher level thinking?
3. How does the use of RIGEL support students developing a greater understanding about the nature of science?
4. As a new ICT, what problem(s) does this technology solve?

The combined Year 7/8 class was surveyed and interviewed after interventions using the RIGEL technology. 85% of the 26 students had changed their views about the way scientists worked, 85% were more interested in science and inventing than before the intervention, and RIGEL was as successful with females as males – there was no gender difference noted.

The Year 13 mathematics students were able to articulate their own definitions of authentic learning, and devised challenges for each other to complete. A comparison of problem based learning (PBL) and the use of case based instruction (CBI) confirmed research that using CBI is a more effective teaching pedagogy than PBL or traditional approaches. The CBI intervention also confirmed earlier findings from the MOTIS and CAS reports that the appropriate use of data loggers can support high level thinking and authentic learning.

Interventions focused on students using computer technology based in real space, as opposed to using computers to work in cyberspace. Findings indicated that:

- Most primary students reached the relational stage of the SOLO taxonomy
- Most students were cognitively as well as physically engaged
- Most primary students changed their views about the nature of science
- RIGEL can be used to raise science teacher self-efficacy and encourage greater practical work as required by the science curriculum document.

Since RIGEL is a new ICT, a subsidiary question “what problem(s) does this technology solve?”

Findings indicate that RIGEL used as a mobile technology:

- permits meaningful science in primary and secondary schools
- permits students to test science text for incorrect concepts or “facts”
- lets learners experience the nature of science

- assists learners with hearing or visual impairment to engage in science
- supports extension as well as accelerated learning programmes for gifted and talented students.
- supports teacher professional development to raising teacher self-efficacy with regard to doing more practical science investigations with students
- supports the *Ka Hikitia* strategy document for Maori education

In the wider context of influencing classroom practice, a number of recommendations are made based of the findings of this research project and issues arising from the literature. Some of these include:

- The use of a new tool, the PACE score, to put pedagogy and creativity on an equal footing with assessment.
- Focusing on students developing a genuine understanding the nature of science in New Zealand schools with modern technology.
- A review panel explore workload and professional development issues to raise the quality of teaching and increase the number of authentic practical investigations in science classes.
- Closer working relationships with professional science associations and tertiary institutes to remedy basic errors of fact perpetuated through the cycle of NCEA assessments and common texts study guides used to prepare for NCEA assessments.

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INTRODUCTION

Professional background

I became a secondary school teacher in 1995 after gaining a post-graduate qualification in science and after 5 years teaching and research at Massey University.

Since then I have taught secondary and tertiary classes in the sciences, mathematics, and information & communications technology (ICT). I have also written 3D games software and commercial multimedia software as well as built scientific equipment for use by students in class.

After two years teaching, in 1997, I co-founded with my wife the only high school based research lab in New Zealand, the Nexus Research Group (www.nexusresearchgroup.com), which we operated voluntarily in our spare time. Former head of the National Aeronautic and Space Administration (NASA) Jet Propulsion Laboratory Dr Sir William Pickering was Patron. Nexus provided high school students with an opportunity to carry out real research, some of which students presented at conferences for peer review (Fenton, Fenton & Stewart, 1999; Fenton, Fenton & Raynes, 2001).

Authentic teaching and learning is nothing new to me.



Detective Grant Coward of the New Plymouth CIB teaches fingerprinting as part of a 3 day Crime Scene Investigation (CSI) workshop run by the Nexus Research Group.

Authentic learning and ICT

There are at least four different arguments that are being used to justify the recent major investment in school Information and Communications Technology (ICT) (Bolstad & Gilbert, 2006). These are:

- efficiency
- community building/connect to the world
- digital generation
- knowledge age/21st-century learning

e-Learning tools have been described as a means to create a 'knowledge' economy yet from my experience outside the classroom 'understanding' is much more important. Understanding is the precursor to solving authentic problems and to innovation later in life or in the work place.

Piaget and other psychologists believe that the learner must be active to be engaged in real learning (Piaget, 1954, 1974). Authentic learning is a pedagogical approach that allows students to explore, discuss, and meaningfully construct concepts and relationships in contexts that involve real-world problems and projects that are relevant to the learner (Donovan, Bransford, &

Pellegrino, 1999). The term '*authentic*' is defined as genuine, true, and real (Webster's Revised Unabridged Dictionary, 1998). Comments from my Year 13 students support this definition. If learning is authentic, then students should be engaged in genuine learning problems that foster the opportunity for them to make direct connections between the new material that is being learned and their prior knowledge. This kind of experience will increase student motivation. In fact, an "absence of meaning breeds low engagement in schoolwork and inhibits [learning] transfer" (Newmann, Secada, & Wehlage, 1995).

I believe that authentic learning is important and occurs when students develop meaningful understanding from activities they initiate and have control over. Ideas for learning activities may come from other students or the teacher but each student should take "ownership"; and the activity should become student centred.

There are three main ways (Wegerif, 2002) of thinking about the role of ICT in teaching thinking skills:

- **as tutor** or teaching machine,
- as providing '**mindtools**' eg calculator
- as a support for **learning conversations**, eg interactions between people.

The use of data loggers as mobile sensor devices is seen as adding value to student learning. Sensors for a range of biological, chemical, physical or environmental phenomena are commonly available. There are three main configurations for recording, display and analysis of data: connection to a personal computer, hand-held computer or a graphic calculator.

Two recent research initiatives in New Zealand schools support the use of data logging tools in science and mathematics. The draft MOTIS (Mobile Technologies in Science) report (Tideswell, 2005) and the CAS (Computer Algebraic Systems) project for mathematics (Neill & Maguire, 2008) report similar positive benefits in terms of engagement and understanding. The cost for the equipment however is prohibitive to many schools and indeed the CAS project functioned largely due to donated equipment.

A literature review revealed three main themes in science and mathematics that were significant to me:

- The importance of using data loggers in experiments for students to construct meaningful knowledge from textbooks.
- Access and availability issues for the teacher or students limit the opportunities for learning using data loggers. Sensor systems are expensive and can be time-consuming to issue, set up, and collect in.
- Investigations were focused on knowledge/concepts that are assessment focused rather than on gaining a wider or deeper understanding of the world in general.

The ‘science problem’

Prior to being awarded this e-Learning Fellowship, I carried out a literature review examining the way science is taught at secondary and tertiary level. There were a number of common themes nationally and internationally.

Changing view of science by society

The general public, including politicians and their advisors, have their own views of the nature of science and what scientists do. As Doctoral Scholar Christine Fenton has recently put it, we now have

“movies that show scientists as unemotional, arrogant and all-knowing – and ultimately flawed and/or impotent in applying their knowledge and insights in times of crisis. This is a huge change in characterization of the scientist compared to popular media earlier in the 20th Century. Jules Vern, Mary Shelly, then to Star Trek, Lost in Space, Land of the Giants, Dr Who, and a vast array of science-fiction, futuristic media that showed ultimate confidence in the scientist. Even Gilligan’s Island had a scientist that had an answer for everything, and was kind, trustworthy and dependable. Kids wanted to grow up and be a scientist.” (Fenton, C.D., 2008).

Not all science teachers are scientists

Teachers and students have their own views of the nature of science and what scientists do. Science teachers’ beliefs about the nature of science may not agree with what scientists describe as the nature of science. For instance, a common myth in schools, as seen in Science Fair projects, is that there is a “Scientific Method” that all scientists follow. Science Fair projects also demonstrate a preference investigations based on ‘fair testing’. This indicates that science teachers have their own culture and accepted ways of teaching science. There is also a big difference between **teaching science** and **doing science** (Haigh, France & Forret, 2005).

According to the New Zealand Ministry of Education (Jones, S., personal communication, 14th November, 2008) there are no statistics available about the qualifications or expertise of science teachers. This is similar to the situation in the United Kingdom. A survey of New Zealand science teachers that focused on microbiology skills indicated that 27 out of 185 teachers (15%) had post-graduate qualifications or relevant work experience (Fenton, Fenton & Raynes, 2001). This explained why such an unacceptably high proportion of the 185 teachers (86%) breached safety guidelines (Ministry of Education, 1997) when attempting to carry out practical demonstrations. This also explains why NCEA assessment tasks are often given inappropriate contexts.

Not enough “doing” science

For various reasons teachers have demonstrated a reluctance to do practical work or experiments. Self-efficacy can be described as a personal expectation about ones’ ability to successfully perform a specific task or behaviour (Bandura, 1986). Teachers with low self-efficacy will avoid doing practical work related to science. For those that do practical work, a distinction must be made that the majority of practical work, if done at all, is a demonstration of a concept, not a true experiment.

The introduction of the National Certificate in Educational Achievement (NCEA) has had an enormously negative impact on the number of senior Science Fair entries in the Taranaki (Sanfelieu J., personal communication, 2 October, 2008) and Manawatu regions (Meikle H., personal communication, 1 October, 2008). As an example, prior to NCEA, senior entries in the Taranaki Science Fair would be in the vicinity of 100 or more. In recent years entries number 20 on average; the last two years as few as 12 senior science investigations from the entire Taranaki region.

It seems one of the basic tenets of science, to question and test ideas, has been ignored and replaced with rote learning of facts and concepts for exams. The number of students gaining Excellence endorsements or Scholarships is not a valid indicator of a good education system as this comment from Nobel Laureate Alan MacDiarmid indicates:

As my parents always said, an ‘A’ grade in a class is not a sign of success.

(quoted in Fenton, C.D., 2008).

Meanwhile, even though there is no examination pressure, primary school teachers report a lack of resources, time and support to teach science. Issues of concern that are barriers to teaching science in primary schools include:

- Lack of resources
- Overcrowded curriculum resulting in a lack of time
- Lack of experienced science teachers at primary level

Articles such as “Kiwi kids behind Kazakhstan in science” (Nichols, 2008), and others during the 2008 year, are evidence that science has been given a low priority in schools.

National and international surveys shed some light as to the impact of this apparent neglect of science education in New Zealand.

PISA, TIMSS and NEMP comparisons – we must do better

The Programme for International Student Assessment (PISA) is an international standardised study that assesses and compares how well countries are preparing their 15-year-old students to meet real-life opportunities and challenges (Caygill, 2008a; Caygill & Sok, 2008).

In a typical media item of the times, the Post Primary Teachers Association (2007) said the PISA report ranked Kiwi teenagers seventh out of 57 countries when it came to performance in science. Robin Duff was reported as saying:

“NCEA also has to be given some credit for this result,” he said.

“More practical work, internal and developmental assessment places a much greater focus on teaching and learning and gives students more control over their education”.

A number of commentators have made criticisms of the manner in which the PISA statistics are generated and interpreted. For instance, Duff’s assertion regarding practical work in science appears at odds with the low numbers of senior students participating in Science Fairs and with independent research findings that New Zealand science classes are doing little authentic practical work or authentic scientific experiments (eg, Hipkins & Neill, 2006).

Haigh, France and Forret (2005) report that the Science in the New Zealand Curriculum (SNZC) document (Ministry of Education, 1993) makes it clear that ‘doing science’ involves more than practical work carried out in the laboratory/classroom. Indeed, they cite research demonstrating a prejudice for ‘fair testing’ activities in schools, with the consequence of reducing the potential for students to gain practical experience in the systems-based sciences such as ecology, geology, and astronomy.

The PISA report itself indicates that the tests do not evaluate schooling, per se, but the “cumulative impact of learning experiences ... starting in early childhood and up to the age of 15 and embracing experiences both in school and at home”.

Salzman and Lowell (2008) argue that it is the numbers of high-performing students that is most important in the global economy. For them the United States clearly outperforms other OECD countries, while New Zealand is relegated to the bottom of the ranks.

There is also no longitudinal study to following students identified in PISA to see if they did go on to do further study or indeed become talented scientists. Instead, there is evidence to the contrary; comments from senior high school students indicate that science and maths are viewed as “too hard to get credits” so students opt for easier subjects with “easy” credits.

The Trends in International Mathematics and Science Study (TIMSS) describes the science achievement of Year 5 students in TIMSS 2006/07 (Caygill, 2008b). Trends in New Zealand's achievement over the 12 years from 1994 to 2006 are examined, along with comparisons with other countries. Some of the findings reported include:

- The mean science achievement of New Zealand Year 5 students was about the same in 2006 as in 1994. Although results from 1994, 1998, and 2002, showed a steady increase, this trend did not continue in 2006 when the results returned to the 1994 levels.
- A comparison with the other countries that have taken part in TIMSS across all three of the cycles shows that the mean science achievement of New Zealand Year 5 students has moved little in relation to these countries.
- The range of New Zealand Year 5 science achievement was narrower in 2006 than in 1994, with fewer students demonstrating very high or very low achievement.

In contrast, there is evidence from my work with students that it is possible for a Year 5 student to develop a good understanding of the nature of science if opportunities to do so are provided.

The recent National Education Monitoring Report (NEMP) Science Assessment Results 2007 report gave rise to a number of articles in the media such as the excerpt below (Arnold, 2008):

TOO MUCH TALK TURNS STUDENTS OFF SCIENCE

Primary school pupils are turning off science at school, and time-poor teachers may be the reason why, new nationwide research shows. The 2007 National Education Monitoring Project (NEMP) report found that 37 per cent of Year 8 students disliked science at school, up from 15 per cent in 1999. The percentages of Year 4 and Year 8 students who thought they learned little about science at school also increased between 1999 and 2007, from 8 per cent to 16 per cent for Year 4 students and from 6 per cent to 11 per cent for Year 8 students.

University of Otago Professor of Education and NEMP co-director Dr Terry Crooks said one of the problems could be that teachers lacked time to do experiments in class.

"There's every reason to say teachers are under pressure for time," said Dr Crooks. "Substantially higher proportions [of students] are saying they never do really good things in science at school." He said children tended to get "talked to" about science but didn't get to "do much science". However, he said it didn't mean students didn't like science at all.

"The survey shows that actually a lot of them want more science. Seventy-one per cent of Year 4 students and 44 per cent of Year 8 students want to do more science at school, both of which are increases over the last eight years.

"What they're saying is that they're actually not happy with the science they're getting at school."

In summary, a picture is painted of a nation with a lack of science education in primary schools and a narrow and simplistic view of science when preparing students for NCEA assessments in secondary schools.

Can the new curriculum make subjects “real”?

Mathematics is a language to communicate a description of the world (real or abstract) in a consistent manner. In this definition, science uses mathematics to describe the physical world. The world supplies the context and reason for “doing” mathematics.

The secondary curriculum has science and mathematics as separate disciplines. This fragmented and atomised approach means the real-world relevance and meaning behind the manipulation of the various symbols can be lost, even by the teacher.

This inability to relate mathematics to other concepts means that achieving a Merit or Excellence grade in assessments may be labelled as high level according to Bloom’s taxonomy, but may still be at a low level on the SOLO taxonomy.

The work of Tideswell (2005) goes a small way to reconnecting mathematics with science. Other relationships in the context of budgeting, economics and dynamic systems are also valid contexts to make maths “real” for students. Indeed, with the introduction of the new curriculum for mathematics, it appears that an opportunity to spend some time in class developing values and attitudes for life-long learning could be possible.

However, there is evidence from teachers discussing aligning year 11, 12 & 13 mathematics courses with the new curriculum that they seem to have missed this point. Discussions appear to focus on assessment with little, if any, talk about pedagogy and student learning. There is a justified concern about workload. If standards that were externally assessed become internally assessed then programmes of study have to be carefully timetabled; to permit time for students to do practice assessments, to do the formal assessments and allow for marking and resubmissions / reassessment. There is even debate about how many teaching hours should be allocated per credit; does a 2 credit standard justify 20 hours (four weeks) of preparation or 10 hours? Four weeks seems too long. If only 10 hours then students will have gained “enough” credits by the end of term two...they will switch off for the rest of the year. It is understandable, with various interests applying pressure to get more students to “pass” NCEA, that these conversations are so narrowly focused.

In this atmosphere teachers may see their discipline as nothing other than a marathon event of assessment and marking. One way to ensure that this does not happen is to validate time spent on permitting students to engage in authentic enquiry and time for teachers to develop effective pedagogies. A mechanism that recognises these as equally important and valid uses of learning time may be the only way to ensure the spirit of the new curriculum is recognised and implemented in a non-trivial way. The Discussion outlines a new mechanism, the PACE score, as a means of doing this.

Assessment philosophies: NZQA is unscientific?

The Nexus website (www.nexusresearchgroup.com) includes a copy of a conversation with the New Zealand Qualifications Authority (NZQA) CEO Dr Poutasi and the New Zealand Microbiology Society (NZMS). Concerns are raised by the NZMS about errors of fact material used to assess Achievement Standard 90188. NZQA seems reluctant to admit its role in the perpetuation of incorrect information in spite of the obvious link; teachers write study guides with content biased to providing 'accepted' answers from past assessments, while NZQA assessments are written by teachers based on content from study guides commonly used throughout New Zealand. They are linked.

A similar interaction occurs in United Kingdom (Curtis, 2007), where one author of a science textbook was reportedly told to write a factually incorrect answer because the mistake had been made in the curriculum and the book had to match. A closer look at the Science in the New Zealand Curriculum document will reveal such an error on page 64 where leukaemia, like AIDS, is described as a disease typically caused by a micro-organism.

The NZMS is a professional society made up of scientists and specialist microbiology teachers such as myself. A request for a mechanism permitting science professionals such as the NZMS to help NZQA assessment writers was denied. NZQA claimed they already had rigorous checking mechanisms with up to four teachers checking questions. It would be interesting to find out what text book they are using. It is sad to note that the so-called experts as viewed by society (scientists) are impotent to influence what is happening in secondary schools. This closed universe of NZQA will only re-enforce the differences between science as done by school teachers and the science of the workplace and research. It is not a matter of professional groups such as the NZMS expecting students to work at a higher level, rather it is that setting appropriate and factually correct Level 1 content and contexts is easy when you work in that area every day.

I find incredible Dr Poutasi's assertion that

"Marker judgements are made with consideration of 'common understanding' which might not always be accurate..."

Dr Poutasi's view of the assessment of a science paper seems to be at odds with the culture of being "scientific". If she is merely voicing that science teachers have set marking schedules based on " 'common understanding' which might not always be accurate" then this also supports the research that science teachers' beliefs about the nature of science may not agree with what scientists describe as the nature of science. This seems to indicate that in New Zealand we have a Qualification Authority that uses a different world view of knowledge from that of the discipline it is assessing...NZQA is 'un-scientific' with regards to assessing science knowledge.

Computers & students - out of cyberspace & back into real space

During my last 10 years of teaching, two main criticisms from students against the use of ICT in the classroom or at home are:

- Games and simulations are not “real” and are poor substitutes for practical science activities and authentic learning.
- Too much sitting inside in front of a screen. Inactivity for long periods of time is unhealthy.

I have developed a cost effective open-ended technology that can provide the function of a data logger (Fenton, 2007) as well as a games unit. A unique opportunity exists to explore how students could use this technology to assist their own learning and develop their own understanding of the world and overcome some of the problems described in the NEMP report. While other curriculum areas may be adequately served by e-Learning and web 2.0 technologies, science cannot be experienced divorced from the reality it was developed to explore.

In using a mobile technology, an interesting paradox becomes apparent; the use of ICT to get students away from ICT. That is, using a hand-held technology (HHT) to get students outside and physically active, away from computer suites, and augmenting their own five senses with the use of man-made sensors. Students use a computer to get plugged into the real world, not cyberspace (Gray-Lockhart, 2008).



Figure 1: Treasure hunt

Students race to find a treasure chest hidden somewhere nearby in the school. The chest emits a radio signal.

Students use a hand-held RIGEL sensor unit configured as a radio tracker that indicates the strength of the received radio signal.



Figure 2: Obstacle course

A hand-held RIGEL sensor unit is configured with simple touch switches that indicate which team completes the course first.

RESEARCH QUESTIONS

The title of this report asks “how can the use of mobile sensor technology create authentic learning and gain understanding?”

The technology used is a new hand-held technology (HHT) that could also be described as a mobile technology. This research using the RIGEL sensor unit differs from other investigations using HHT's such as data-loggers or other mobile technologies. RIGEL has an open-ended architecture and connectivity with other applications. As a mobile sensor unit, RIGEL can be used in a variety of ways to support many curriculum areas other than just science or mathematics (see appendix 12).

Due to daily teaching commitments and the part-time nature of the research Fellowship awarded, four areas were briefly explored:

1. How does the use of RIGEL as a mobile technology support authentic learning?
2. How does the use of RIGEL as a mobile technology support higher level thinking?
3. How does the use of RIGEL as a mobile technology support students developing a greater understanding about the nature of science?
4. As a new ICT, what problem(s) does this technology solve?

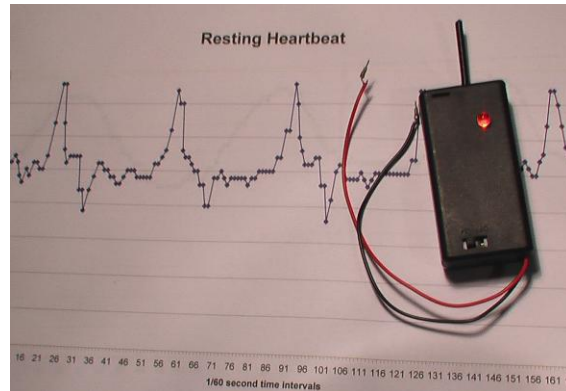


Figure 3: Human heartbeat recorded using RIGEL

LITERATURE REVIEW

Learning Theory – two approaches

Introduction

There are many different ways to organise theories of learning. There are based on ontological and epistemological assumptions about the world. For more detail on this, refer to the section “Understanding the Nature of Science”, page 29.

What is meant by ontology and epistemology?

- Ontology as a branch of philosophy is the science of articulating the nature and structure of the world.
- Epistemology is the nature of human knowledge and understanding that can possibly be acquired through different types of inquiry and alternative methods of investigation.

Epistemologically, observers get their knowledge about the world by experiencing it.

There are two common approaches to understanding learning. These are summarised in the table:

	Focus areas	Well-known theorists	Usefulness
Behaviourism	Stimuli Responses Reinforcement	Guthrie Skinner Thorndike Watson	Explains learning of skills and attitudes.
Cognitivism	Decision making Understanding Cognitive structure Perception Information processes	Ausebel Bruner Paiget	Explains development of meaning & understanding

Table 1: Theories of Learning (after Lefrancois, 1982)

Behaviourism includes those theoretical positions which are concerned chiefly with the observable and measurable aspects of human behaviour. Behaviourism explains how skills and attitudes are learned, through a process known as conditioning. Conditioning does not have to be overtly based on the teacher rewarding good behaviour / punish bad, but rather conditioning as you will see later is an unconscious process.

Cognitivism by contrast implies intention, by the student or teacher. It is largely preoccupied with memory, attention, decision making, information processing and understanding.

Behaviourism and social and authentic learning

Social learning theory was advanced by Bandura and Walters (1963). Socially acceptable behavior is learnt by imitation from observing other individuals. This observational learning as has been described as “one of the fundamental means by which new modes of behaviour are acquired and existing patterns modified” (Bandura, 1969, p.118)

Social learning involves more than simply learning a set of behaviours that *are* acceptable; it also requires learning about conditions where behaviours are *unacceptable*.

Scientists have their own set of beliefs and values. It could be argued that the only way a child can learn to be scientific is to be exposed to others that model the appropriate behaviours and attitudes. Science encourages a philosophy of “doing” rather than rote learning “facts”. Observational learning may include using replicas of tools scientists use, or being provided with exemplary role models. It could be argued that school Science Fairs provide students with model investigations that could be imitated by others. The prizes offered certainly provide positive reinforcement. It would be expected that the process of carrying out a technological development or scientific investigation would elicit appropriate thinking and behaviors in the classroom or exam situation. This may be negated however if judges and teachers place too much emphasis on the use of one particular “scientific method” (Haigh, Frances & Forret, 2005).

Cognitivism and constructivism

Jerome Bruner and David Ausubel's ideas are similar in some respects but quite different in others;

Constructivism and Discovery Learning

Bruner suggested that learners should organise material for themselves as a result of having been provided with the opportunities to discover relationships inherent in the material. Teachers may recognise Constructivist theories and discovery learning pedagogies fit in this philosophy. Students are required to code and classify material themselves and create their own relationships in order to make anything “meaningful” from the material.

Early childhood and primary science have been strong supporters of this philosophy based on the developmental changes a child goes through as outlined on the following page:

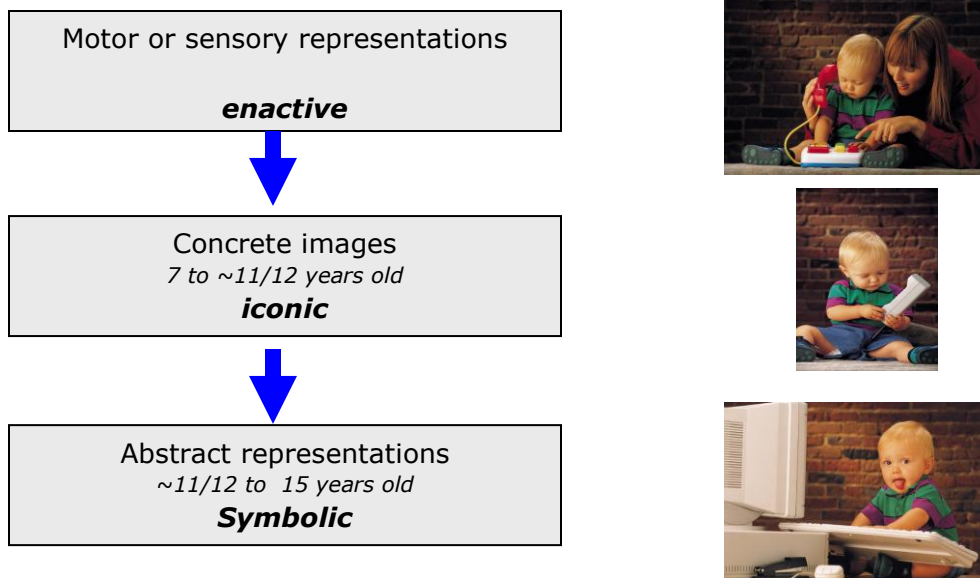


Figure 4: Piaget's stages of development

A sequence of teaching should reflect this; present a subject so a child can experience it, react to a concrete presentation of it, and create a symbolic representation of it. Bruner also advocates the “spiral curriculum,” or “stair-casing”. This approach develops and redevelops topics at different levels of difficulty (as in the science and mathematics curriculum documents).

Expository teaching or reception learning

David Ausubel on the other hand, advocated that in most instances the material can be organised more profitably by the teacher and presented to the student in relatively final form. This can be termed “expository teaching” or ‘reception learning’. He argued that discovery approaches are not in fact demonstrably superior to the alternative approach. Ausubel (1960) used the strategy of an “advanced organiser” on two groups of students of similar ability. One was given a resource about the similarities and differences of metals. The other group was not. Subsequently both groups were given information about a chemistry topic that did not directly refer to the resource provided earlier. The first group scored significantly better than the second.

Best of both philosophies

Teaching and learning involves many different strategies. There is no evidence that a single approach or mode is “best” for any or all learners. I have decided that there are benefits in using a positivist or constructivist epistemology at appropriate times:

1. Discovery learning may have advantages at Piaget's *concrete operations* stage of young students.
2. Discovery learning can establish intrinsic motivation, assist problem solving and encourage plausible guesses.
3. Expository techniques favour rapid learning and long retention when the learner has a large store of information to which new content can easily be related.

Authentic learning

Authentic learning indicators

The main points of authentic learning, a type of social learning, will be used as indicators later in this report, they are reproduced here from a literature review by EDUCAUSE (2007):

Authentic learning activities cultivate the kinds of “portable skills” that newcomers to any discipline have the most difficulty acquiring on their own:

- The *judgment* to distinguish reliable from unreliable information
- The *patience* to follow longer arguments
- The *synthetic ability* to recognize relevant patterns in unfamiliar contexts
- The *flexibility* to work across disciplinary and cultural boundaries to generate innovative solutions

A useful checklist can be adapted to any subject matter domain:

1. **Real-world relevance:** Authentic activities match the real-world tasks of professionals in practice as nearly as possible. Students work actively with abstract concepts, facts, and formulae inside a realistic—and highly social—context mimicking “the ordinary practices of the [disciplinary] culture.”
2. **Ill-defined problem:** Authentic activities are relatively undefined and open to multiple interpretations, requiring students to identify for themselves the tasks and subtasks needed to complete the major task.
3. **Sustained investigation:** Problems cannot be solved in a matter of minutes or even hours. Activities are sustained over a long period of time, requiring significant investment of intellectual resources.
4. **Multiple sources and perspectives:** Students examine the task from a variety of theoretical and practical perspectives, using a variety of resources, and are required to distinguish relevant from irrelevant information in the process.
5. **Collaboration:** Authentic activities make collaboration integral to the task, both within the course and in the real world.
6. **Reflection (metacognition):** Authentic activities enable learners to make choices and reflect on their learning, both individually and as a team or community.
7. **Interdisciplinary perspective:** Authentic activities have consequences that extend beyond a particular discipline, encouraging students to adopt diverse roles and think in interdisciplinary terms.
8. **Integrated assessment:** Assessment is not merely summative in authentic activities but is woven seamlessly into the major task in a manner that reflects real-world evaluation processes.
9. **Polished products:** Conclusions are not merely exercises or substeps in preparation for something else. Authentic activities culminate in the creation of a whole product, valuable in its own right.
10. **Multiple interpretations and outcomes:** Rather than yielding a single correct answer obtained by the application of rules and procedures, authentic activities allow for diverse interpretations and competing solutions.

Educational researchers have found that students involved in authentic learning are motivated to persevere despite initial disorientation or frustration, as long as the exercise simulates what really counts—the social structure and culture that gives the discipline its meaning and relevance.

Problem based learning or case-based instruction?

Not surprisingly, the way science is taught or delivered tends to have a big impact on student learning. Research indicates science students tend to prefer active learning such as discussions, experiential or creative science and having a lesson memorable and entertaining (Tobias, 1990).

In contrast, laboratory classes may not necessarily be effective sources of learning. Teaching ‘experiments’ are often designed with unrealistic or highly predictable outcomes that do not engage students cognitively. These ‘experiments’ may also be considered tedious and dull by the student so they are unlikely to be remembered. They are better described as “exercise” than as “experiments”.

Problem-based learning (PBL) is an instructional method where students learn through facilitated problem solving. Students learn through the experience of solving problems has been shown to help with learning content and thinking strategies. Often the problem is complex and may not have a single correct answer. Students working in collaborative groups to problem solve and engage in self-directed learning and apply this new knowledge to the problem (just-in-time learning) and then reflect on what they have learnt (Hmelo-Silver, 2004).

Problem based learning involves teaching content (theory) in context (practice). In the case of primary schools, very simple scenarios can be used to permit the students to problem solve situations that link to scientific concepts or theories.

At secondary level more complex scenarios or problems can be presented to provide appropriate contexts to a wider range of or more complex scientific concepts.

Case-based instruction (CBI) is a guided inquiry method and provides more structure than problem-based learning. Case scenarios are self contained and address specific learning outcomes. In contrast to the rather open-ended and vague outcomes of PBL pedagogies, students learning from CBI seem to gain greater benefits. For example, medical students might be asked to ‘work a case’ for treating a patient based on following an actual historical case file. The University of California has two medical schools and conducted a study which suggests that the students overwhelmingly preferred the CBI over the problem-based learning. The main reason for the preference appeared to be a perception that case-based studies had fewer

unfocused tangents than the PBL programme (Srinivasan, Wilkes, Stevenson, Nguyen & Slavin, 2007).

PBL and CBI promote students' skills in problem-solving, analysis, self-directed learning, and collaboration. It is, however, often a time-consuming task to discover, design, and present a good problem or case that is attractive to students, appropriate for course content, and relevant to the subject.

I decided I would briefly explore these alternative teaching strategies with a Year 13 Calculus class. The two learning activities were as follows:

- **Problem-based learning:** Construct a robot using the parts provided, and any others you provide, to your own design and purpose.
- **Case-based instruction:** Create a challenge for your peers to complete based on either a NASA engineering problem or a Crime Scene Investigation (CSI) problem.

Higher level thinking and understanding

Blooms taxonomy

Bloom's Taxonomy (Bloom, 1956) consists six levels divided into "lower order thinking"; knowledge, understanding and application, and "higher order thinking"; analysis, evaluation and synthesis.

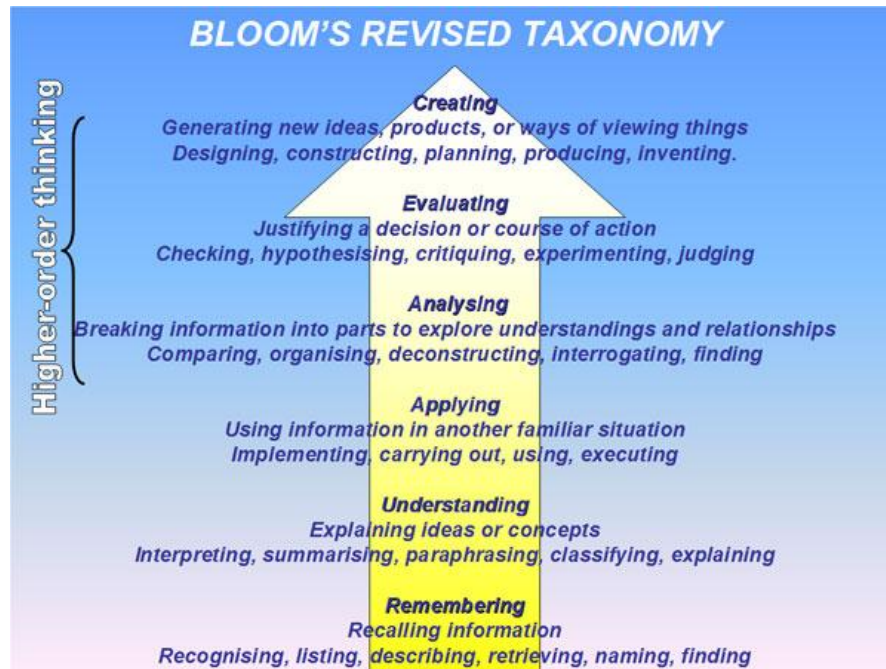


Figure 5: Revised Bloom's Taxonomy

Bloom's Taxonomy is widely known and used yet there are issues being raised about its effectiveness as a tool. John Hattie (2007) comments:

"Most of the evaluations are philosophical treatises noting, among other criticisms, that there is no evidence for the invariance of these stages, or claiming that the taxonomy is not based on any known theory of learning or teaching"

The greatest criticism of the Bloom taxonomy is that there is little evidence supporting the invariance and hierarchical nature of the six levels."

Bloom's presupposes that a student needs to move through the levels in an ordered fashion, and that before a student could effectively evaluate a given context, they must have successfully negotiated, knowledge, comprehension, application, analysis and synthesis.

SOLO taxonomy

SOLO, which stands for Structure of the Observed Learning Outcome, provides a systematic way of describing how a learner's performance grows in complexity when mastering many tasks, particularly the sort of tasks undertaken in school. A general sequence in the growth of the structural complexity of many concepts and skills is postulated, and that sequence may be used to guide the formulation of specific targets or the assessment of specific outcomes.

Biggs and Collis (1984) write:

"The SOLO Taxonomy is, as far as we are aware, the only instrument available for assessing quality retrospectively in an objective and systematic way that is also easily understandable both by teacher and student. For this reason, the Taxonomy may be used as an instructional as well as an evaluation tool." (p. xi)

It is for this ability to be used as a tool in developing instructional material that the SOLO Taxonomy is more useful than Bloom's Taxonomy.

According to Biggs and Collis, one model of instruction of the teaching process requires teachers to first decide on a learning "intention". They use the term "intention" rather than "objective" as "intentions" are more general than a learning objectives, though they may be the same.

Hattie and Purdie (2007) report that the taxonomy makes it possible to identify the stage at which a student is currently operating. In this consistent sequence, or cycle, the following stages occur:

- **Prestructural.** *There is a preliminary preparation, but the task itself is not attacked in any appropriate way.*
- **Unistructural.** *One aspect of a task is picked up or understood serially, and there is no relationship of facts and ideas.*
- **Multistructural.** *Two or more aspects of a task are picked up or understood serially, but are not interrelated.*
- **Relational.** *Several aspects are integrated so that the whole has a coherent structure and meaning.*
- **Extended Abstract.** *That coherent whole is generalised to a higher level of abstraction.*

Further, they write:

*Such learning develops in a hierarchy of levels of increasing structural complexity.
The levels are ordered in terms of various characteristics:*

- *from the concrete to the abstract*
- *an increasing number of organising dimensions*
- *increasing consistency; and*
- *the use of organising principles or relating principles*

One feature of the SOLO model (Hattie and Brown, 2004) is its ability to be used successfully across different curriculum areas.

1. Drawing conclusions from a display of information (e.g., a lesson, an original document)
2. Making value judgements about an event
3. Reconciling conflicting evidence from different sources
4. Constructing a plausible interpretation from incomplete data
5. Inducing the meaning of a concept from a context (p. 35)

The SOLO Taxonomy can be used as a tool to not only develop questions, but to assess responses.

This highlighted a potential problem with the Bloom's Taxonomy. A Bloom's question asked at the Knowledge level supposes a response at that level, whereas under the SOLO taxonomy, any question asked could have a range of responses from unistructural to extended abstract. This seems to be to mirror my experience in the classrooms (not surprisingly as the SOLO taxonomy was developed out of ordering classroom responses).

At senior levels of schooling students may be expected to operate at an extended abstract level of the SOLO Taxonomy - though this is "an unrealistic goal in the high school curriculum for many students." (p. 164). At junior levels of the school, a multi-structural level of understanding might be sufficient.

Understanding the nature of science

Many people, including teachers, have their own views of the nature of science and what scientists do.

Introduction – scientific “knowing”

People make sense of their environment via 3 modes

1. EXPERIENCE

Common sense “knowing”
Uncritical, assumed to be correct,
Loose generalisations

versus

Scientific “knowing”
Critical, tested, tight (particular)

2. REASONING

DEDUCTION (Aristotle)
Generalisation (self-evident
subjective truths)
Leads to conclusion about particular
observations

versus

INDUCTION (Francis Bacon)
Individual particular observations
Lead to generalisations (testable
objective truths)

[In practice, modern scientific research moves back and forth between inductive and deductive logic.]

3. RESEARCH

Experiences are systematic and controlled, empirical (*based on observations*) subjective belief is checked against objective reality and is self-correcting via public scrutiny (publication in journals, etc)

Educational Research in general has absorbed two competing views of the social sciences

- i. That the social sciences are essentially the same as the natural sciences, discovering natural and universal laws regulating individual and social behaviour.
- ii. That, while sharing the rigors of the former view, emphasis is on how people differ from inanimate natural phenomena and each other.

These competing views stem from how we view social reality as well as individual and social behaviour.

Ways of knowing - cultural influences

When an individual is constructing a knowledge base, he/she is influenced not only by his/her own experiences and grasp of the concepts, but also by the presence of other people. Knowledge construction therefore has a social contribution and cultural influences are important factors. Ways-of-knowing can be influenced in multiple ways such as; women's ways-of-knowing, indigenous people's ways-of-knowing, and so on (Tobin & Tippins, 1993). Maori and Pasifika students are over represented amongst students who are underachieving in school science (Waiti and Hipkins, 2002). New Zealand's science curriculum aims to be inclusive of these students and to that end they suggest contexts for learning that take account of different types of life experiences.

Ways of knowing – the four patterns of knowing

Carper (1978) identifies four patterns of "knowing" knowledge;

- empirical (scientific content knowledge),
- aesthetic (art or skill or natural ability/manner),
- ethics (values/morality)
- personal (built from past experience, eg, ability to decide when to act contrary to set policy or procedure when justified)

The above four patterns of knowing are not as irrelevant to the classroom as some educators may believe. New Zealand television shows such as "*Sensing Murder*" demonstrate that students are exposed to other beliefs portrayed as having validity. Necromancy is given legitimacy by the New Zealand Police Force if this information is looked at as any other information would be to help "know more about the case".

Knowledge then is a cognitive activity influenced by social and cultural processes, often within a community of actively thinking individuals. This has impact in science teaching and learning because students must end up sharing the scientific explanation of the teacher (or the textbook) when, depending on their own experiences, background and culture, they may not find the explanations plausible (Cobern, 1993). A student's view of the world may be something between the alternate view and the scientific view, and aspects may be completely compatible, while others are completely incompatible with the scientific view.

Alternative views can be accepted as valid within the workforce. For instance, in nursing, many 'alternative views' may be desired qualities, or be part of nursing culture.

Ways of knowing - science teachers' world views

Understanding the beliefs of teachers is critical if those in science teacher education are going to develop programmes that have a lasting impact on our teachers. A paper by Hipkins, Barker and Bolstad (2005) explores the nature of a continuing mismatch between curriculum reform rhetoric in science education and actual classroom practice.

“Lack of philosophical consensus about the nature of science (NOS); lack of appropriate curriculum guidance, classroom materials and pedagogical content knowledge for NOS teaching; teachers' personal theories of learning; and the realities of classroom constraints are all implicated as interacting factors that contribute to the mismatch.

Because curriculum policy is political, with pressure brought to bear by many interest groups, it is suggested that the science teaching community cannot adequately address the issues raised in the absence of wider community debate and support.”

A New Zealand Ministry of Education report (Hipkins and Neill, 2006) found that:

“Science teachers say they are now using fewer strategies that help students to clarify their own ideas. Again, it may be that the NCEA implementation has exacerbated an existing tension in competing classroom priorities, rather than arising as a new issue.”

Science teachers' views then about how science should be taught is partly due to identifying as belonging to the wider scientific community but mainly due to belonging to the culture of the secondary teaching profession, the influence of government policies, local community expectations, and the pressure to conform to “norms” of practice.

At a workshop I facilitated working with local science teachers, we reflected on the “standard” world view as practiced in the science curriculum. It seemed a good fit.

- Causal thinking
- Matter and Motion
- Atomistic
- Part to Whole
- Linear Time
- Biological Process seen as Physical/Mechanical
- Innovation/Progress
- Industrial/Natural Resource-based Economies
- Transient Geographies
- Pyro-technologies

Then we compared this world view with alternatives in the table on the following page:

Premodern/Organistic	Modern/Mechanistic	Postmodern/Cybernetic
Correlative Thinking	Causal Thinking	Systems Thinking
Vital Force/Spirit	Matter and Motion	Information
Holistic	Atomistic	Behavioristic
Whole to Part	Part to Whole	Reflexive within System or Field
Cyclic Time	Linear Time	Virtual Time
Tradition/Repetition	Innovation/Progress	Creation/Neo-evolution
Dependence on Nature	Domination of Nature	Reinvention of Nature
Self as Communal	Self as Autonomous Individual	Self as Virtual
Participation	Representation	Simulation/Programming
Biological Process seen as Spiritual/ Metaphysical	Biological Process seen as Physical/Mechanical	Biological Process seen as Inscribed/ Informational
Regional Geographies	Transient Geographies	Virtual Geographies
Tribal/Feudal Agrarian/ Craft-based Economies	Industrial/Natural Resource-based Economies	Postindustrial/Information- based Economies
Archaic Technologies	Pyrotechnologies	Cybertechnologies

Table 2: Three ages of world views (Becker & Buchanan, 1996)

High school science appears to be taught using a Modern/Mechanistic view when 21st Century western society appears driven by the Post-modern/Cybernetic world view.

The role of play and luck in science

Anyone can possess 'knowledge'. How much an individual or society benefits from this knowledge depends on other factors which may be deemed even more useful but take time to develop. Two factors that are undervalued and underdeveloped in high school are ***understanding*** and ***creativity***.

Innovation could be described as applying your understanding of a topic in a creative and novel way. This suggests an investment in time to develop these characteristics is at least as important as time devoted to acquiring and assessing knowledge.

There are other important factors that contribute to thinking scientifically. These may at first appear at odds with what many associate with the art of science:

- ***play***; undirected 'what would happen if' personal interest investigations and a chance to follow intuition rather than physical evidence.
- ***luck***; serendipity or being at the right place at the right time.

There are many well celebrated examples of past major breakthroughs in technology and science arising from 'play' or being lucky (Bodanis, 2000; Bryson, 2004).

In contrast, school texts and traditional learning activities portray knowledge as being gained almost as of right from following a single prescribed scientific method. The fun, creativity, and at times dumb luck surrounding the art of being scientific is ignored. As mentioned previously, teachers and students preparing for NCEA assessments claim that there is no time to do authentic science activities. Unless a student is fortunate to have the support of an appropriate mentor, involvement in Science Fair is still unlikely to provide an authentic learning experience. Teachers and students may not even recognise that there is a difference between Science Fair and authentic investigations.

According to one report (Ferguson, 2006), New Zealand has long been renowned internationally for the quality of its Science curriculum. The suggested pedagogical approaches and learning activities to develop a true understanding of the nature of science lead the world. As mentioned later in the Discussion, other authors lament the failure of classroom practices to develop this potential in our students.

“Doing Science” in schools - a proven model for others

Is it possible to develop a model of authentic learning in New Zealand that enables students to develop a true understanding of the nature of science? If so, has anyone applied this model so it works within the restraints of the existing education system?

A model for implementing a practical research industry in schools does exist. From 1997 to 2004 the only secondary school based research lab in New Zealand, the Nexus Research Group, provided students with an opportunity to carry out real research, some of which students presented at conferences for peer review (Otago Daily Times, 1999; Fenton, Fenton & Raynes, 2001). Former head of the Jet Propulsion Laboratory Dr Sir William Pickering was Patron.

This model of learning answered many of the criticisms of conventional school science mentioned earlier.

Examples of the benefits of this type of learning included:

- authentic learning (working with experts, using authentic tools, etc)
- social learning
- stimulating creativity
- catering for technically gifted as well as academically gifted
- authentic products of learning
- Integrated use of ICT
- authentic audiences, eg, post-graduate science conferences, The Royal Society of New Zealand, The Western Institute of Technology at Taranaki

Feedback from parents and students involved as members of the group included typical comments such as “life-changing” and “a completely different kid”, indicating the positive change to attitude to learning and the consequential raised academic achievement.

New Zealand students had the opportunity to make discoveries from playful experimentation, being lucky, and getting their hands dirty. Even ‘failed’ experiments were learning opportunities.

Both Pakeha and Maori students experienced success even if they were turned off from traditional school examinations (Fenton, 2003).

For more information visit www.nexusresearchgroup.com

The integration of ICT into science teaching

More than half of teachers that were part of an ICTPD cluster professional development programme had used ICTs 'often' or 'always' for lesson planning and preparation. For those teachers who *had* used ICTs with classes before the programme, the highest proportions had been using word processors for writing or project work, the Internet for 'research', or content specific (eg: drill and practice) software (Ministry of Education, 2006b).

The TELA report (Ministry of Education, 2008b) found Mathematics teachers were somewhat ambivalent about the value of computers; they saw more possibilities for the use of graphic calculators. In contrast, science teachers saw ICT as being able to contribute everyday examples and illustrations of ideas.

This is similar to the UK experience reported by Gray and Souter (2000). Relative to other subject teachers, science teachers came out positively with regard to use of and confidence in ICT. However, in absolute terms although the availability of computing facilities was reportedly quite high, actual level of use was quite low. In addition, where level of use was higher, it was with regard to a rather narrow range of applications, particularly word-processing. In addition, little was reported in the way of pupil use of ICT in science classes.

Although there appeared to be an awareness of the potential for ICT in science, teachers indicated that they did not see the introduction of ICT as radically changing the way in which teaching took place, nor changing the teacher-pupil relationship. Science teachers were reasonably confident in their use of ICT but felt that they needed much more in the way of support and professional development to maximise their use of ICT in the classroom.

Being trapped by an assessment driven curriculum appears to be a global problem. Chen, Taylor & Aldridge (1998) report what could just as easily be said for New Zealand:

"Qualitative analysis revealed the examination-driven nature of teaching. The classes were mainly teacher-centered. The teachers seemed mostly concerned with the content coverage. The students were left with little chance to experience science in their classrooms."

Leach and Moon (2000) reflect on the experience of the United Kingdom teachers trying to integrate ICT in their subjects as *'at best random, at worst banal and inconsequential'*.

If science teachers have their own world view of what science is, then it should come as no surprise that it will take more than simply supplying technology to change classroom practices. If New Zealand is to develop greater technical capability and fulfil the opportunities the new curriculum offers students in terms of authentic learning experiences, an investment in time for meaningful non-trivial professional development of science teachers appears long overdue.

Research on data loggers and a new opportunity

There have been two research initiatives in New Zealand schools examining the use of data logging tools in science and mathematics. The draft MOTIS (Mobile Technologies in Science) report (Tideswell, 2005) and the CAS (Computer Algebraic Systems) project for mathematics (Neill & Maguire, 2008) cite positive benefits in terms of engagement and understanding in these curriculum areas. The cost of the equipment however is prohibitive to many schools and indeed the CAS project largely relied on donated equipment. The research confirmed findings overseas that practical hands-on investigations resulted in more authentic learning, higher student engagement and greater understanding of concepts.

Yet RIGEL does more than data logging. The open-ended architecture permits students to explore electronics and electrical circuits of their own design. According to Mike Forret of Waikato University, (personal communication, 2004) there has been almost no research in this area other than one paper he presented in 2003 (Forret, 2003).

It seems ironic that there is so little opportunity for students to explore electronics and electrical circuits in an age when ICT's that depend on electrical circuits are more common than ever.

The NEMP report (Crooks, Smith & Flockton, 2008) does not shed any light on the issue as the Year 8 results were inconclusive due to equipment problems!

I decided that an opportunity to explore student interest in electronics and robotics at Primary school would be of value in light of the paucity of research and information in this area. One approach was to encourage the students to invent there own activities using sensors as part of a game.

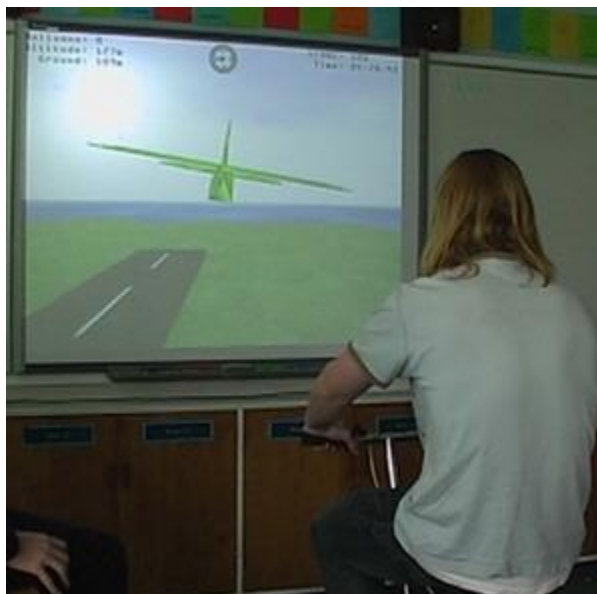


Figure 6: An exercycle operates a glider in a flight simulator

METHODOLOGY

Selection of students

RIGEL is a general purpose mobile technology consisting of a hand-held computer, sensors, and associated software invented by the author, Michael Fenton. During this project, RIGEL was to be tested for its suitability for two different teaching pedagogies:

- an enquiry-learning focused (constructivist) class of Year 7 & 8 students.
- an NCEA assessment focused (positivist) class of Year 13 Calculus students.

A local State Primary school agreed to participate in the research and a mixed ability combined Year 7 and Year 8 class of 27 students was chosen as a test group.

A second school, a local State secondary school, agreed to the Year 13 Calculus class being approached to participate as case studies for the second test group. Four students were selected as case studies.

Ethics and consent

The students selected to participate in the research project each received an information sheet outlining the scope of the research and a permission sheet to sign in conjunction with their parents (Appendix 13).

Data collection

Data was collected over a ten-week period. Methods of data collection included surveys, interviews, video recording, audio recording, observations, student writing, student reflections and finished products such as the Olympic Games Day (appendix 4). The students also engaged in peer and self-assessment.

Data analysis

Four Secondary school students were followed as case studies looking at individual skills and attitudes.

Primary school students were followed as a cohort and data analysed qualitatively and quantitatively.

Comparison against Blooms taxonomy, SOLO taxonomy, authentic learning indicators and understanding the nature of science indicators were carried out.

An analysis based on developing a grounded theory of student responses was used to determine common themes and categories of student responses to questionnaires and interviews.

The principle of triangulation was employed in an attempt to verify that what I believed I had observed was supported from data from other sources. Hence the requirement to collect data from multiple sources when observing a student activity; note my own interpretations of what I had seen, and compare against data from interviews or products made by the students (eg, PMI analysis or data from student work books, appendix 4 and 10)

According to Hitchcock and Hughes 1989, Cohen & Manion 1994,

“Triangulation demonstrates the internal validity of the findings, but cannot guarantee external validity; these outcomes may not be reproducible in other settings, with other students or teachers.”

Indicators of authentic learning

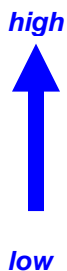
The following table outlines the indicators and evidence of authentic learning used in this study:

Indicators of authentic learning	Notes and examples
Real-world relevance	Match the real-world tasks of professionals in practice as nearly as possible Examples: <i>using tools, equipment or processes students see as “sophisticated” or “high tech”</i>
Sustained investigation	Activities engage the student over the period of days
Reflection (metacognition)	Authentic activities enable learners to make choices and reflect on their learning, both individually and as a team or community. Examples: <i>student PMI analysis, student peer review “that was good/bad/would be better if...”</i>
Interdisciplinary perspective	Students adopt diverse roles and think in interdisciplinary terms. Examples: <i>students fabricate prizes and artwork for the Olympic Games, students take role of teacher/instructor</i>
Polished products	Activities culminate in the creation of a whole product, valuable in its own right. Example: <i>a performance or challenge to complete</i>
Multiple interpretations and outcomes	Diverse interpretations and competing solutions
Informal learning	Learning that takes place as part of a ‘hidden curriculum’. Unconscious or covert learning Examples: <i>students report knowledge they have picked up from the activity that was not explicitly taught</i>

Table 3: The seven indicators of authentic learning used during this study

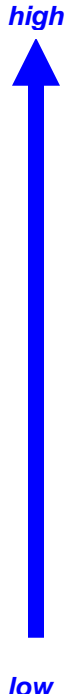
Indicators of high level thinking

The following tables outline the indicators and evidence of high level thinking used in this study:



Indicators of high level learning	Notes and examples (Bloom's Taxonomy)
Create	<u>Example:</u> Design and produce an Olympic Games event
Evaluate	<u>Example:</u> Debate the usefulness of authentic learning
Analyze	<u>Example:</u> Contrast the terms belief, knowledge and truth
Apply	<u>Example:</u> Explain how you could remotely control a toy
Understand	<u>Example:</u> Give examples sensors used at home
Knowledge	<u>Example:</u> Name one sensor we have used this term

Table 4: Indicators of high level thinking (Bloom's taxonomy) used during this study



Indicators of high level learning	Notes and examples (SOLO Taxonomy)
Extended abstract	The student makes connections not only within the given subject area, but also beyond it. <u>Example question:</u> List 4 types of sensor you have used and discuss their usefulness in everyday life.
Relational	The student is now able to appreciate the significance of the parts in relation to the whole <u>Example question:</u> What advantages do you think will come from attaching the sensor units to our calculators?
Multistructural	A number of connections are made but the meta-connections between them are missed, as is their significance for the whole. <u>Example question:</u> List the uses of a temperature sensor.
Uni-structural	One aspect of a task is picked up or understood serially, and there is no relationship of facts and ideas. <u>Example question:</u> Name one of the sensors we have used this term.
Pre-structural	There is a preliminary preparation, but the task itself is not attacked in any appropriate way.

Table 5: Indicators of high level thinking (SOLO taxonomy) used during this study

Indicators of understanding the nature of science

The following table outlines the indicators and evidence of understanding the nature of science used in this study:

Indicators of an understanding of the nature of science	Notes and examples
Able to describe general or specific knowledge of a physical process using appropriate scientific terms and explanations.	The student is able to appreciate the significance of a scientifically defined process. <u>Example statement::</u> "Mirrors can be used to bounce/reflect light around corners"
Able to articulate a plausible explanation for observations using appropriate scientific terms and thinking.	The student is able to use their thinking in a scientific way. <u>Example statement::</u> "I found out that the magnetic sensor was active near my desk so I think it means there is something magnetic inside affecting it"
Able to articulate that their view of "being scientific" has changed because of the activities using RIGEL	A new understanding has been developed that the student did not have before. <u>Example statement::</u> "I didn't know that scientists made toys"
Expressing a desire to find out how a process works (curiosity)	A desire to investigate the natural world has been made that the student did not have before. <u>Example statement::</u> "I want to find out how it works"

Table 6: Indicators of understanding the nature of science used during this study

Overview of data collected, purpose & analysis

The following table outlines the data collected during this study and how it was used:

Type of data	Purpose of data	Method of Analysis
Teacher interview	To elicit data about beliefs, attitudes and the teacher as an agent of change.	Grounded approach Frequency analysis of responses
Video	To capture different activities an student-student/student-teacher interactions	Grounded approach Frequency analysis of behaviours
Student work (artefacts in books, products of learning in any form, products made during the learning process)	To capture evidence of a change in students thinking and evidence of higher level thinking	Grounded approach Frequency analysis of responses
Student interviews	To determine attitudes and confirm video observations. To capture evidence of higher level thinking	Grounded approach
Student survey/questionnaire	Elicit further details of student thinking and confirm video observations	Grounded approach Frequency analysis of responses

Table 7: Overview of data collected, purpose and analysis methods used in the study.

Student surveys:

In order to permit a quantitative analysis, five questions in the survey (see appendix 3) required circling one option. I assigned a 5 to 1 value to the responses (5 for “strongly agree” down to 1 for “strongly don’t agree”).

Student interviews

In order to permit a quantitative analysis, three longer discussion questions were assigned a 1 if I felt the student had adequately responded, a 0 if they had no opinion/answer or if their views had not changed (see appendix 3).

FINDINGS

The findings of are divided into four sections in alignment with the research questions:

1. How does the use of RIGEL support authentic learning?
2. How does the use of RIGEL support higher level thinking?
3. How does the use of RIGEL support students developing a greater understanding about the nature of science?
4. A subsidiary question was what problem(s) does this new technology solve?

Each section is split into sub-sections:

- Year 7/8 students combined analysis
- Year 13 Calculus students individual comments and analysis

The Year 13 students were preparing for Achievement Standard 90636 Integrate functions and use integrals to solve problems.

Supporting authentic learning

Year 7/8 students

The enquiry topic took place during the lead up to the Beijing Olympics. Using RIGEL configured according to the students plans, the class created an Olympic Games based on 8 different events (see appendix 4). The teacher developed his own lesson plan for this work involving the students. This included:

- Brainstorming ideas for events that use RIGEL sensor units
- Get into teams to develop a specific activity (decide rules, prizes, banners/signs/artwork, what sensors or programming is needed for sensor units, etc)
- Trialling the events and improving where necessary
- Putting on a performance - running the 8 events as the Olympic 'officials' and technicians while two other classes participate as competitors
- Students carrying out a PMI analysis of their activity

Data from classroom observations, video recordings, student interviews and student workbooks clearly demonstrated that all seven indicators of authentic learning, as described in Table 3, were evident.

One 'complaint' from students was that they needed longer for the 2 classes to try each event without rushing. The class had 1 ½ hours for this but I think they could have kept themselves happily occupied for 2 hours. There were no discipline problems that I could see.

Indicators of authentic learning	Examples from data
Real-world relevance	Using tools, equipment or processes students see as "sophisticated" or "high tech", eg, RIGEL
Sustained investigation	Activities engage the student over the period of days and involved work from home
Reflection (metacognition)	Student PMI analysis, student peer review <i>"that was good/bad/would be better if..."</i>
Interdisciplinary perspective	Students adopt diverse roles and think in interdisciplinary terms. Students fabricate prizes and artwork for the Olympic Games, students take role of teacher/instructor
Polished products	Activities culminate in the creation of a whole product, valuable in its own right. Two classes participated in an event created and supervised by the Year7/8 class.
Multiple interpretations and outcomes	Students had to work in teams, discuss what their event would be, test, and modify if necessary, their events prior to the Olympics Day.
Informal learning	Students reported knowledge they have picked up from the activity that was not explicitly taught, eg, how the sensors worked or could be configured for their event.

Table 8: Example evidence of authentic learning from Primary students

Quotes from student interviews indicated that the event was fun and engaging. An example is:

"I don't think people realised how strongly they were going to be drawn into it (the technology). When we started we had no idea we would make games. When they started thinking about the Olympics everyone got really excited and then we came up with a really strong product with their games (activities)...I reckon they'd do it again."

The only other 'complaint' was that the class didn't have a chance to try each others events and see how the sensors worked:

"Now I know our event and what we did was successful I'd like to go and help other teams and learn about their activity and how it works."

Students that used the 'cybercycle' (appendix 9) used a flight simulator that was designed with input from other students. Students had to test and modify their events and afterwards carried out a PMI analysis (see example appendix 10). The two other classes thoroughly enjoyed the 1 ½ hour slot. They were reported by one teacher as describing the Year 7/8 class as 'geniuses' for creating and running such an activity.

Year 13 Calculus students

The Year 13 students were preparing for Achievement Standard 90636 “Integrate functions and use integrals to solve problems”. This is an externally assessed standard that includes using Simpson’s rule. Simpson’s rule is particularly suited to profile problems where the equation for the profile is unknown. We use Simpson’s rule to approximate area under curve:

$$\text{Area} = \frac{h}{3} [y_0 + 4y_1 + 2y_2 + 4y_3 + 2y_4 + 4y_5 + \dots + 2y_{n-2} + 4y_{n-1} + y_n]$$

h is the interval length (must be constant) and the number of y values must be odd.

Before starting the practical activities associated with the research questions of this study, students were asked about the value of doing the practical activities provided.

1. How would you describe what high school mathematics is about?

Adam: *Doing lots of questions out of books, you just do the exercises.*

Bob: *Boring.*

Chad: *You don’t do anything real until you do the merit or excellence type questions.*

Dave: *It’s all just algebra, lots of algebra and formulas over and over again.*

Bob: *Lots of questions with not much point. Sort of what you expect at school.*

2. What does the word “authentic” mean to you?

Adam: *Real.*

Bob: *Outside.*

Dave: *Original, genuine.*

Chad: *What he said.*

3. What does “authentic learning” mean to you?

Chad: *Problem solving.*

Adam: *Has to do with the real world, to prepare for getting a real job.*

Bob: *I guess you can do inside activities since you might run out of time.*

Adam: *Using maths for something real.*

4. What are the disadvantages of “authentic learning”?

Bob: You spend so much time on the activities that you run out of time to cover all the course material.

Chad: It might be fun and you learn a lot but it's not covered in the exam.

Dave: Yeah.

5. What are the advantages of “authentic learning”?

Dave: Well you get to do more than just one thing at a time, makes it more complex.

Adam: It's based on problem solving first and what you learn comes in the process as you do it.

Chad: You get to do something new and different.

Bob: You get to use maths in the real world. It doesn't feel like work, it's fun.

Adam: You will remember better since its much more is hands on.

Dave: You end up learning more than just what you have to.

6. What advantages do you think will come from attaching the sensor units to our calculators?

Chad: Takes the boredom out of collecting the data so you can spend more time on figuring out what it all means.

Adam: If you can leave it to record stuff for you, you can spend your time on more important stuff.

Bob: You waste less time filling in tables or drawing graphs.

General observations:

Throughout this discussion, Bob contributed more than the other three students, and continued to do so during informal discussions. This is interesting in light of the fact Bob scored lowest in formative assessments during the year. The students were able to define their own understanding of the term “authentic learning” and describe the advantages and disadvantages of this approach. The students decided they would like to try some activities based on their definitions.

Two tasks are described on the following pages.

Problem based learning (PBL) task and case based instruction (CBI) tasks:

After the discussion outlined on the previous pages, students worked in pairs. Each pair had the opportunity to work on the PBL task and the CBI task.

PBL task, Team A: Construct a robot

Bob and Dave happily began assembly of a Tamiya dual drive gearbox as the first task to construct a robot for use during the Calculus course (see appendix 7). The size, sensors and general materials for the robot design were not specified other than it could operate by remote control or autonomously. This activity involved

- using tools (screwdriver, Allen key)
- reading instruction with few words and complex visual guides
- determination of correct sequence of assembly
- fault finding
- justification as to which of the four gear ratios to use
- patience
- persistence
- communicating
- Trial and error

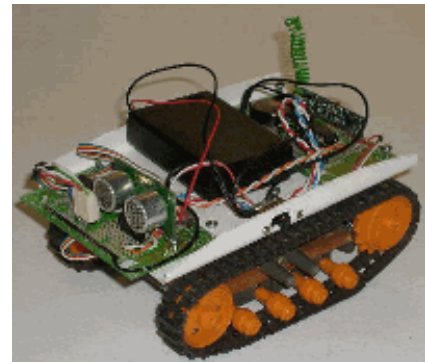


Figure 7: Example robot

Bob initially thought that there was nothing to do with maths in this activity, then smiled and said “of course, ratios!”

Both students had to work together to decipher the correct sequence of assembly and identify the parts from names such as “bushing” and other jargon. One student had never used an Allen key. Both showed persistence and patience and helped each other as a team to complete the task. They then began planning how to fit the gearbox to a body of their own design.

During the time it took to assemble the gearboxes, the two students spent a lot of time talking to the teacher (researcher) about a wide variety of topics including plans for university, home life, applications of robotics, etc. The nature and quality of the conversation was much wider and deeper than the conversations a teacher may have using the traditional “work from book exercises” lesson. They demonstrated this by the level/quality of the questions about physics, chemistry and astrophysics applications and problems. For the teacher (researcher) it felt more of a challenging conversation with a peer rather than an empty headed student being filled with content. The discussions are more about seeing relationships and making connections to other disciplines rather than using the equation for Simpson’s rule out of context.

When asked if this was an “authentic learning” opportunity, both students said yes.

CBI task, Team B: A Survey of Mars

Adam and Chad were happy to design a scenario for Bob and Dave to work on next lesson (see appendix 8). They planned to use a Casio graphic calculator attached to a RIGEL unit configured with an ultrasonic range finder to measure a scale model of a Martian landscape. The range finder was thought of as part of a robot on the ice of the north pole of Mars. The students in Team A would use the set up to collect distance measurements to calculate the cross sectional area of the ice below the robot. Team B took the role of NASA engineers testing a design on Earth using a mockup before Team A (in the role of NASA mission control operators) ran the “real” mission. The Team B engineers would then assess the accuracy of the profile the Team A operators returned to them from the “real” mission. In return, the Team A operators could make recommendations to the engineers for improvement to the design and use of their robotic sensor system. This activity involved

- using tools (screwdriver, retort stands, clamps, tape)
- calibrating the range finder
- programming a Casio graphics calculator
- planning and sequencing
- fault finding
- understanding the physics of wave reflection
- justification as to the shape and size (exaggeration) of the terrain for the sensor to detect
- Trial and error to determine best practice
- teamwork
- leadership
- communicating
- when to ask for “expert” help (asking the teacher how to reprogramme the calculator)
- using appropriate materials (eg, books to build a terrain profile)
- patience
- persistence
- analysis of data against expected norms
- consideration of how other people are likely to use/operate the satellite sensor

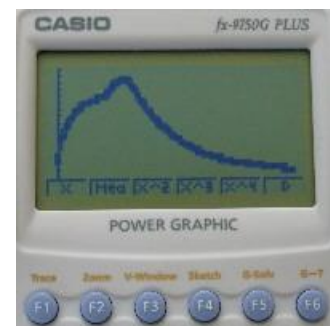


Figure 8: Example of ‘Martian’ landscape profile

When asked if this was an “authentic learning” opportunity, both students said yes.

Adam and Chad were puzzled for a while about the profile they had created from test books placed in piles along the floor and the profile the range finder had reported on the Casio graphic calculator screen. The reported profile was flat and one point where they had created a V-shaped valley. It dawned on them that the transmitted vertical waves from the range finder were being reflected at a 45 degree angle horizontally so the receiver couldn’t “see” the valley. This lead to

them altering their mock up profile and discussing how surveying satellites might overcome this problem. Both students were fully engaged with the activity for the entire lesson.

One of the students recognizes that they will have to “set the scene” (see appendix 8).

Adam: Won't we have to write something up so the others know the situation we have set up for them?

This team debated the approach to solving one of the variables needed to use Simpson's Rule...the h value.

Adam: If we go over a known distance...(pause and thinking for 25 seconds)...if we go over a known distance and we know how long we took to do that, we could figure out velocity, and divide that by how much time between sensor readings, that will give us how much distance each height reading was taken for h .

Chad: *But that's assuming we move at a constant speed*

Adam: Yeah but...(more explanation/justification)...mmm, we need to test it...

They decide to change their method of taking range readings so a more accurate profile is determined (take readings at certain intervals to match h variable in Simpson's rule)

This demonstrated the adaptation of original ideas, trial and error, and consideration of how their peers would be likely to use the equipment.

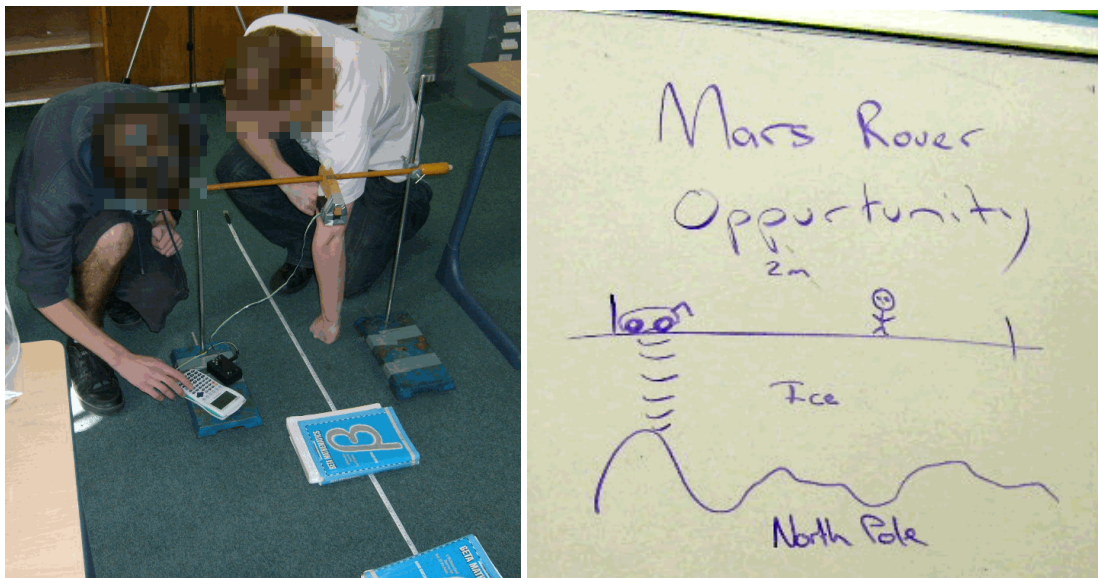


Figure 9: In the role of NASA engineers; testing a range finder sensor unit

CBI task, Team A: Crime Scene Investigation

Bob and Dave decide that they are going to challenge Adam and Chad with a scenario based on Crime Scene Investigation (CSI) using Newton's cooling curve to determine time of death (see appendix 6). Bob and Dave used a RIGEL unit configured with temperature sensors connected to a Casio graphic calculator.

Both students showed persistence and patience for 20 minutes recording data and altering the temperature by adding various amounts of cool water.

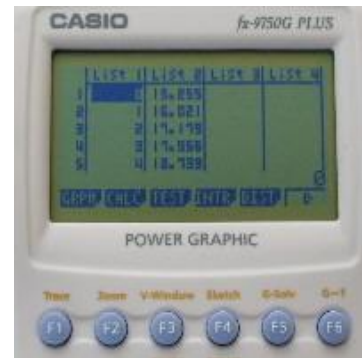


Figure 10: Casio calculator configured as a data logger

Bob: We'll use a pigs head and get the others to measure it. They have to tell us time of death from the rate of cooling.

Dave: Maybe we could use a piece of steak.

Bob: I guess we'll have to find out about the rate of cooling for a human and see if it's the same as pigs.

Dave: We'll have to warm the pig up first and let it cool...the others have to tell us when it died.

Both students were fully engaged with the activity for the entire lesson.

During the time it took to calibrate the sensors, Bob and Dave continued to discuss how the other students (Team A, Chad and Adam) would do the challenge:

- Team B would provide evidence staggered as a series of clues to mimic the time delay of real evidence being gathered or discovered by investigators
- Team A would have to use the internet to find information about the identity of the offender
- The evidence would point to one offender but the motive would have to be constructed or guessed by the investigators (Team A).
- The students doing the CSI challenge (Team A) would have completed the activity when they had correctly determined the time of death, the offender, and provided a motive.

This demonstrated the adaptation of original ideas, trial and error, and consideration of how their peers would be likely to use the equipment.

Case-based instruction (CBI) peer teaching / peer assessment

The researcher/teacher simply observed the student interaction. The students assessed and taught each other as peers.

Mars Survey:

Team A (Chad and Adam), as the creators and assessors of this challenge, assembled the Martian landscape on the floor of the classroom according to their previous test profiles.

Bob and Dave (Team B) did not upload a new version of the range finder programme into their graphic calculators. Consequently, though they proved quite capable of using the equipment and set up devised by their colleagues (Team A), the data collected from the model Martian terrain was inaccurate.

After a period of time to apply Simpson's rule to the data they had collected, Bob and Dave, as NASA mission controllers, were able to report to Chad and Adam, as NASA engineers, the vertical area they had calculated for the Martian landscape.

Chad and Adam reported back that Team B had over-estimated the area by as much as 100%.

A discussion followed that led to Team B realising they had an old version of the range finder programme.

Team A suggested that if a simple manual approximation of measurements were made, using a simple height multiplied by the width calculation, Team B might have discovered their error, rectified the problem, and successfully completed the mission.

Crime scene investigation (CSI):

Team B (Bob and Dave), as the creators and assessors of this challenge, were not as organised as their original challenge plans had called for. Consequently, a much simpler challenge was used: determine the time that the water in the container was at 70°C.

Team A (Chad and Adam) spent a period of time to collect temperature data using RIGEL attached to their graphic calculators (see appendix 6). They then chose an appropriate mathematical model (equation) of their own design to fit the data collected. From this they extrapolated to a time before the lesson when the water temperature was at 70°C.

A discussion followed that led to Team B realising that Team A had come up with a more appropriate mathematical model that correctly determined the time than the one they were using as the assessors. The lack of preparation by Team B was evident.

Supporting high level thinking

Year 7/8 students

Using RIGEL configured according to the students plans, the class created an Olympic Games based on 8 different events (see appendix 4). The teacher developed his own lesson plan for this work.

Transcripts from student interviews, questionnaires completed by students, and videotaped observations were analysed and matched to indicators for the SOLO taxonomy (table 5).

Indicators of high level learning	Number of students
Extended abstract	2
Relational	20
Multistructural	4
Unistructural	1
Prestructural	0
TOTAL	27

Table 9: Number of students at each level of the SOLO taxonomy

A similar analysis was undertaken to match data to indicators for Bloom's taxonomy (table 4).

Indicators of high level learning	Number of students
Create *	17
Evaluate	NA
Analyze	26
Apply	23
Understand	22
Knowledge	26

Table 10: Number of students at each level of the Bloom's taxonomy

Due to the nature of Bloom's taxonomy, students could perform at more than one level. A tally of students performing at each level was made.

* Due to students working in teams, I decide the top level was not applicable unless I could assign a piece of work to a particular student. This is a conservative estimate then as the entire class helped created the Olympic Games activity.

P (positive/plus)	M (minus)	I (improvement)
Got kids active	The people who won generally got chocolate and too much chocolate is bad for you	Longer time allowed to find the treasure
Had fun	Some of our clues flew away	More time for Game Day next time we do this
People who organized the game were using their minds without knowing	Some teams needed more time	The event organizers (our class that made the Olympics for the other class to compete in) should get a go!
Showed we can be trusted with electronics devices		
Showed we can be trusted with the responsibility of organizing and planning a Game Day		

Table 11: Example of a PMI analysis carried out by a Year 8 student

The host teacher was interested in how the activity had stimulated their thinking. A few examples of the conversations from student interviews included

- sensors and tectonic plates
- the moon and its influence on the tides
- how our radio hunt transmitter sends signals
- how they didn't realize scientists actually worked like I did
- 'Myth Busters' TV show investigations they could now do with the sensors

Teacher:

It would be interesting to see if their thinking about how it worked was triggered if it hasn't has it been a waste of time? Was it all just a fun activity?

Students:

Now I know our event and what we did was successful I'd like to go and help other teams and learn about their activity and how it works.

I didn't know that radio could send letters like "C" as a code, I thought they had to be sound waves.

...I have an idea for using a laptop. The black box with a camera is outside and when it senses something with that (infra) red light nearby it sends a radio transmit to your computer then you could say back "get out of there or I'll call the cops!"

Researcher: So that's a bit like what you see on Mission:Impossible with their laptops
...yeah but what they do on Mission Impossible is their radio uses satellites (pointing skyward)

Teacher:

How many students will go “Well I’ve learnt this, and I can apply it to a real situation”?

Students: *Discuss with examples using sensors in everyday life*

	safety/ security	Health/ medicine	science/ data collection	games for fitness	games for education	toys/ games for entertainment
Male	6	1	1	1	1	6
Female	0	0	2	3	0	3
TOTAL	6	1	3	3	1	9

Table 12: Uses of sensors in everyday life

From the table above, 54% of students (14 out of 26) could relate the use of sensors to activities other than games for fun.

From interviews, 81% students (21 out of 26) could list 4 types of sensor and discuss at least one sensors usefulness in everyday life.

Students: *If you could keep RIGEL, what sorts of things would you use it for?*

	safety/ security	Health/ medicine	science/ data collection	games for fitness	toys/ games for entertainment
Male	6	2	1	4	0
Female	2	4	0	1	3
TOTAL	8	6	1	5	3

Table 13: Uses of RIGEL at home or school

From interviews,

- 85% (22 out of 26) of students had learnt something new about science/technology or about themselves.
- 85% of students had changed their view of what scientists do or how they work.

Overall, the findings are interesting as we had in fact done almost no “science” explicitly and from classroom observations the students appeared to be “just having fun” with the equipment.

Year 13 Calculus students

The case based instruction (CBI) challenges permitted all four students to work at the highest levels of the SOLO and Bloom's taxonomy as evidence from discussions, peer teaching, and peer assessment indicated.

As an example, Bob and Dave had recorded inaccurate data while carrying out the Mars terrain profile NASA challenge. However, this provided an opportunity to discuss whether mistakes involving failure to have a systematic procedure to follow was realistic. There was a brief discussion about the TV series "Seconds from disaster" and plane crashes, and the *Challenger* space shuttle disaster. If mathematics is to model the real world then there are real world consequences for how findings or concepts are applied.

One student commented

"It's the stuff on the tangent that you will always remember. You forget really quickly all the book work...mainly because it's just for exams. But the other connecting ideas and experiences are what sticks and makes a difference."

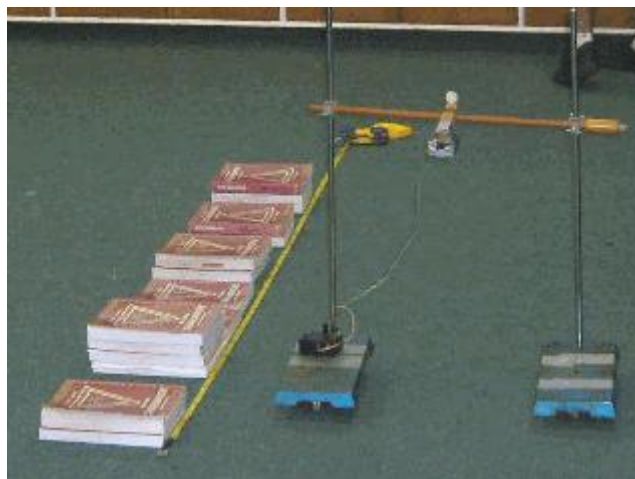


Figure 11: Student solution for Mars survey challenge

Supporting an understanding of the nature of science

Year 7/8 students

The students had just finished a unit about the human body. This prior knowledge was used to help students gain an understanding that computers can be given senses like the five senses humans have. They were introduced to the hand-held sensor unit (RIGEL) that permitted them to investigate the kinds of “extra” senses (sensors) that could be useful for further science-based activities. The lesson plan for this science based round robin activity is included in appendix 11.

General observations:

- A group of boys plugged in a set of headphones they had in class. Usually a teacher might punish this failure to follow instructions to use the sensors provide. However, some of my sensors work by putting them in a circuit deliberately the wrong way around. A sensor unit and lesson like this copes with both types of directed and more "discovery" or “what would happen if...” based student approaches.
- All 24 students were on task for the 45 minute session. There were lots of smiles. Frowns appeared to be of puzzlement rather than negativity.

Each student had a job assigned in introduction to the activity:

- One leader (all boys group) did not supervise his colleagues very well as he was busy trying to find other objects to test. He found a pair of headphones from a computer and plugged this into the sensor unit to see what it would do.
- One recorder (all boys group) failed to write anything from 6 stations but enjoyed the activity and using the gear.

This was the first time according to the students that they had experienced a round-robin activity and their first ‘real’ science activity. Overall there was a positive atmosphere and high student engagement with minimal direction needed.

Example comments include the following:

Open ended enquiry

“This is neat...I wonder if hands will work”

- a student using static sensor

“Why did the wet sponge make the light come on?”

electrical conductivity sensor showing a wet sponge passes an electric current.

A chance to look at electricity at home and school.

New learning/ideas to follow up

"Oh, it doesn't work...yes it does, I just can't see it." - a student using an infra-red (IR) light and IR sensor. A chance to consider how TV remotes operate and how annoying it would be to see flashes of light.)

"Could you make a game that senses if you are lying? That would be cool!"

Link to computer programming and electronics; a new RIGEL game to develop!

"I found out that static is on everything...could we use it to power things?"

Teamwork:

The hand held RIGEL units and sensors require some manipulation so at least two people must handle to gear for reliable readings. A third student allocated by the teacher recorded information. Teams appeared to operate well with the three students minimum.

Forming conclusions:

There was no time for a more detailed reflection to make conclusions but students made judgements about differences or similarities in what they had observed;

"We found that three of use had the same hand temperature but one of us was colder than the others."

"We found that wet things could conduct electricity but dry things didn't"

This comment might indicate gaps in knowledge or the need for more time for further investigation to see if assumptions based on a few objects actually apply to all objects, eg dry metals.

"If you made it sense the Earths magnetic field it would be useless because it (the warning light) would be on all the time...it wouldn't detect anything else magnetic..."

This activity involved using the RIGEL sensor units as simple surveying tools. A visual signal from the LED gave a presence/absence indication. However, data could still be tabulated if desired and graphed by the students.

Quantitative measurements or other student initiated activities were going to be the next phase for investigation. The 2008 Science Fair was coming up and so a list of possible scientific investigations were created from students' ideas (see appendix 5).

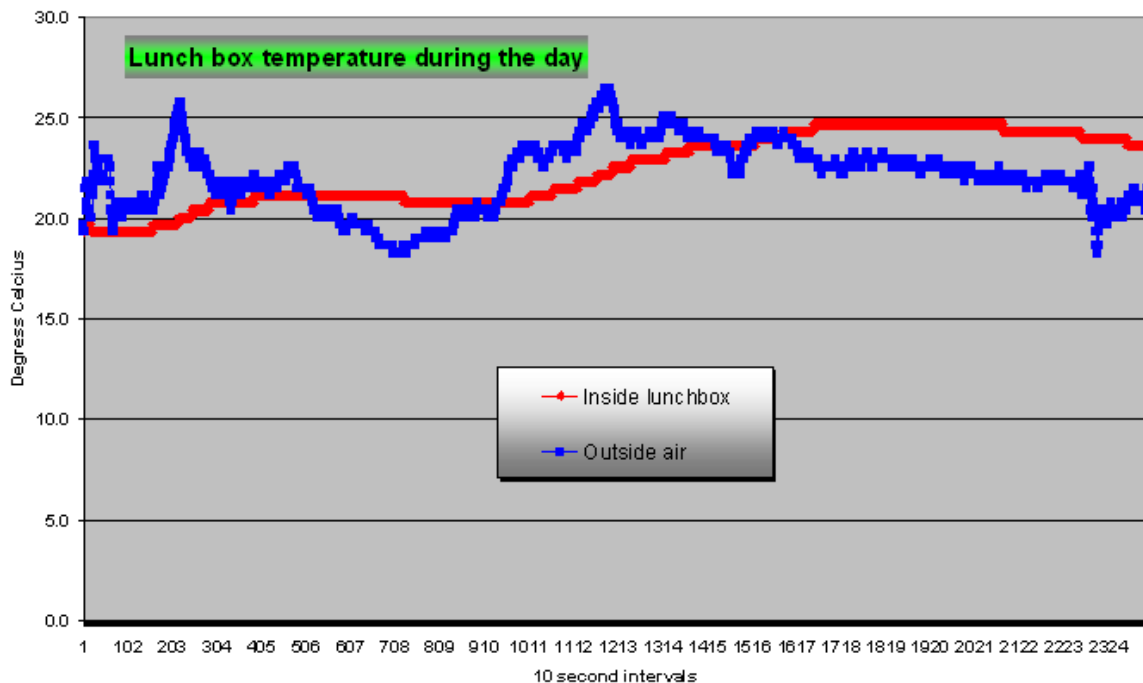


Figure 12: Science Fair data collected by a Year 5 student using a RIGEL data logger

A Year 5 student from a neighbouring class was eager to investigate if her lunchbox could be a source of food poisoning. She had noticed that by lunch time her sandwiches were very warm and did not taste very good. She was worried that at high temperatures bacteria reproduced quickly and might spoil her food. Her idea was to use the RIGEL unit as a data logger and record the outside air temperature and internal lunchbox temperature at 10 second intervals. Uploading the data to a PC and using the EXCEL chart wizard were new skills to her but they did not appear to be difficult for her to learn. With a little guidance from the researcher, she was able to explain that it was not only the temperature but the length of time at a high temperature that mattered. She said that charts were easier to understand than lists of numbers (the RIGEL data logger collected approximately 3,000 readings each day). She will collect data during February and March and is obviously excited at the end of each day to see the patterns on the chart and think about what they mean.

If a Year 5 student is able to learn to use a new ICT appropriately, it is no surprise that the Year 7 and Year 8 students find it is easy to use this type of mobile technology.

Comparison of teacher and students' views

Teacher:

The ordinary student will not have much electronics or science knowledge. What level of sophistication do the students have to be at in terms of science and electronics knowledge to be able to really explore using the box (RIGEL hand held sensor unit) ?

Students:

I discovered that I had more patience than I thought. When you first came in I thought "I can't do this, I won't know what to do, this is going to be really hard, I'm not really brainy, I can't do any of it". But then you walked us through it and it got really interesting and I was like "this is really interesting!"

The whole thing was new really. It's a bit more high tech really because at our school they don't let us use stuff like that because they think we're too young. They think we're not capable and too young and the teenagers get to use all this stuff anyway. Why can't you start when you are young then you'll be so much smarter when you're older!

I quite liked using the black boxes because it was a new experience for me. I usually use computers for mucking around and playing games or playing games on Safari (Internet games). I've never used a computer for science stuff and I quite liked it.

*I liked using the computer for something other than just games or mucking about.
Science is cool!*

Teacher:

The students enjoyed interacting with the technology, because practical things are always more fun than being simply told about it.

Students:

I used to think science was quite boring but now I think it's quite fun. The whole lot was fun.

An experience like no other I have ever had at school.

It was cool working with the little black boxes.

I want to make more games (note "make" not "play")

It was really fun. I want to build heaps more stuff now.

Teacher:

Weren't very sophisticated with what we did.

Students:

Usually we don't get to use sophisticated stuff like this, is like they think we're too young and we might muck it up.

...there are some kids in our class who are really in to this kind of stuff and you didn't start so high people lower like us didn't turn off and you didn't do it too low so those interested turned off.

I've discovered that I really like science; I understand science, before that I wasn't interested at all but using RIGEL has made a difference.

I liked seeing what you could do with all the sensors, trying them out and that.

I wasn't really into technology that much but I learnt that now I'm really into it because of what we did.

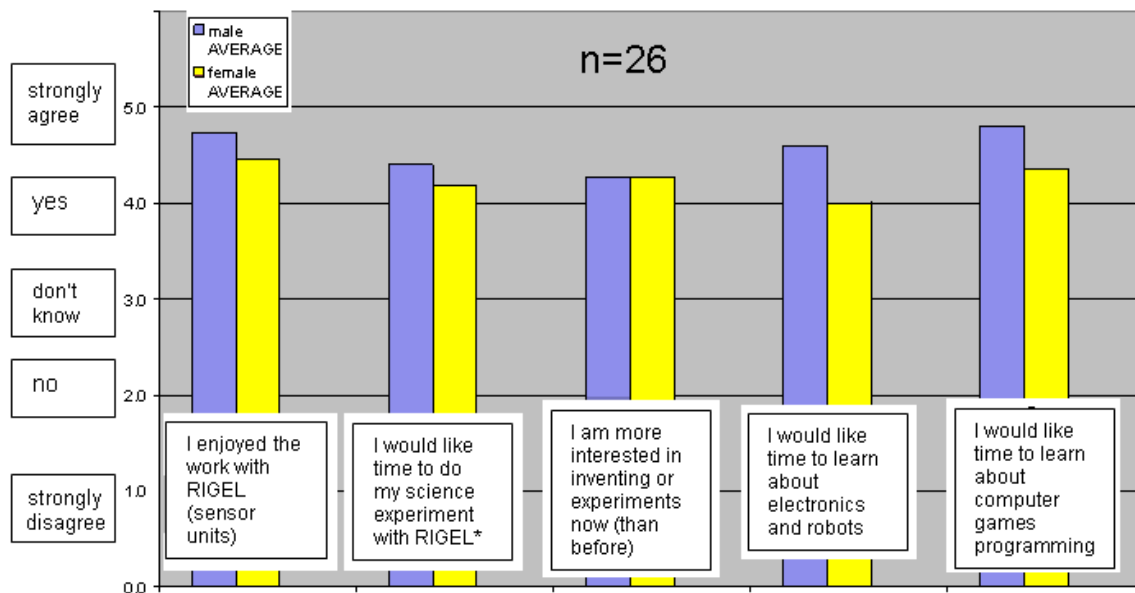


Figure 13: Results of Year 7/8 survey

- Q1: NO students score less than 4
Q2: One student scored 3, all others 4 or more
Q3: Four students scored 3 or less, all others 4 or more
Q4: Two students scored 3, all others 4 or more
Q5: One student scored 3, all others 4 or more

85% of students learnt something new about science/technology or about themselves.

85% of students had changed their view of what scientists do or how they work.

Year 13 Calculus students

The Year 13 students did not show such a dramatic change in their understanding of the nature of science. Most were also studying a science subject and, after five years of secondary schooling and life experiences, had formed a view in broad consensus with a scientific philosophy as indicated in the following discussion.

How would you arrange these words to show their relationship to one another?

TRUTH BELIEF KNOWLEDGE

Adam: You have a belief, you gain knowledge then you know the truth.

Bob: Knowledge and truth should be pretty much the same.

Adam: But what you THINK the truth is can change...

Bob: But in court cases often no one really knows what the truth is."

*Chad: Beliefs can change due to the knowledge gained but truth is independent.
You can never really be sure you know truth.*

Another written comment concluded:

Knowledge influences belief, and beliefs affect the way we interpret information to gain "knowledge". Truth is the concept of an absolute, independent thing; non-subjective and applying to the real, material world.

What is the role of Science then? What is the nature of Science about?

Adam: To give you knowledge

Chad: About the truth

Bob: Not necessarily, as in chemistry our knowledge about atoms still depends on a belief that atoms exist as we can't see them.

Chad: Like in physics, he says (teacher) that we are not sure if this is true, it's what we believe for now.

RESEARCHER: So are you saying you have to have beliefs in Science?

All: Yeah.

So how is Science “better” than magic or anything else that people believe in? How does a scientific approach help?

Chad: *By using experiments.*

How does the use of equipment such as sensors/ data loggers fit into the diagram above, if it does? Why/why not?

Chad: *Sensors help us experience the world in a different way but we still have to believe they are doing what they are supposed to. Like last week we found a fault with the sensor system...it was inaccurate...if you didn't know that you would make false assumptions based on what it said.*

Another written comment concluded:

It stimulates the mind to search for truth. This search uses the sensors as an extension of oneself, giving the self new information influenced by the real world “truth”. This allows the mind to observe the laws of mathematics which appear to exist both in the mind and the real world.

This affirmation helps mathematics and scientific theory seem less abstract to practical people. It also piques peoples curiosity into the nature of the real world, encouraging scientific thinking and allowing effective experimentation.

What would you expect students to be doing and able to do by the end of the course?

Chad: *Do the problems out of the book.*

Bob: *Pass the exams.*

Adam: *They should enjoy the subject and want to do more. Students should have time to do the bookwork but also have regular opportunities to do practical and applied stuff. It has to be balanced.*

What activities, if any, changed your ATTITUDE to science and/or mathematics?

No comments, no changes identified. It appears that attitude is set by this age.

Solving other teaching / learning problems

Special learning needs

The most powerful image I have is this poster image for the Year 7/8 Olympic Games day:



The student that drew the artwork rated the work we did with RIGEL as "really enjoyable" but did not speak more than three or four words to anyone all day. This student apparently does almost no work in written, or any other, form. Being part of the team that created the radio transmitter Treasure Hunt provided an opportunity to communicate and demonstrate a wonderful drawing talent, something that could never be talked about or conveyed in written form. As the best artist in the group (and the class), this student was a valued and sought after member of the team (according to opinions and comments from the other team mates). This student is aware that art is a real talent so drawing is the one bit of work that is done to a high standard, usually it is in inappropriate places or done constantly at inappropriate times. The Olympics Games provided a legitimate outlet for this talent. Other students were obviously impressed with this poster drawing.

There are two other issues mobile technology such as RIGEL could address:

- Visual or hearing impaired students can engage in science and experience raw data in non-conventional ways. Data can be exported as pulses/patterns of light and sound. For example a student could hear hi/low tones via RIGEL software for sunlight levels over 24 hours, over 7 days, etc
- 'Hyper-active' students found a legitimate activity to engage in such as the Olympic Games events and the science round-robin.

Teacher instead of technician

If the technology is uncomplicated and intuitive to use, the focus on teaching and learning remains the top priority. The science round robin activity was a breakthrough or introductory task, chosen to be accessible to students and teachers who are new to the technology. By the second of the Year 7/8 activities the host teacher felt confident to plan a 'normal' lesson sequence with the RIGEL sensor technology no more than supporting the main context; the 2008 Beijing Olympic Games. The technology came second to the learning of the students, as indicated by the questions the host teacher asked about student learning and thinking:

It would be interesting to see if their thinking about how it worked was triggered if it hasn't has it been a waste of time? Was it all just a fun activity?

The ordinary student will not have much electronics or science knowledge. What level of sophistication do the students have to be at in terms of science and electronics knowledge to able to really explore using the box (RIGEL hand held sensor unit)?

How many students will go "Well I've learnt this, and I can apply it to a real situation"?

Learner as the expert and initiator of learning

The Year 7/8 class provided evidence that even 'young' students may view themselves as being perfectly capable of taking charge of learning and become expert users of technology.

- One Year 5 student from another class is currently undertaking a 5 month investigation, using a RIGEL hand held unit, for the 2009 Science Fair.
- Students still came to me after the research intervention asking about other uses for the sensor units and other investigations they would carry out if given the opportunity.
- 93% of the students (25 out of the 27) said they would like to carry out their science fair investigation from Term Three (see appendix 5).

Learning outside the classroom

Taking the tedium out of data collection (automated collection) encourages greater enthusiasm for practical investigations as the Year 5 student demonstrated (see page 57). As noted above, 93% of the class wanted to carry out investigations, many of which were based outside of the classroom (see appendix 5). RIGEL has built in TCP/IP and network capabilities. If time had permitted, it would have been possible for students to leave an investigation running at home, and send data to school via an internet connection. In this manner, it is what is happening outside of school that becomes the source of ideas and learning, rather than the classroom. One student in particular had a plausible and workable idea of how to monitor cars travelling above the speed limit outside the school grounds.

DISCUSSION

Research findings

Increasing student engagement

The use of authentic learning pedagogies in this study demonstrates that students gain more than empirical knowledge. 100% of the 27 primary students said they enjoyed the work using the RIGEL sensor units. The majority said they had changed their views about science and wanted to do more.

Observations of primary student behaviour during the science round-robin activity (see appendix 11) showed no disruptive student behaviour and hence no discipline problems.

Observations of student behaviour during the Olympic Games activity (see appendix 4) showed no disruptive student behaviour and hence no discipline problems.

Observations of the secondary students showed no evidence of truancy or discipline problems; rather students were engaged up to the bell at the end of the lesson and often stayed after class, even at the end of the school day.

Overall, using RIGEL to support authentic learning means to time appears to pass quickly leaving few opportunities for boredom and hence disruptive behaviour. Students take ownership of the learning activity and appear quite capable of identifying that they, not the technology, do the thinking.

These secondary student comments support this view:

"...takes the boredom out of collecting the data so you can spend more time on figuring out what it all means"

"It's based on problem solving first and what you learn comes in the process as you do it"
(formal learning is secondary not main focus or driver)

This primary student comment:

"I don't think people realised how strongly they were going to be drawn into it (the technology). When we started we had no idea we would make games. When they started thinking about the Olympics everyone got really excited and then we came up with a really strong product with their games (activities)...I reckon they'd do it again."

At times it was difficult to see that the students were cognitively engaged. Some time could be spent, which to the observer, looking as if the student had "switched off" or become disengaged or bored. However, evidence from interviews and interactions outside the classroom indicated

they were merely taking time to process the new material learnt and reconciling this with prior knowledge. Both secondary and primary students also showed evidence of quiet “planning ahead”. The primary students for instance, decided to go to the extra effort at home to make medals and prizes for the Olympic Games events. Based on the SOLO taxonomy, many students would be classed as operating at the relational level, ie, why were they making medals and prizes? Because the other student competitors would enjoy the events more. It would be more fun for everyone.

As the observer/researcher I had the luxury of being able to take time to question each student and discover this “hidden” higher level thinking.

I suspect that most teachers under time pressure mis-interpret or underestimate the cognitive learning and processing occurring when students appear to be “day-dreaming”. Many educators seem to think being cognitively active can only occur when students engage in a physically active way, such as using Discovery Learning techniques.

Students need time to engage with their teacher.

Supporting higher level thinking

The findings from both the combined Year 7/8 class and the Year 13 Calculus class are consistent with findings from both MOTIS (Mobile Technologies in Science) report (Tideswell, 2005) and the CAS (Computer Algebraic Systems) project for mathematics (Neill & Maguire, 2008):

- High levels of student engagement
- Positive effect on students attitudes
- Learning happens more easily and in depth
- A need for changes to NCEA summative assessment tasks to better align with constructivist teaching pedagogies that encourage exploration rather than following or recall of procedures.

A point of difference however is the ability for the RIGEL units to do more than data logging. As a mobile technology, an interesting paradox becomes apparent; the use of ICT to get students away from ICT. That is, using a hand-held technology (HHT) to get students outside and physically active, away from computer suites, and augmenting their own five senses with man-made sensors. Students use a computer to stay plugged into the real world, not cyberspace.

The Olympic Games event created by the Year 7/8 class was a delight to see and a privilege to be part of. The event demonstrated that if the learning comes first, and the technology second, students of all ranges of academic ability could perform at a high level on the SOLO taxonomy.

As a new ICT, RIGEL engaged students both physically and cognitively, permitted students to take charge of their own learning and supported authentic learning for all students in this study.

Further evidence to support this included primary students bringing me broken equipment outside of class and after school, wondering how it can be repaired or made into some new gadget or toy. One student in particular, identified by the teacher as giving very low level explanations, was the most talkative and helpful student. I identified him as operating at the relational level of the SOLO taxonomy as he talked widely and constantly about using RIGEL for a variety of security and environmental applications. He was quick to point out advantages and limitations of various approaches and justifying the problem that RIGEL technology could solve.

Supporting authentic learning

Authentic Learning, and derivatives such as Problem Based Learning (PBL) and Case Based instruction (CBI), requires a different approach from the receptive or lecturing mode of teaching commonly found in science classes. The work with the Year 13 students using RIGEL confirmed research that using CBI is a more effective teaching pedagogy than traditional approaches. The work overseas using CBI also reported that CBI leads to quicker transitions in thinking levels than PBL. This is not surprising since students engaged in problem based learning are faced with an "anything goes" situation with few signposts to indicate if they are going in the right direction to meet learning outcomes. The PBL activity involved building a small robot. Not surprisingly, the open-endedness of this task can lead to confusion as well as learning, and a great deal of time involved if it is unclear as to when the task has been completed well enough. In contrast, the same students using the CBI approach based on a CSI and a NASA activity had a goal to compare their work against, but the freedom to get to that goal as they saw fit.

As an experienced secondary teacher, well aware of the demands of teaching NCEA classes, I have found that authentic learning activities do not negatively impact on the academic achievement of students. In contrast, they provide an opportunity to explore some of the values and key competencies of the new curriculum. Students said they preferred a balance between trying to pass exams and doing other things viewed as equally valid and worthwhile.

"It stimulates the mind to search for truth. This search uses the sensors as an extension of oneself, giving the self new information influenced by the real world 'truth'. This allows the mind to observe the laws of mathematics which appear to exist both in the mind and the real world."

Reflections on the state of science education in New Zealand

Since the MOTIS and CAS reports, as well as others, have already identified that the appropriate use of ICT's can support thinking and learning, I have focused the rest of the discussion on the issues of science teaching and other issues that came to my attention during the course of this research.

21st Century learners or 21st Century workers?

As a geneticist I can state that there is absolutely NO evidence of any significant evolution in human genetics, and consequently brain function, during the last 100 years. Marc Prensky's (2001) assertions that 21st Century students operate at "twitch speed", etc, are based on nothing other than conjecture and have no basis in biology. Changes to pedagogy and classroom practice must be based on more than buzz-words like "digital natives". There is plenty of discussion by writers such as Rebecca Hastings (2007) on the myths of generational differences.

There seems to be some confusion as to whether educators are asking questions about the 21st Century learner or the 21st Century work force. Is there a difference?

It would be prudent to reflect on the rapid changes in technology and consequently trade and industry in 20th Century. The beginning of the 1900's dawned with the airwaves all but silent and heavier than air flight was not yet possible. Nobody would have predicted that less than 100 years later, by the 1990's, the world-wide-web, nano-technology and other advances would arise, culminating in the concept of a "knowledge economy".

Yet Roger Kerr (2002) of the New Zealand Business Round Table had this to say:

We would do better to stop talking about the knowledge economy, at least in the sense of being some new phenomenon. Like other fashionable terms such as sustainable development, it lacks a hard core of meaning and isn't an aid to clear thinking.

Nor is there anything economically special about the so-called information revolution. Kerr gives examples of countries where greater investment in education is no guarantee of greater economic success. He says that British professor Alison Wolf, author of *Does Education Matter? Myths about Education and Economic Growth* makes the point that because some of a thing is good, it doesn't follow that more of it must be even better. In other words, according to Kerr,

...we can over-invest in education just as we can in anything else. Moreover, a preoccupation with the economic benefits of education can narrow and distort the purposes of education.

So what then is the purpose of education? Is it about instilling a love of learning or is it a means of getting a job?

Lobbyists pushing for a greater investment in ICT and technology in schools are sending mixed messages about the purpose and justification for such investments. No wonder teachers are confused as to the role of ICT in the classroom.

Why are so many people attempting to predict the skills required of the 21st Century workforce? If the changes last century were rapid, how much greater will the changes be this century?

ICT technologies will develop rapidly and the current fascination and substantial investment in ICT may be looked back upon as short-sighted and arising from tunnel-vision.

If education is deemed to be vocationally focused, it may be more useful to take a wider view, to teach resilience and strategies to cope with constant change, including dealing with failure and taking risks. Such a 21st Century workforce would demonstrate a number of desirable qualities such as

- The ability to easily unlearn and relearn
- Individuals used to change will experience little physiological stress, with associated benefits in the home and family as well as the wider community.

If we want the 21st century learner/worker to be more intelligent and creative they should be permitted more opportunities in the curriculum for play and imagination. This is consistent with the previous findings as outlined in *The role of luck and play* (page 33). I was pleased to see that 'young' students were able to suggest plausible inventions and investigations in spite of an apparent lack of explicit learning.

Research has shown that intelligence and creativity do not necessarily go together, yet students who are less academic, even though they may be creative, are often relegated to "alternative" or applied programmes, and little is expected of them.

Creativity takes time to develop. Past major breakthroughs in technology and science have come from "play" and time to experiment. Low cost mobile technology that students bring to class, such as the RIGEL units or calculators with sensor ports, will permit students greater opportunities to get creative.

Failure is also something that can be learnt from although our current assessment system at high school does not reward risk taking and failure. Failing but maintaining perseverance is something the 21st Century learner may have to get used to.

Students want more authentic science

According to one report (Ferguson, 2006), New Zealand has long been renowned internationally for the quality of its Science curriculum. The suggested pedagogical approaches and learning activities to develop a true understanding of the nature of science lead the world. However, a number of investigations with regards to classroom practice show a large gulf between ideals and reality (eg, Hipkins, Barker and Bolstad, 2005).

The introduction to this study made a number of assertions:

- Not all teachers are scientists
- There is little practical work or learning by “doing” science. Providing opportunities for students to experience the nature of science is a low priority over learning facts for assessment tasks.

Some educators may respond that there are opportunities for students to carry out ‘experiments’ as internally assessed tasks, yet these follow the so-called “scientific method” and do not permit alternative valid forms of scientific investigation. There is also a big difference between carrying out a practical technical investigation and true experimentation or research. An example of the former case is an analysis of the amount of amount of vitamin C in drinks. An example of the latter is the work carried out by students of the Nexus Research Group that was presented at the New Zealand Microbiology Society conferences in 1999 and 2001 (Fenton, Fenton & Stewart, 1999; Fenton, Fenton & Raynes, 2001). Examples of authentic research work carried out by Nexus students include the isolation of *Caulobacter* species in Taranaki waterways and the creation of software to model protein folding. It became routine for Nexus students to win prizes at the local Science Fair year after year.

Throughout the year, students in primary and secondary schools complained that they felt “real” science was being kept from them. This complaint is not restricted to the students of this study, but has been reported to the author over many years at different schools. Actual comments from students, as examples, are

- *We never **do** anything in Science, it's all book work.*
- *It is so boring, we don't do anything real.*
- *Its not even real science, just end of year exam questions they make you go over so in the end you can do end of year exam questions!*
- *I think it would be cool to measure your own stuff and look at it. That would be real (science).*
- *Even if you watch a video it's still not real because often things are different or in a different situation from in the video...so it's still not real science.*

Comments from Primary students participating in this study include:

- *“Usually we don’t get to use sophisticated stuff like this, is like they think we’re too young and we might muck it up.”*
- *“The whole thing was new really. It’s a bit more high tech really because at our school they don’t let us use stuff like that because they think we’re too young. They think we’re not capable and too young and the teenagers get to use all this stuff anyway. Why can’t you start when you are young then you’ll be so much smarter when your older!”*

Overall, there appears to be evidence that students have a perception that science in schools is not the “science” they are wanting to do. The primary students in this study provided evidence of “hidden” prior knowledge and high self-efficacy to use mobile technology such as RIGEL. Comments from the students typically included “I wish we had time to do more”.

Low cost mobile technology that students own themselves, such as the RIGEL units or phones with sensor ports, will shift the reliance on the teacher to be the expert user of technology in the classroom and permit students greater opportunities to carry out authentic investigations. There are already a number of science apps available for the iPhone that are free to install.

The desire to do authentic science work is an important consideration in science lessons. Practical work cannot be adequately substituted with videos, animations or cyberspace simulations. A recent Australian report (Azer, 2007) noted that medical students still preferred dissection laboratory time over any other mode of learning. Indeed the use of a good anatomy textbook came second in a list of preferences, and was ranked higher than using computer aided learning (CAL) or multimedia ICT resources.

Raising teacher self-efficacy

A recent national campaign to offer professional development to teachers to raise ICT practical skills has set a precedent for investing resources to raise teachers’ laboratory practical skills.

Providing teachers with improved skills to carry out practical work will raise teacher self-efficacy and remove one of the barriers to students learning about the nature of science.

Students come to class equipped with mobile technology, such as phones, iPods, and MP3 players. A mobile device equipped with sensors, such as RIGEL, could be owned by the student rather than schools having to purchase and maintain more ICT. As a new ICT, RIGEL can be configured as a very simple surveying tool. There are no display screens or menus to navigate. Simple presence/absence data could be tabulated.

Students in this study became confident users very quickly, and could justifiably lead the use of this type of technology, even if a teacher's confidence was low.

There is however an opportunity to raise teachers confidence in doing practical work away from the spotlight of the classroom. The in-built on-line chat and 'video' link capability of RIGEL permits teachers to share professional and technical expertise about experiments they are running in real time. That is, a teacher with data being displayed can share this on-line in real-time with other teachers for discussion and professional development.

RIGEL is an open-ended technology, data can be imported to other applications, or uploaded for real-time display on a web page. This collaborative feature can support resource sharing and brain-storming of authentic learning activities.

Research has shown that an enthusiastic and confident teacher is a significant factor in raising student achievement. Tan (2005) reported that "the unique affordances of datalogging are not being fully realised in science learning because teachers generally lack the vision for how dataloggers can be used to enhance the student learning experience in inquiry-based science."

Teachers require more professional development to become better users of science equipment and need time to develop more effective pedagogies.

An opportunity for pedagogical change

Pedagogy can be defined as the conscious deliberate actions of one to enhance the learning of another. Some refer to the particular "styles" of teaching or techniques.

There are two types of learning outcomes specified in the integrating strands of the SNZC (Ministry of Education 1993), which connect to the 'doing' of science. It is clear, therefore, that SNZC identifies that 'doing science' involves more than practical exercises carried out in the laboratory/classroom.

With the introduction of the new national curriculum the importance of documents such as the SNZC are reduced to that of support documents. However, it could be argued that the values and key competencies in the new curriculum reinforce the SNZC stance regards students gaining an understanding the nature of science.

Haigh and Forret (2005) argue that, although there is an assumption that 'doing science' provides the learner with a glimpse of the scientific enterprise, in fact the limited view of 'doing science', as

practised in classrooms, is pedagogically deficient. The requirement that schools implement the new curriculum may inadvertently provide teachers with the opportunity to justifiably ask for more professional development time and more non-contact time to develop better pedagogies and practical skills in science classes.

Raising teacher confidence and technical competence is a significant factor in raising student achievement. In New Zealand, the Ministry of Education already has a report that made a number of recommendations that support this author's experience:

"The studies reported here collectively suggest that teacher professional development must be an important part of any planned initiative to raise achievement in science. The clear message from the literature is that teachers need the opportunity to engage in long-term professional development experiences. Just as the process through which students collaboratively build scientific understandings requires sufficient time, so too do teachers need the time and experiences to develop their own professional capability."

Curriculum, Learning and Effective Pedagogy: A Literature Review in Science Education, 2002

As a new ICT, RIGEL supports the new curriculum, by acting as linking technology:

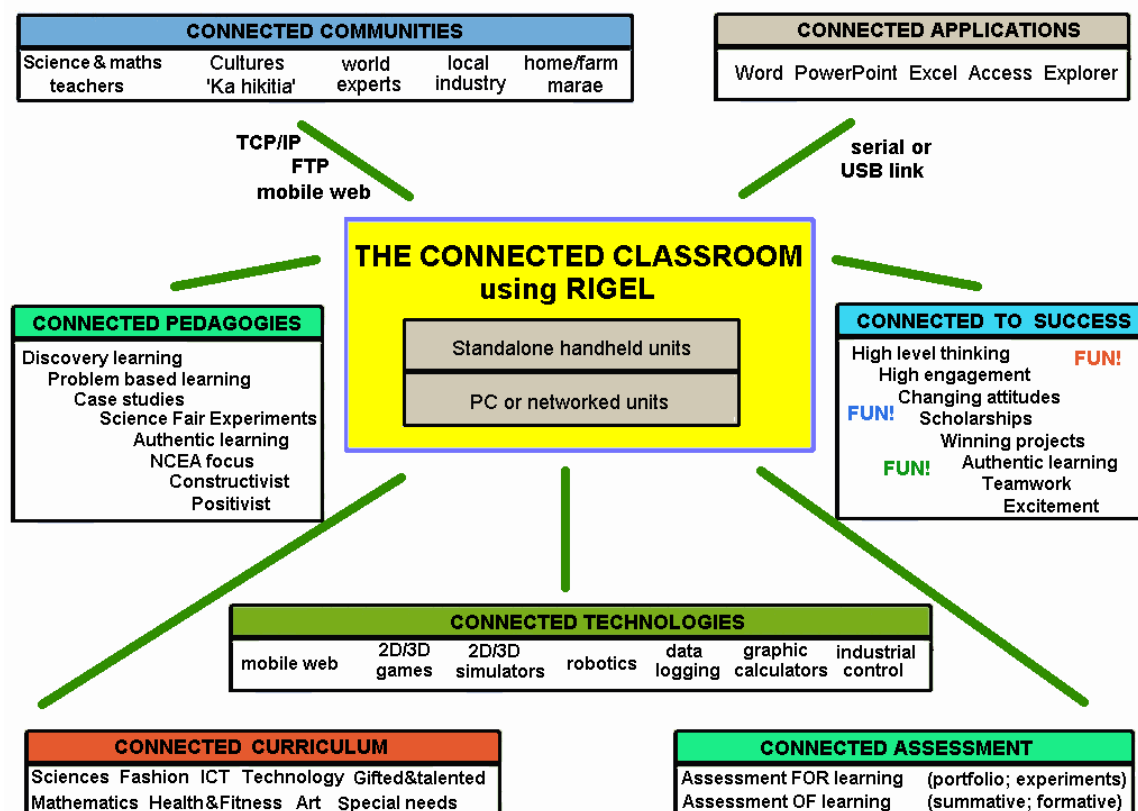


Figure 14: Use of a mobile technology to empower students and teachers.

The conflict between learning and NCEA assessment

There have been many articles in the media describing how NCEA has 'dumbed down' the quality of learning. Students have criticisms too, for example, that profiles of expected performance is scaling in another guise (Edmonds, 2006). The almost yearly 'tweaking' of the workings of NCEA, some arguably more significant than others, are the source of debate in education and the wider community. Unfortunately, due to the polarized views that seem to have arisen, any comment at all about NCEA that is less than positive risks being labeled as anti-NCEA or the commentator accused of being one of the 'NCEA refuseniks' (Maharey, 2007).

There are a number of reports already cited from authors that clearly are not 'NCEA refuseniks'. They point to a conflict between the learning and curriculum messages being delivered to teachers, parents and students, and the messages being delivered about assessment (eg, Hipkins, et al, 2005; Hipkins & Neill, 2006, Neill & Maguire, 2008).

It seems ironic that the constructivist movement that appears to be the agent for change in teaching is the opposite of the positivist "it's right or wrong" philosophy of the assessment system. Indeed, there is evidence that teachers are judged according to how students perform in examinations. Schools themselves find they are ranked on "league tables".

It could be argued that secondary teachers lack professional autonomy to significantly depart from the prescriptive nature of assessments laid down by NZQA. This view can be supported by the number of recent papers on New Zealand science teaching that have shown little evidence of having filtered down into classroom practice.

Students have told me that they are avoiding the 'hard' subjects and opting for what they perceive as easy subjects, a phenomenon not unique to New Zealand. According to an article in the British Sunday Times, "It is overwhelmingly the state school students dropping sciences and languages" (Grimston and Waite, 2008).

Standards based assessment appears valid for some subjects but clearly there are valid arguments that there is no one universal 'right' way to assess learning. As mentioned earlier, it seems that in New Zealand we have a Qualification Authority that uses a different world view of knowledge from that of the discipline it is assessing...NZQA is 'un-scientific' with regards to assessing science knowledge.

So how do we get out of this energy sapping and circular pit we seem to have fallen into?

We need a new tool to 'dig our way out' ...

A new quantitative tool – the PACE score

Creativity and innovation requires time for the individual to play and investigate. A case in point is the RIGEL system itself; time investigating going against conventional wisdom on electronics yielded novel sensors with interesting applications.

It was also reported that, with various interests applying pressure to get more students to “pass”, a teacher may see their discipline as nothing other than a marathon event of assessment and marking.

One way to ensure that this does not happen is to validate time spent on permitting students to engage in authentic enquiry and time for teachers to develop effective pedagogies. A suggested mechanism could be something like the PACE score. I have decided to use four indicators that could be used to identify courses that facilitate the development of competencies, attitudes and values as well as gaining academic knowledge:

P	effective p edagogy	1 or 0
A	valid a ssessment	0.5 or 0
C	relevant c urriculum	0.5 or 0
E	time for e nquiry & creativity	1 or 0

A numerical value is assigned based on the presence or absence of the indicator.
--

Since assessment and curriculum is largely externally driven or controlled, the weighting is less than the two other indicators that can be directly influenced and driven by classroom practices. It is recognised in education research that the single biggest influence on student learning is the classroom teacher. For the first time, a tool exists that empowers the teacher and validates using learning time for activities in the spirit of the new curriculum in a non-trivial way. If traditional NCEA courses are run on the basis of ‘ticking the box’ of standards assessed, then it could be argued the only way the teacher/student will spend time on activities that develop attitudes, values and creativity is to provide another box to tick.

The debate about curriculum and assessment can be seen to be only half the story of what occurs in the classroom. The PACE tool suggests that effective pedagogy and time for authentic learning and creativity will put an end to the NCEA ‘tail wagging the dog’ arguments. A return to exploring the purpose of education and rediscovering the joy of teaching is possible. For instance, teachers and students can justifiably spend time on science based activities that explore ideas that seem to go against conventional wisdom. It would be no shame to ‘waste’ time on experiments that ‘fail’. They can get their hands dirty and spend some time just thinking. Even if this learning is ‘invisible’ as far as earning NZQA credits.

Example scores are given below where the PACE score is calculated as follows:

Score = sum of PACE values x (A + C values)

Example where a course uses an effective pedagogy, uses valid assessments, has a relevant curriculum, and allows time for enquiry/creativity:

COURSE	P	A	C	E		Score
Electronics	1	0.5	0.5	1	3 x (1) =	3

Example of regional comparisons of a course using PACE scores:

COURSE	SCHOOL	Indicators					Score
		P	A	C	E		
Electronics	NP	1	0.5	0.5	1	3 x (1) =	3
Electronics	WN	1	0	0.5	1	2.5 x (.5) =	1.25
Electronics	CH	1	0	0	1	2 x (0) =	0
Electronics	TG	0	0.5	0.5	0	1 x (1) =	1
Electronics	OT	1	0.5	0.5	0	2 x (1) =	2

Lesson observations, units of work, products of student learning, etc, can serve as indicator evidence. Assessment can be formative as well as summative, and is not limited to NZQA standards. PACE scores could be reported by the Education Review Office (ERO) and innovative practices could be presented at conferences such as SCICON or ULearn.

In order for teachers to develop effective pedagogies, professional development and an investment in equipment will be necessary. Science teachers could justifiably request extra non-contact time to prepare, trial, and monitor practical investigations and mentor students. As a science teacher myself, the lack of time to test protocols and equipment is a significant issue. Also, certainly in the sciences, the availability of modern equipment may need to be addressed before students could participate in authentic investigative activities.

Further discussion about the practicalities or implementation of such a tool is beyond the scope of this report. I hope to develop this and other ideas further as part of a Ph.D thesis some time in the near future. For instance, a longitudinal study of students in courses with high PACE scores could evaluate the prediction that time invested in developing effective teacher pedagogy and student creativity translates into knowledge, skills, attitudes and values required for the 21st Century.

Communities of Learning & the Ka Hikitea link



Our current model of science education is that science happens in a classroom.

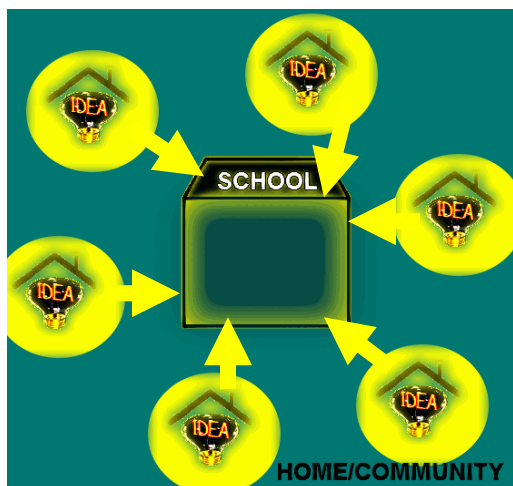
The school is the 'light' or knowledge store and teachers attempt to get information flow out to homes via the students.

Students comment that they forget what was 'learnt' once they leave the class.

Many will not connect what happened at school with events or processes at home.

As a new ICT, RIGEL has web capabilities, on-line chat and real-time webpage update/display.

Technology like this can be used for more than traditional 'distance learning' courses. Instead, a move to a type of 'community based' learning would reverse the information flow and relocate the knowledge store to students homes (Fenton, 2007).



According to one report, students said that, in most subjects, their ideas and opinions were rarely brought into their classroom learning (Bolstad and Hipkins, 2005).

Both home and the wider community are valid sources of data and ideas for use in science classes.

Technology such as RIGEL with online and network capability permits students to show the class and teacher the investigation they have set up at home, marae or farm.

The teacher is still able to look at ideas, experiments or data from outside the classroom as context for formative or summative assessments. The teacher remains the expert assessor.

According to one Ministry of Education report, Maori and Pasifika students are over represented amongst students who are underachieving in school science.

The concept of Ako

The concept of ako describes a teaching and learning relationship, where the educator is also learning from the student and where educators' practices are informed by the latest research and are both deliberate and reflective. Ako is grounded in the principle of reciprocity and also recognises that the learner and whānau cannot be separated. Ako incorporates two aspects:

- **culture counts** – knowing, respecting and valuing who students are, where they come from and building on what they bring with them
- **productive partnerships** – Māori students, whānau, hapū, iwi and educators sharing knowledge and expertise with each other to produce better mutual outcomes.

Ka Hikitea

The Ministry of Education has published a document called *Ka Hikitea: Managing for Success // Māori Education Strategy 2008-2012*. This document outlines the philosophy behind the strategy;

'Ka hikitia' means to 'step up', 'lift up', or 'lengthen one's stride'. In the context of Ka Hikitia – Managing for Success it means stepping up the performance of the education system to ensure Māori are enjoying education success as Māori.

In terms of ICT and e-Learning, there are parallels with the e-Ako pedagogy below:

DIAGRAM OF E-AKO PEDAGOGY

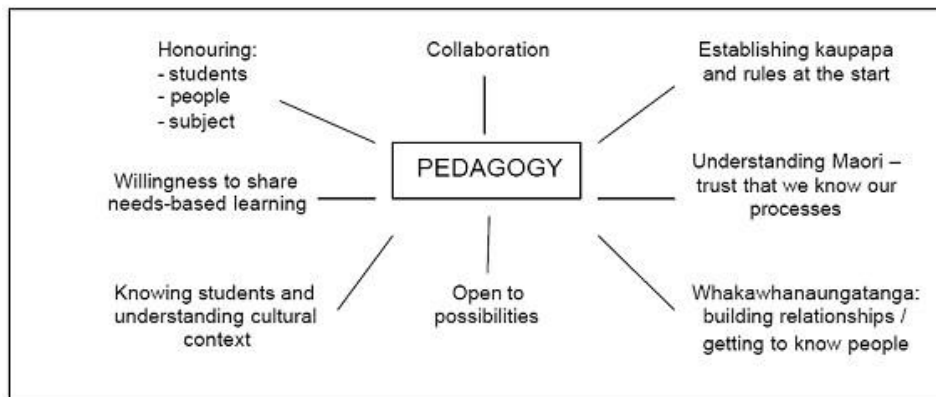


Figure 15: Critical success factors for effective use of e-Learning with Māori learners

Institutes of Technology and Polytechnics of New Zealand eCDF Project, 2005.

Mobile technology such as RIGEL can support the *Ka Hikitia* goals for young people engaged in learning;

- Support professional leaders to take responsibility for Māori students' presence, engagement, and achievement.
- Increase the effectiveness of teaching and learning for Māori students in Years 9 and 10.
- Support Māori students to stay at school and stay engaged in learning (eg, Fenton, 2003).

Personal challenges

Over the last two years, in my own time, on top of daily teaching duties, I have crossed off a long list of challenges:

- learn to programme in Delphi,
- design graphics and animations for RIGEL games, simulators and data logging
- learn new electronic circuitry and theory
- engineer and optimise my own circuits
- invent a networking protocol and circuit to connect multiple units to a single PC and display multiple units data on one screen
- Learn the Casio calculator communications protocol and circuitry to link sensor units to the calculator
- learn 3D game design and coding techniques
- develop novel and inexpensive sensors (temperature, light, heart rate, ultrasonic range finder, conductivity, force, magnetism,)
- integrate hardware and software into a universal science/maths data logger and game engine (MS-Windows based)
- integrate RIGEL data into various applications students are likely to use for analysis or presentation, eg Windows or Apple applications such as Excel, Word, PowerPoint
- Build a class set of units on a small budget
- Create student/teacher user manual
 - primary; very simple, preset experiments/games
 - secondary; option of more configurable settings/user defined uses
- Create lesson plans for the primary students (I am not primary trained!)
- Develop an over-arching strategy so the learning opportunities RIGEL opens up for students is the focus, NOT the technology itself
- Become familiar with a wide range of disciplines to see how the RIGEL system can be integrated across the curriculum (eg, the sciences, mathematics, physical education, ICT/games design, electronics and the arts).
- Become familiar with a wide range of views on different teaching pedagogies, developments in e-Learning and ICT, curriculum design and assessment.
- RIGEL interfaces with the schools renewable energy generation system to display real-time generated energy (see www.inglewoodhs.school.nz)

CONCLUSION

The combined Year 7/8 class was surveyed and interviewed after interventions using the RIGEL technology. 85% of the 26 students had changed their views about the way scientists worked, 85% were more interested in science and inventing than before the intervention, and RIGEL was as successful with females as males – there was no gender difference noted.

The Year 13 mathematics students were able to articulate their own definitions of authentic learning, and devised challenges for each other to complete. A comparison of problem based learning (PBL) and the use of case based instruction (CBI) confirmed research that using CBI is a more effective teaching pedagogy than PBL or traditional approaches. The CBI intervention also confirmed earlier findings from the MOTIS and CAS reports that the appropriate use of data loggers can support high level thinking and authentic learning.

Overall, interventions focused on students using computer technology based in real space, as opposed to using computers to work in cyberspace.

Interventions focused on students using computer technology based in real space, as opposed to using computers to work in cyberspace.

1. Most primary students reached the relational stage of the SOLO taxonomy
2. Most students were cognitively as well as physically engaged
3. Most primary students changed their views about the nature of science
4. RIGEL supported both reception/participation (positivist/constructivist) modes of learning/teaching including authentic learning pedagogies
5. Overall, there appears to be evidence that students have a perception that science in schools is not the “science” they are wanting to do.
6. Overall, there is evidence that students are eager to do what they perceive as ‘real’ science. This is different from traditional science course work. Traditional work is unchallenging and course work done with a focus on preparing for NCEA assessment is reported ‘not real science’.

Since RIGEL is a new ICT, a subsidiary question “what problem(s) does this technology solve?”

Findings indicate that RIGEL used as a mobile technology:

- assists synthesis, evaluation, communication
- permits meaningful science in primary schools
- permits students to test science text for incorrect concepts or “facts”
- lets learners experience the nature of science

- assists learners with hearing or visual impairment to engage in science
- supports extension as well as accelerated learning programmes for gifted and talented students.
- supports teacher professional development to raising teacher self-efficacy with regard to doing more practical science investigations with students
- supports the *Ka Hikitia* strategy document for Maori education

According to one report (Ferguson, 2006), New Zealand has long been renowned internationally for the quality of its Science curriculum. The suggested pedagogical approaches and learning activities to develop a true understanding of the nature of science lead the world. However, a number of investigations with regards to classroom practice report a large gulf between ideals and reality.

In the wider context of influencing classroom practice, a number of recommendations are made based of the findings of this research project and issues arising from the literature.

RECOMMENDATIONS

1. Better alignment between NZQA assessment practices and curriculum teaching philosophies is urgently needed.
2. Closer working relationships with professional bodies, such as the New Zealand Microbiology Society, are needed to correct basic errors of fact in science texts and NCEA assessments. Contrary to some views, input from such organisations is not necessarily too academic or beyond the level of school science. The NZMS had school teachers as panel members reviewing science texts used in New Zealand schools. NZQA should be willing to acknowledge its part in the perpetuation of errors and actively seek assistance to raise the quality of teaching in preparation for NCEA assessments.
3. A recent national campaign to offer professional development to teachers to raise ICT practical skills has set a precedent for investing resources to raise teachers' laboratory practical skills.
4. Better alignment with science teaching practices and the 'Ka Hikitia' strategy document would benefit all students.
5. A mechanism that validates and encourages time to be set aside for science teachers to develop effective pedagogies as well as time allocated to students to develop and demonstrate creativity and encourage risk taking is well overdue. The proposed PACE score is a starting point for further discussion and development. Unless conversations about pedagogy, creativity and innovation are validated in a non-trivial way, the focus on assessment, in particular the move to greater internal assessment due to the new curriculum in science and mathematics, will prevail.
6. Consensus by commentators, researchers, educators and the Ministry about the role of education would help prioritise some of the issues raised in the literature. Currently there appears a lot of rhetoric but little substance to claims made in particular about the role of ICT and e-Learning in science education. It is important to distinguish fads from trends and make sure the limited funds for education are directed to areas of the highest priority.
7. In light of the recommendation above, in my experience, science is a neglected discipline, with essentially the same primitive equipment and facilities of a 1905 laboratory. If creativity and innovation via authentic experimentation are to be properly implemented throughout New Zealand, a review of science texts with a focus on developing authentic activities is urgently required. Current texts appear to be over simplistic low cost study guides for assessment preparation via rote learning. A resource for teachers as well as students that encourages practical investigations could be created as a national reference document. An investment in making sure all science laboratories

met a minimum standard for carrying out practical work is overdue. Regional science (not curriculum) advisors / facilitators, with proven skills in practical work, could be appointed for a 3 -5 year programme to up skill science teachers. A science review panel could be convened that would examine these issues.

8. Mobile technology, such as RIGEL, that can be used in multiple subjects should be utilised more often to help students see relationships between subjects, particularly a secondary school. Innovation often results from seeing connections between seemingly disparate domains. The use of ICT's to integrate learning between subjects should result in students reaching a high level on the SOLO taxonomy.
9. 'Linking technology', such as RIGEL, supports a flexible programme of learning across subjects and has the potential to link home and school. The use of ICT's to integrate learning from outside the classroom should result in students reaching a high level on the SOLO taxonomy, supporting authentic learning, and permit real-world problem solving.

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APPENDICES

The following are various documents referred to in the main body of the report. They include:

- student questionnaires / surveys
- lesson plans
- examples of student work
- curriculum support ideas
- descriptions of equipment or software created by the author for use by students
- informed consent letters

Appendix 1: Secondary student survey / discussion – the nature of science

1) How would you arrange these words to show their relationship to one another? TRUTH

BELIEF KNOWLEDGE

2) Arrange these words to show any relationships to one another

MATHEMATICS THE WORLD ME MY MIND SCIENCE

3) How does the use of equipment such as sensors/ data loggers fit into the diagram above, if it does? Why/why not?

4) What activities, if any, changed your ATTITUDE to science and/or mathematics. Explain what the change was.

5) What activities, if any, changed your KNOWLEDGE of the world /universe you live in. Explain what the change was.

Appendix 2: Secondary student survey / discussion – authentic learning

Questions BEFORE intervention using sensor units; italics indicate student clarification of remarks

1. How would you describe what high school mathematics is about?
2. What does the word “authentic” mean to you?
3. What does “authentic learning” mean to you?
4. Discuss any disadvantages of “authentic learning”?
5. Discuss any advantages of “authentic learning”?
6. What advantages do you think will come from attaching the sensor units to our calculators?

Appendix 3: Primary student survey / discussion – authentic learning

I enjoyed the work with RIGEL

strongly agree yes don't know no strongly don't agree

I would like time to do my science experiment with RIGEL

strongly agree yes don't know no strongly don't agree

I am more interested in inventing or experiments now than before

strongly agree yes don't know no strongly don't agree

I would like time to learn about electronics and robots

strongly agree yes don't know no strongly don't agree

I would like time to learn about computer games using Game Maker

strongly agree yes don't know no strongly don't agree

Any other comments:

List 4 types of sensor you have used and discuss their usefulness in everyday life.

Draw picture or diagrams to help...

If you could keep using RIGEL, what sort of things would you use it for and why?

Draw picture or diagrams to help...

Did you discover new things you are good at or new things you are interested in now?

Mr Fenton is a scientist. Has using RIGEL changed your ideas about what scientists do or how they work?

Appendix 4: Lesson plan development for Year 7/8 Olympics – games and physical education

Use sensors to help create a set of events for a class activity:

- 8 events (can be fewer as long as group size does not impede participation)
- each team is responsible for setting up one event, gold, silver, bronze certificates?, decide rules and scoring, simple instruction sheet, what sensor is most useful to use
- whole class does a round robin of events
- A mix of standing, sitting, moving activities, outside or in hall.

1) BMX race

Two teams compete to complete a course in the quickest time

[touch sensor detects which team finishes first, can only be triggered once so only one team is indicated as the winner]

2) Infra-red Spotlight

Teams race to find “flag” sensor unit in the quickest time.

[use IR sensor to IR pistols/torches and audible//visual alarm when found]

3) Treasure hunt.

Find the hidden radio in the shortest amount of time. Take a sensor unit and track where the treasure is hidden. Hide radio in another room

[sensor turns on a light when a radio signal is nearby...hot / cold type indicator]

4) Cyber cycle

Ride a cycle with attached sensors to control a game projected onto the whiteboard. Pedal to move/increase speed, steer with handle bars.

[motion sensor?]

5) Co-ordination tester

A wire loop (in the shape of the Olympic flame?) is traced along but must not be touched or an alarm is activated. Have different maths questions on flash cards to answer for a chance to have a go with the wire loop.

[sensor is simple touch sensor if the main loop and tracer touch then the alarm is activated]

6) Simon Says

Simon flashes a light and you must carry out an activity then press the DONE button before Simon sounds his alarm (different difficulties, eg, run a certain distance, go through a maze, climb a rope, etc)

[sensor is simple touch sensor. The unit starts a counter after it flashes its light. When the counter gets to a certain time then alarm is activated unless the touch sensor button is pressed first]

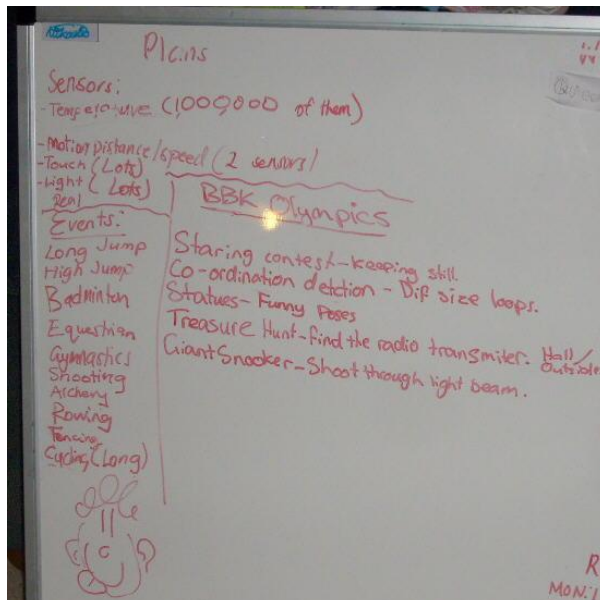
7) Target practice

A target must be shot at and the number of hits in a certain time are recorded. Alternatively, a moving target (on rope pulley?) is aimed for as opposed to an easier stationary one.

[infra-red sensor]

Host teacher has taken over and feels confident that RIGEL technology works at this level. He has developed his own lesson plan for this work, including

1. **Brainstorming** ideas for events that use RIGEL sensor units
2. **Get into teams** to develop a specific activity (decide rules, prizes, banners/signs/artwork, what sensors or programming is needed for sensor units, etc)
3. **Trialling** the events and improving where necessary
4. **Putting on a performance** - running the 8 events as the Olympic 'officials' and technicians while two other classes participate as competitors
5. **Carrying out a PMI analysis**



Original student ideas...

Appendix 5: Question generated by students for investigation using RIGEL as a data logger

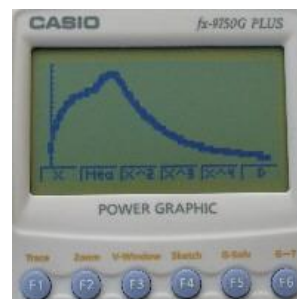
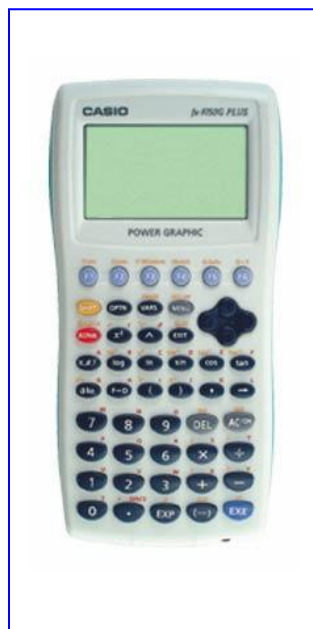
Note: Science Fair student ideas using the temperature sensor only. This lesson was after the round robin activity and students were familiar with the RIGEL units.

1. How cold and warm does it get in my backyard in the time period of one day?
2. What time of the day is my bedroom the coldest?
3. What is warmest during the day; a car with leather upholstery or non-leather upholstery?
4. Does the body heat increase the overall temp of the room?
5. Does someone's body temp change when *they* are excited?
6. Do mashed potatoes get warmer when extra ingredients are added?
7. What is the temperature in a car at night?
8. What is the temperature in a car at day?
9. Which room in school is the hottest and coldest?
10. How cold is my fridge compared to my fridge-freezer and freezer?
11. How hot is a car's interior after sitting in the sun after a long period of time?
12. What is the temperature inside compared to the outdoors?
13. What class is the hottest out of Mr X's class, Mr Y's class and Mrs Z's?
14. What time of the day is my bedroom the hottest?
15. Is Mr X's fish tank colder or hotter than the water from the cold water tap?
16. Is it colder at one end of the class than the other?
17. Is the fridge in the staff room colder than the hall?
18. When is it the hottest and coldest temperature in the classroom?
19. Is it hotter at night, morning, lunch, brunch or afternoon?
20. Are some rooms in the school hotter or colder than the fridge at times of the day?
21. What section of the fridge is the coldest top, middle or bottom?
22. Is it hotter or colder in a room when more people are in it?
23. What time of day is the hottest and coldest?
24. How hot is a car's tire after a long drive?
25. Is a coffee hotter or colder with half a teaspoon of milk?
26. What is the body temperature after one lap of the field and how long does it take for the temperature to go back to normal?
27. What is the temperature difference in rooms 10 and 11?
28. What is the temperature difference between the bottom and top of a fridge?
29. What is the temperature differences between two people that have done the same amount of exercise over the same amount of the time but the two people are at different exercise levels?
30. What is the temperature difference between someone who has exercised for 5 minutes and someone who has done nothing for 5 minutes?
31. What is the temperature difference between rooms 9 and 10?
32. Does the temperature of our creek vary over the period of one hour?
33. Does temperature the engines on our different cars vary?
34. Is the temperature 4 metres in the air different to the ground level?
35. Does your body temperature change when you walk from inside to outside?

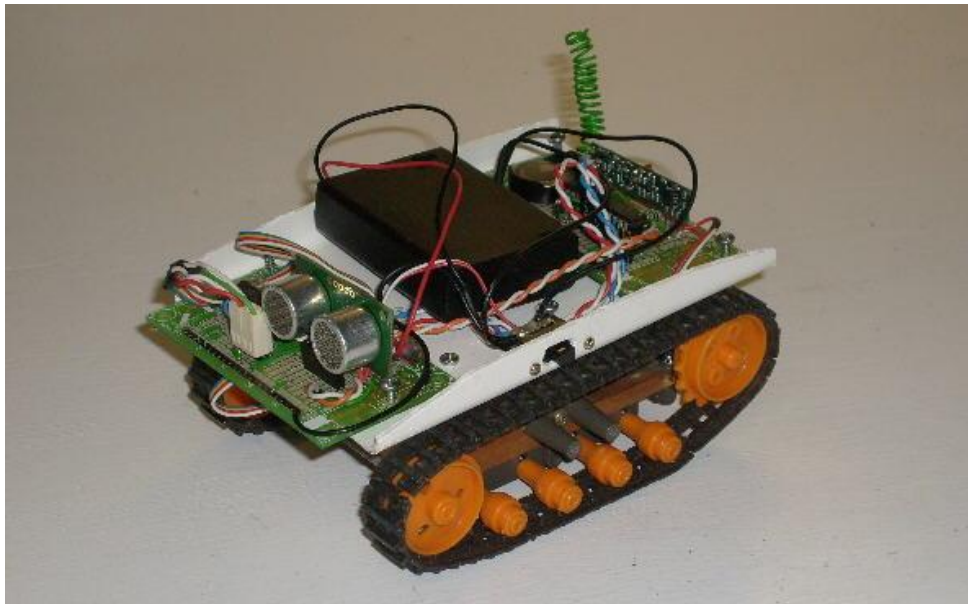
Appendix 6: Casio 9750G graphics calculator program for CSI Forensics CBI challenge:

CAT file text: 2 channel temperature logging Created by Michael Fenton

```
%Header Record
Format:TXT
Communication SW:0
Data Type:PG
Capacity:297
File Name:2TEMP
Group Name:
Password:
Option1:NL
Option2:
Option3:
Option4:
%Data Record
\Locate 1,6,"1=AUTO    2=MAN"
?\->P
255\->\Dim \List 1
255\->\Dim \List 2
255\->\Dim \List 3
1\->Z
\Lbl 2
"GET READING(S) 1=YES"?\->A
A=1\=>\Goto3
\Goto2
\Lbl 3
\Receive(R)
-0.357*R+72.175\->F
\Receive(R)
-0.357*R+72.175\->G
\If P=2
\Then \Getkey\->I
\If I\<>47
\Then \Goto4
\IfEnd
\IfEnd
\If Z<256
\Then F\->\List 2[Z]
G\->\List 3[Z]
Z-1\->\List 1[Z]
Z+1\->Z
\IfEnd
\Lbl 4
\ClrText
\Locate 1,1,Z-1
\Locate 8,1,F
\Locate 8,2,G
\If Z=256
\Then \Locate 1,5,"LIST FULL"
\IfEnd
\Goto3
%End
```



Appendix 7: CASI, the Casio 9750G graphics calculator remote-controlled & autonomous robot for NASA Mars Rover CBI challenge



CASI designed and built by the author, Michael Fenton



Appendix 8: NASA challenge created by Year 13 Calculus students

Welcome to Mars!



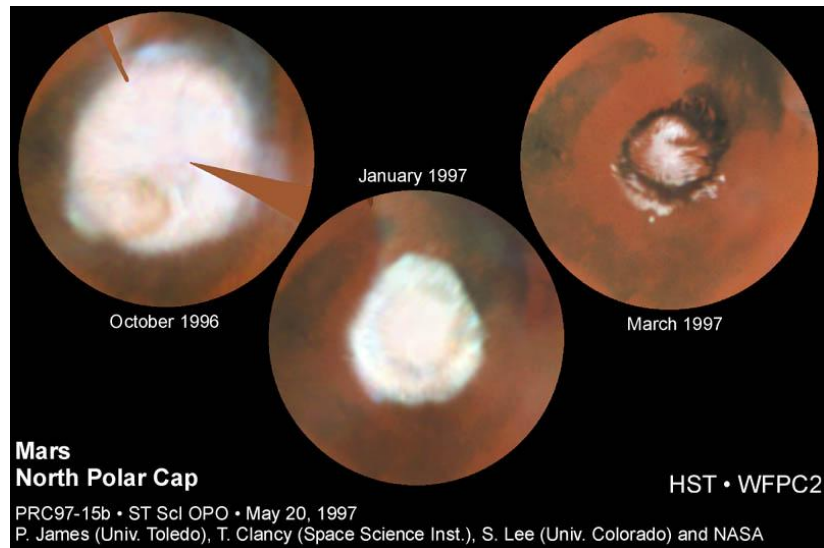
Your Mission:

To investigate the terrain under the northern ice cap of Mars.

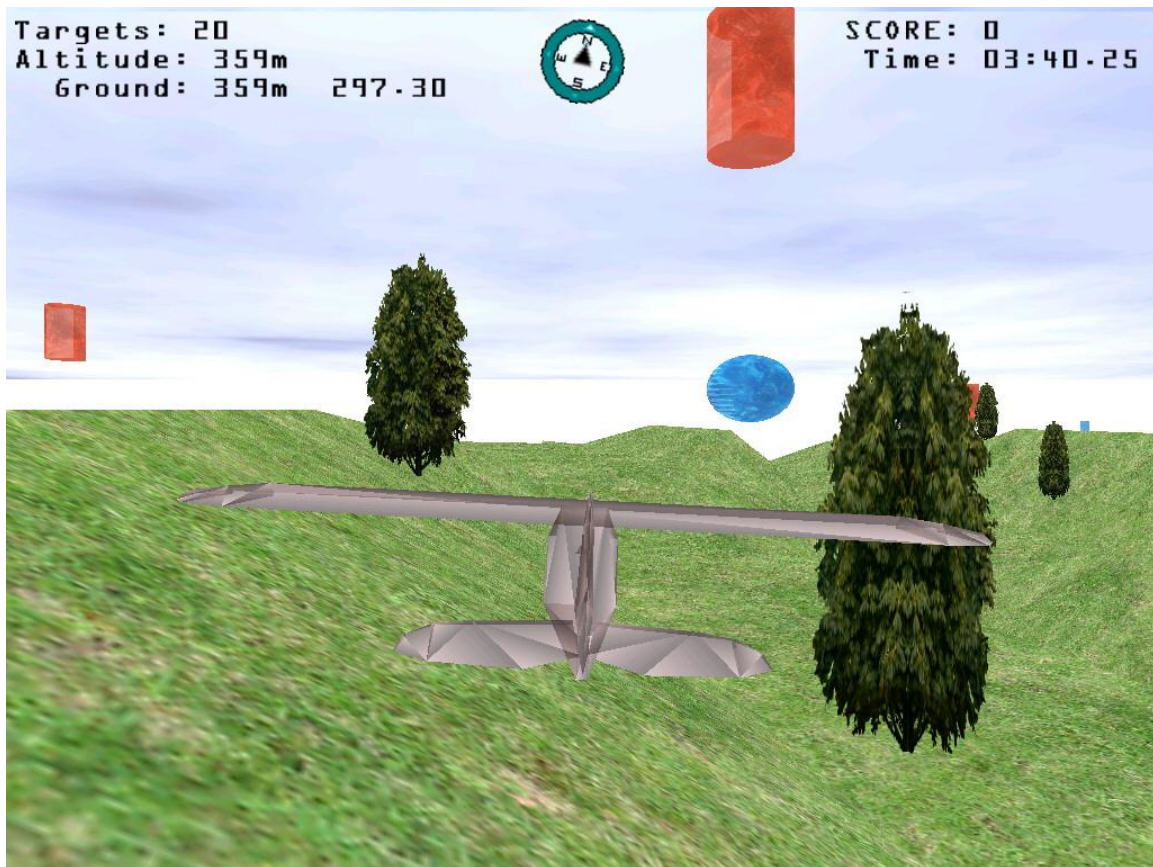
You will need:

A tape measure, the ultrasonic range finder and an understanding of Simpson's' rule.

Find the area under the range finder to determine the amount of ice!



Appendix 9: Screenshot of “cyber cycle” 3D flight simulator



RIGEL interactive sensor/game engine designed and written by the author, Michael Fenton.

Above is a screen shot of the 3D flight simulator.

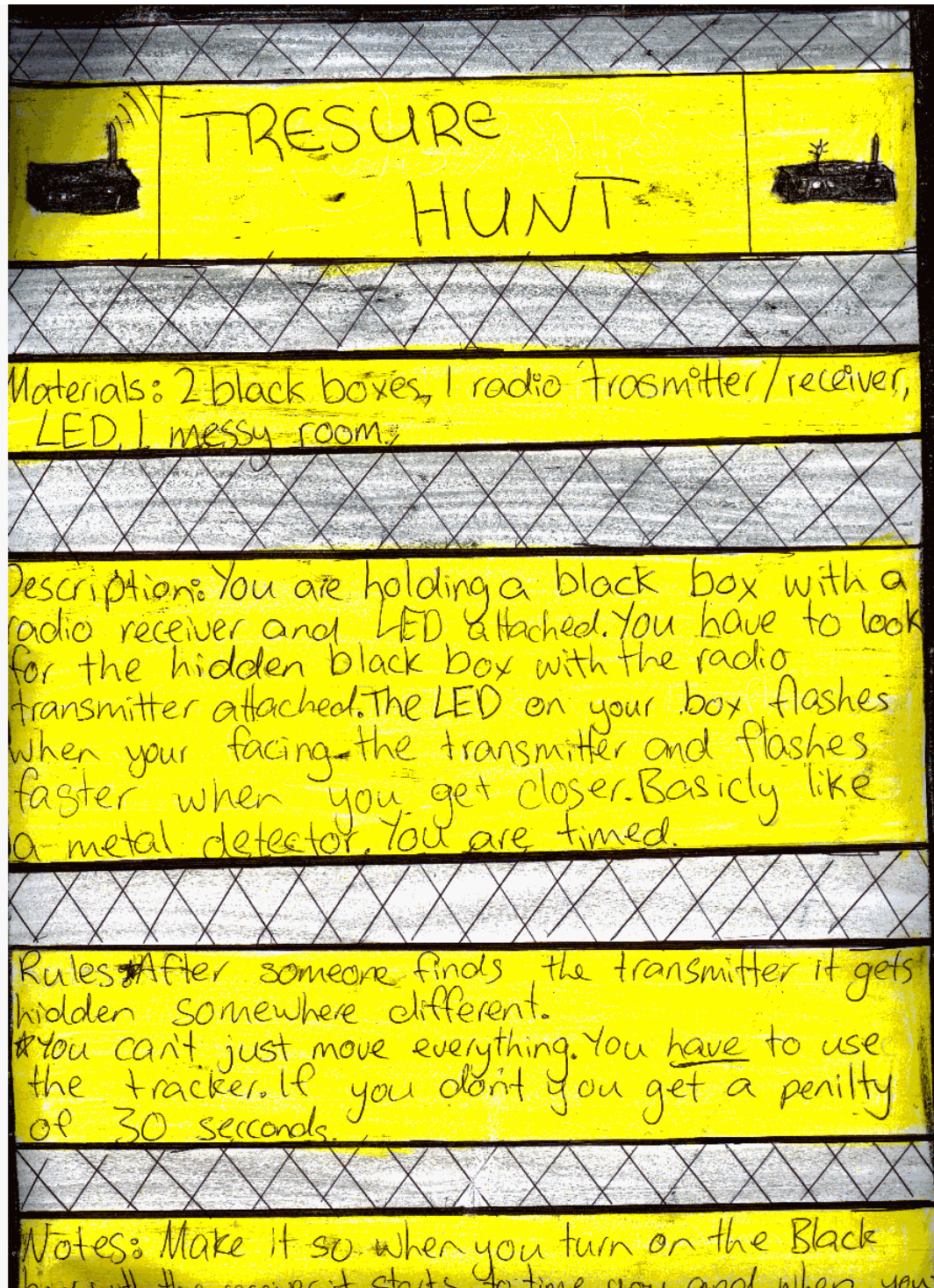


Interactive “cyber cycle” used to control the flight simulator built by the author, Michael Fenton

“...getting computers into real space...”

Appendix 10: Treasure Hunt activity for the Year 7/8 Olympic Games

Plan before event was tested...a Year 8 student



RADIO HUNTERS - TREASURE HUNTERS

Materials: 1 black box with radio transmitter, 1 black box with clever and LED, 1 tin lunch box, clues, prizes, rules, instructions, and a record sheet.

Rules:

You get given a clue. You solve it as a team. You go to the place that the clue means. You will find another clue. ect... One of the organizers will go with each team to ensure fair play. The last clue leads to where the transmitter is roughly located. Once there you must use the tracker to find it. The tracker will flash when close to transmitter. The transmitter will be in a tin lunch box with the lid open. Team with the shortest time wins. It is timed. The timer stops when the whole team crosses the finish line. The last clue will change after each team. You **MUST** put all the clues back exactly where you found them once you have solved them.

You put the radio transmitter in the tin box because the box helps to give the transmitter a smaller range. If it has a lesser range then it is easier to track because the LED only flashes when you're really close. It makes it easier to find the transmitter when when you have a huge range and the LED is always flashing.

Prizes:

1st = 1x mini block of chocolate and 1x mini bar and 1x gold medal each
 2nd = 1x mini block of chocolate to share and 1x silver medal each
 3rd = 1x mini bar of chocolate to share and a bronze medal each

Modified plan after testing the event



On the day...doing the event...

Students race to find a treasure chest hidden somewhere nearby in the school. The chest emits a radio signal.

P (positive/plus)	M (minus)	I (improvement)
Got kids active	The people who won generally got chocolate and too much chocolate is bad for you	Longer time allowed to find the treasure
Had fun	Some of our clues flew away	More time for Game Day next time we do this
People who organized the game were using their minds without knowing	Some teams needed more time	The event organizers (our class that made the Olympics for the other class to compete in) should get a go!
Showed we can be trusted with electronics devices	Year 8 student PMI analysis reflecting on the process and the product.	
Showed we can be trusted with the responsibility of organizing and planning a Game Day		

Appendix 11: Lesson plan for Year 7/8 Science round-robin activity

Lesson plan information

<i>Instructional level</i>	Novice user
<i>School level</i>	Year 7/8
<i>Curriculum areas</i>	Science/ICT
<i>Learning Outcomes - students will...</i>	<ul style="list-style-type: none">• Participate in their first “round-robin” science-based activity• Gain experience of working in teams• List examples of what the RIGEL units can be used for (data logging and interactive games, etc)• Become aware of “invisible” forces and energy around us (eg, UV light, magnetism, static)• Become technically competent users of the RIGEL sensor units• Begin listing ideas for a scientific investigation (qualitative or quantitative) of something personally relevant (authentic learning based)• Describe what scientists do and how they work
<i>Class time</i>	2 sessions, 1 ½ to 2 hours each
<i>ICT required</i>	Data projector, notebook PC running Windows, Microsoft Powerpoint presentation, Robot Wars DVD, “Who wants to be a Millionaire” game, RIGEL sensor units (pre-programmed), RIGEL data capture / game engine.

Student Prerequisite skills:

None

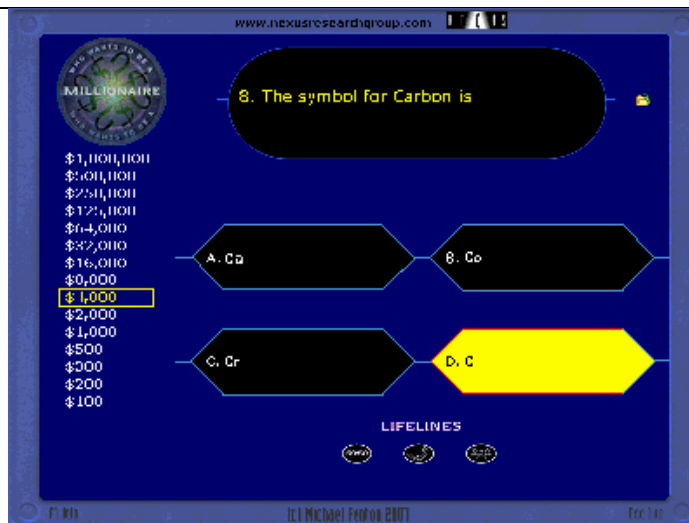
Teacher/student activity outline

Day 1: Slide Show (10 minutes) interactive, question based, large graphics. Question/ answer session (10 minutes)	<ul style="list-style-type: none"> Humans as machines human senses computers with senses (eg mouse, keyboard), Robots as computers that move examples from TV & movies.
Class demonstration (all up for activities, 10 to 15 minutes) RIGEL – Real-world Interactive Games and Electronics Link Question/ answer session (10 minutes)	<ul style="list-style-type: none"> sense current flowing in ring of students holding hands (touch sensor) Sense light as burglar alarm (light sensors with torch) Graphing - look for patterns trends from light sensor (wave torch) Use in Science Fair Demonstrate black box unit Examples of computer games and people interaction, robot remote control demo
Millionaire game; (by Michael Fenton) (as long as class seems on task – 10 to 15 minutes, class in teams)	<ul style="list-style-type: none"> formative assessment of lesson (terminology, recap of sensors & science that can be done with RIGEL units, forces and energy, etc)
DVD segment (10 minutes)	settling class down; fun things robots can do, UK “Robot Wars”

“Who wants to be a millionaire?”

Game engine with question bank made by the author, Michael Fenton.

Formative assessment of lesson (terminology, recap of sensors & science that can be done with RIGEL units, forces and energy, etc)



Teacher/student activity outline (cont'd)

Day 2: Round Robin; (1 – 1 ½ hour approx) Interactive activities Allow time for changing stations	<ul style="list-style-type: none">• Groups of three to four, students have 7 minutes at 6 stations. See Rigel_pod_manual.doc• use units to see what type of sensors can be attached and use for surveying – simple presence/absence tabular records as opposed to time series graphs• Class report back at end of activity to summarise findings of interest and ideas to follow up on• Begin thinking of investigations using sensors that are of interest to them, eg, student curious as to why some had colder hands than others.
Millionaire game; (by Michael Fenton) (as long as class seems on task – 10 to 15 minutes, class in teams)	<ul style="list-style-type: none">• formative assessment of lesson (terminology, recap of sensors & science that can be done with RIGEL units, forces and energy, etc. Carry on from question level last lesson to get to \$1 million!)

Student activity (round robin)

Description

As part of a team, you will create a short report describing what the sensor units helped you understand or discover. Make sure you do your job as part of the team:

- 1) Leader: makes sure the few instructions are followed and everyone gets to use the sensor unit fairly. A simple instruction sheet* is provided.
- 2) Reporter: jots down thoughts and ideas from the group that you think are important or interesting.
- 3) Time keeper: makes sure that the team is aware of how much time is left before changing to the next station.
- 4) Equipment manager: makes sure the sensors are used appropriately and the gear returned as you found it before moving on to the next station/activity

Only move to the next station when the teacher instructs you too!

At the end of the activity, collate your information, discuss it, and be ready to report to the class

Appendix 12: Curriculum support possibilities using RIGEL

Mathematics

Integers

Raw data sent as values between 0 and 255, or 0 and 1023.

Decimals

Example, digital temperature sensor sends values to 0.1 C

Binary

Computer data transmitted as 8 bit or 12 digital binary code

Statistics

Average three readings before transmit or display to dampen noise or minor insignificant fluctuations in readings

Collect eg, 1000 samples, and store for downloading to PC

Pattern recognition

Linear, sine (daily sun light levels), s- curves (biology), Newton's cooling curves

Pattern prediction

Extrapolations of linear, sine (daily sun light levels), s- curves (biology), Newton's cooling curves

Graphing

Graph construction

Displaying multiple data sets

Dependant/independent variables and which axis to use

Appropriate graph types to suit time series, consumer surveys, etc

Modelling using equations

Formulate equation to model pattern shown

Manipulate known equations to determine rates, frequency, periods or physical constants, eg CPR has frequency = 1/period, can see on the scope that the wider the gap (longer the period) the less frequent the heart beats.

Understanding / interpreting (placing meaning on the results)

Identifying outliers

Accuracy / precision of data

Significant / insignificant findings (within accepted norms? anything unusual / new?)

Ethics / value judgements (eg high temperature in animal cage results in stressed animal...consequences for responsible use of findings...non-disclosure/privacy issues)

Science

Automated data recording

Remote environmental, indoors/outdoors real time, etc

Personal data

About own home, body, animals, crops, equipment

Desire for accuracy and precision

Leads to repeat experiments and data averaging

Distance learning

At home for homework or virtual communities via www

Distance support

Peer to peer (group work or peer support)

Student to tutor (tutor support, formative assessment, lesson delivery)

Tutor to Tutor (peer training or technical support)

Equipment monitoring (leaving experiments running and receiving data via www)

Pattern recognition

Linear, sine (daily sun light levels), s- curves (biology), Newton's cooling curves

Pattern prediction

Extrapolations of linear, sine (daily sun light levels), s- curves (biology), Newton's cooling curves

Graphing

Graph construction

Displaying multiple data sets

Dependant/independent variables and which axis to use

Modelling using equations

Formulate equation to model pattern shown

Manipulate known equations to determine rates, frequency, periods or physical constants, eg CPR has frequency = $1/\text{period}$, can see on the scope that the wider the gap (longer the period) the less frequent the heart beats.

Understanding / interpreting (placing meaning on the results)

Identifying outliers

Accuracy / precision of data

Significant / insignificant findings (within accepted norms? anything unusual / new?)

Ethics / value judgements (eg high temperature in animal cage results in stressed animal...consequences for responsible use of findings...non-disclosure/privacy issues)

Also contributes to understanding the nature of science

Technology

Understanding Science and Maths in context

Accuracy / precision of data

Significant /insignificant findings (within accepted norms? anything unusual/new?)

Ethics/value judgements (eg high temperature in animal cage results in stressed animal...switch on automated cooling unit)

Improving existing technology

Less expensive alternatives

More features

Environmentally friendly

Cater for alternatively-abled

Inventing new technology

"Where there's change there's opportunity" (eg, global climate change)

Combining existing technologies for new purpose (eg, RIGEL)

Specific needs-based requests

Blue skies research and development

Physical Education / Health

Understanding Science and Maths in context

Accuracy / precision of data

Significant /insignificant findings (within accepted norms?)

Ethics/value judgements (eg when is it time to start/stop an exercise regime, is food being stored at a safe temperature, is the home well insulated for winter, how exposed to UV are you inside a car, do shade sails limit the amount of UV)

Improving fitness / health

Monitoring of biological rhythms

Increasing awareness of behavioural and environmental factors on health

Means to monitor the effectiveness of various exercise or food safety techniques

Distance learning

At home for homework or virtual communities via www

Special needs students/ Gifted and talented students

Assists learners with hearing or visual impairment to engage in science. Open ended technology supports extension as well as accelerated learning programmes for gifted and talented students.

New curriculum values and key competencies

Excellence; innovation, enquiry, and curiosity; diversity; equity; community and participation; ecological sustainability; integrity and respect.

Managing self; relating to others; participating and contributing; thinking; and using language, symbols, and texts.

Appendix 13: Informed consent

E-Learning Fellowship Project - “Toward a Better Understanding”

INFORMATION SHEET FOR PARTICIPANTS

Thank you for your interest in this project. Please read the information below before deciding whether or not to participate. Participation is voluntary. If you decide not to take part, you may withdraw at any time without prejudice and we thank you for considering our request.

What is the aim of the project?

Michael Fenton has been contracted by the Ministry of Education through CORE Education to conduct a research project investigating how students learn using Information and Computing Technology (ICT). The project will involve students using data loggers with mobile sensors. The main research questions are:

- How does the availability of mobile sensors encourage student enquiry about themselves and/or their environment?
- How does the use of mobile sensor technology contribute to developing understanding and higher level thinking?

The pocket data loggers provided to the students is the RIGEL system as described in:

Interactive ICT tools for Mathematics, Science and Robotics - getting the most from Game Maker.

(presented at the New Zealand Association of Mathematics Teachers conference 2007).

This presentation is available from **www.nexusresearchgroup.com**

What will your involvement be with the researcher?

To complete this project the researcher will observe a teacher and students as they carry out a science investigation of the students' design using temperature sensors. The students will be issued with data loggers for approximately two weeks and may take them home if required to complete their investigations.

What will we ask you to do?

We seek your approval to take part in this project. This will involve:

1. *students taking part in a science investigation of the students' design as a learning activity;*
2. *The researcher documenting the learning process using video, audio and other appropriate media*
3. *students taking part in recorded interviews and conversations as the learning process occurs;*
4. *The researcher making copies of student work at the beginning, middle and end of the learning process.*

Can you change your mind and withdraw from the project?

You may withdraw from the project at any time without affecting your learning. Should you withdraw, you may request the removal of data on your work from the research.

What data or information will be collected and what use will be made of it?

A range of data will be collected over the course of the project. This may include: making sound or video recordings of students as they work, carrying out and recording reflective discussions with students and the teacher, copying student presentations etc.

Information that could identify individuals will be kept confidential unless prior permission has been granted, eg, to show a short video clip of the teacher and students carrying out a task.

Data collected will be pooled or referred to in such a way as to preserve the anonymity of the participants.

Please note that the project is about evaluating how students learn. It is not about evaluating the practices of teachers or schools.

The work will contribute to a report to the Ministry of Education . Final outcomes such as this report, and other publications, will be available through the Ministry of Education, research journals, conference proceedings and the Internet.

What if I have any questions?

If you have any questions about our project, either now or in the future, please feel free to contact:

Michael Fenton
Inglewood High School
(06) 758 1234
fe@inglewoodhs.school.nz

Dr. Michael Winter format below
michael.winter@core-ed.net
CORE Education Ltd
PO Box 13678
Christchurch NZ
Mob: +64 21 225 8520
DDI: +84 3 379 0715

The ethical procedures outlined for this project have been reviewed and approved by CORE Education Ethics Committee.

Declaration of Consent – Information for parents and students

I understand the information provided to me about the research project *Toward a Better Understanding*, and what will be needed from me if I take part in the project.

I understand that the research will involve the following activities to gather data, and agree to the researchers using these materials for their research

- Collecting written and electronic examples of my/my child's work and learning activities.
- Recording interviews with myself and/or my child about their learning
- Video tape recordings of my/my child taking part in learning activities at his/her school.

I also understand that:

- I may withdraw myself/ my child from the research at any time, without any effect on his/her learning
 - all data collected for the research will be kept confidential to the researcher and his colleagues at CORE Education
 - examples of my/my child's work or short excerpts from interviews may be used in publication of the research.
- You/your child will not be able to be identified by name from this material
- short video clips or photographs may be used as part of a live presentation such as a workshop or conference or in the published report.

Participant:

I agree to take part in the project *Toward a Better Understanding*.

Signature: _____ Date: _____

Parent/Guardian

I give permission for _____ to participate in the project, *Toward a Better Understanding*.

I agree that short video clips or photographs may be used as part of a live presentation such as a workshop or conference. These will not be used in any presentation document that is retrievable by members of the public.

I have read and understood the information about the research project and what will be required of participants.

I am satisfied that _____ understands what will be required of participants in the project.

Name: _____ Date: _____

Signature: _____