Designing an Effective Science Curriculum for Primary Schools

An Examination of NZ and English practice 2015
A Sabbatical Investigation by Gary Shirley

Contents

Executive Summary

Why is it that pre-schoolers are full of awe and wonder about their world and by the time they get to year 8 they have very little?

AIM OF SABBATICAL

1. Improve transition to high school in Science
2. To come up with a plan to improve teaching and learning in Science in our school
3. To investigate ways of supporting teachers with resources.

METHOD

- Consult our recent ex pupils on their experiences in Science and transition
- Visit schools in New Zealand with successful Science programmes… Weston, Karori Normal
- Consult Otago Science Advisors and liaise with Otago University Science Outreach Programme
- Research best practice in current literature
- Consult high schools and compare Year 9 syllabi and collate feedback – St Kevins, WBHS, WGHS and Onslo College in Wellington
- Study UK system for primary Science, liaising with six schools and their practice
- Collect and collate resources, ideas and recommendations.

KEY OUTCOMES AND OBSERVATIONS

Consultation with Past Pupils

1. Mixed results – some felt well-prepared and others felt poorly prepared
2. Many students felt they hadn't done enough Science to a deep enough level
3. Recording in Science was a jump at Year 9 level
4. The laboratory was new and initially overwhelming.
5. Many students preferred the Arts

What I noticed about English Practice

1. Focussed intentional acts of teaching Science from 4 years of age
2. Vocabulary of Science front, dead and centre
3. Clear Curriculum expectations, followed up by Science head teacher
4. Two hours per week/100 hours per year.
5. Two aspects ….. 50% Scientific Knowledge of Concepts….50% Thinking scientifically (Nature of Science)
6. Best Practice
   a. · Refer to previous learning
   b. · Introduce WALT
   c. · Demonstration – Discussion – Explanation
   d. · Recording of new understanding
   e. · Follow up activity
   f. · Recording of one aspect of activity
   g. · Plenary session
7. High expectation of teacher, students to closely cover syllabus at an appropriate level
8. High expectation for literacy in Science "If they can write to a high level in the morning, they can do it in the afternoon".
9. School-wide practice around wall displays, recording in books and teacher planning
10. Lead teachers monitor teacher performance closely through checking or student work
11. Everything recorded by students is checked and given feedback from teacher
12. Low levels of differentiation. Mainly whole class teaching

13. Higher expectations in for literacy – 1.5 – 2 years ahead of our students by Year 8
14. Teaching students at 4 years old with around two hours of a five hour session on the mat learning literacy, numeracy and Science in an oral session (45 minutes work, 45 minutes play)
15. Teachers work/plan collegially
16. Teachers driven by OFSTED, high stakes testing focussed on teaching to the test
17. Schools are like Fort Knox, only access is through the office which you often need to ring a doorbell and be admitted
18. Safety regulations are extremely high – nervousness around any risk taking
19. Low tech – computers not used regularly by students – Schools networks usually not working efficiently
20. Budget cuts meant teachers often having to supply expendables for Science, etc.
21. Children listen for much longer periods of time than in New Zealand
22. A teacher-aide in most classrooms full time
23. Many similarities with WALT planning and thinking skills
24. Less integration in practice
25. Narrower Curriculum with less EOTC, Arts Week, PrEp, etc.
26. School-wide feedback to students is colour co-ordinated and standardised
27. English teachers were enthusiastic but reported extremely long weeks and an absolute dread of OFSTED
28. Top down model of leadership with explicit targets delivered down the line
29. Little flexibility to deviate from school's delivery plan
30. Success of school measured by external exams and inspection with no quarter given for decile. Held up to public scrutiny
31. Children that have experienced both systems (NZ and UK) resoundingly prefer New Zealand's delivery citing:
    a. · "teachers are more calm and friendly"
    b. · "You learn more interesting things"
    c. · "You get to do more on your own and with small groups"
    d. · "We have more work at our level"
32. School dinners were healthy and a fantastic way of putting students on an even footing
33. Children from families where parents had not been in work for a number of years were given extra funding to try and break the cycle
34. ESOL was common, but not seen as a barrier to learning. The teacher aide in each room supported these students who caught up quickly
35. Parents generally not able to move into school environment easily
36. The top 15% of learners are syphoned off into "Grammar Schools". Very competitive for 11 year olds who sit entrance examination
37. Principals able to take initiatives provided they deliver in OFSTED
38. High reliance on bookwork to measure progress and to measure the teacher's effectiveness.

<u>What I Learned from High Schools</u>

Students need the following to succeed at Year 9:

1. Resilience – It's ok to make mistakes
2. Literacy – Can read and respond to scientific texts
    - Can record accurately
    - Can write quickly and efficiently
3. Numeracy

- Create and read graph and tables
- Read scales
- Calculate statistics, eg. Average, range, outlines

4. Vocabulary - Have a good Science vocabulary
5. Attitude - Have a positive attitude towards Science and learning
6. Knowledge - A range but not necessarily extensive knowledge of concepts – the fewer misconceptions the better
7. Nature of Science - Fair testing yes, but don't forget about the other ways scientists know about their world: Looking for patterns, research, observations, etc.
8. Confidence in the Laboratory
9. Ability to complete unfinished work in their own time
10. Ability to ask Scientific questions

<u>The Plan to Improve Teaching and Learning in Science</u>

1. A series of Staff Meetings has been thoroughly planned to put Science front, dead and centre
2. A plan for Year 8 programme of orientation to laboratories at high schools – May involve Waitaki Network of Schools
3. Development of staff understanding of the Nature of Science/NZ Syllabus
4. Job Description for Science Leader to better monitor and develop Science Department
5. An approach is to be agreed/developed by staff that ensures:
   - Two hours per week or 80 hrs of Science per year is delivered
   - A balance of knowledge and nature of Science is achieved
   - Science capabilities are taught explicitly
6. Lift expectations of recording in Science
7. Ensure Science is integrated into Maths and Literacy
8. To lift Literacy and vocabulary in Science through reading texts
9. Improve wall displays
10. Develop a safe and comprehensive Science equipment storage system within the school
11. Share my ""Pinterest" account – follow "Gary Shirley"
12. Purchase Bunsen burners, test tubes and a wider variety of key Science equipment
13. Purchase a lockable cabinet
14. Purchase safety glasses and gloves, etc.
15. Keep examples of age/levelled text books to ensure expectations of staff is at the correct level.

CONCLUDING STATEMENTS

1. In New Zealand we have a freedom that English teachers envy, but it does allow for a greater spread of efficiency in teacher and learning from poor to outstanding. It is up to us to embrace the freedom of the Curriculum and to use it to teach Science in a relevant, effective and balanced way.
2. Teachers need to lift their expectations of themselves and their students when it comes to understanding scientific concepts. Be more direct and explicit.
3. Teaching Science needs to be done by balancing **<u>Scientific Knowledge</u>** **with the** **<u>Nature of Science.</u>**
4. **We need to deliver 80 hours of quality Science per year in the senior rooms and at least 40 in the junior rooms**
5. **We need to teach vocabulary explicitly**
6. **We need to teach children how to read scientific texts and record accurately**
7. **We need to relate maths to Science through statistics, tables and graphs**
8. **Teachers need to be supported with physical resources, Curriculum resources and ideas as well as to upgrade their scientific knowledge and pedagogy**

9. Teachers need to be more explicit about when they are teaching Science
10. The key is to feed children's sense of awe and wonder in our world and how it works.

Please feel free to contact me at …

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Designing an Effective Science Curriculum for Primary Schools

An Examination of NZ and English practice 2015

For several years our past pupils reported they were well-prepared for success at high school in all areas except science. In science, they felt out of their depth and typically took up to two terms to feel confident. Consistent with national trends,[1] our senior students were less enthusiastic about science than our middle school students, and many of our more academic students expressed negative attitudes to science as a career path.

Meanwhile in England, a heavily mandated and prescriptive science curriculum has seen a lift in science learning. Anecdotal evidence from teachers returning from the UK pointed to UK students being further along in understanding science concepts and having engaged with a wider number of contexts for science.

Why is this so?

This study investigates these issues further and lays the foundation for developing a successful primary science programme using what we can learn from research, expectations from high schools, England's experience and examples of best practice in teaching Science in New Zealand. Along the way it answers the following key questions;

1. What should we teach in Science?
2. What do our Y8s need for successful transition to high schools?
3. What can we learn from listening to our students?
4. What can we learn from England's approach?
5. What does best practice in teaching science look like?
6. What resources are available?

Method

This study has drawn on the opinions of 150 primary students from NZ and English schools through two online surveys.

Four NZ high school science HODs were interviewed around their year 9 and 10 science syllabus and their views on the knowledge, skills and competencies year 8 students needed to arrive with to be successful.

Extensive time was spent researching and reflecting on current academic thinking on science curriculum.

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[1] Crooks and Flockton, 1996, p.47

Contact was made with five English Schools and time spent going over their documentation and observing their programme in action along with extensive interviews and data gathering.

What Should We Teach in Science?

In other words, what subject matter matters?

The dilemma is, do we teach the breadth of the curriculum so children have knowledge and experience of wide range of contexts, or do we go deeply into a smaller number of contexts?

Let's start with, "**What is Science?"** Science is a systematic and objective way of looking at the world and how it works. It is a body of knowledge.
Science has both processes and content. (An excellent child-friendly way to explain this question is found at Understanding Science)

In New Zealand we have an amazing curriculum that gives teachers freedom to to teach science in an engaging, relevant and responsive way to meet the needs of our students and communities. The problem however is that our Science delivery has generally become watered down and marginalised within the curriculum. Years with little professional development, national standards, teachers with a literacy rather than science background and no bottom line has meant that science teaching varies greatly from school to school and classroom to classroom. As a result too many of our academically successful students are turned off science and seek career paths in other fields.

In England there is a prescribed and nationally tested curriculum (Keystone 1 exams for science have ceased since 2012) that ensures key concepts and contexts in science are systematically covered. The national high-stakes tests ensured that schools are accountable for progress in Science and that practice is more even across schools and classrooms. The problem is that the easiest things to measure in tests are recall and knowledge, which leaves aspects such as Attitudes to Science and Understanding the Nature of Science to being incidental.

In designing a curriculum for science there are four key things to consider;

1. The breadth - What subject matter will be taught?
2. The depth - How much detail and complexity at each level is expected?
3. Integration - How will the science learning integrate with the other areas of learning?
4. Student Agency - How will the learning be structured to allow students increasing levels of self-directed learning?

The NZ Curriculum places the following five areas at the forefront of our thinking when it comes to planning our programs;

- An emphasis on Science for Citizenship
- A future focus

- The Nature of Science Strand as the Core Strand
- Students showing an ability to think with what they know
- Students taking an active part in science based issues in their community

The informed citizen will be a "competent interpreter or critic". of science , even if not a practitioner of Science - *Allchin 2011*

According to the Science Academy the following should be the basis of the curriculum.

Students need to learn what and whom to trust; How confident can we be about a particular claim?, How robust is the evidence?, What was the research method?, Who did the research?, Has it been peer reviewed? and What other explanations may there be?

Students need to be able to;

- *Gather and interpret data*
- *Use evidence to support ideas*
- *Critique evidence*
- *make representations of science ideas*
- *engage with science*

Future Oriented science curriculum aims to;

- *Engage students intellectually and emotionally*
- *Foster science capabilities*
- *Build an understanding about powerful ideas of and about science*
- *Provide opportunities for creativity and knowledge building*
- *Carefully balance depth and breadth*
- *Provide opportunities to engage with complexity and uncertainty in real world issues*

The Royal Society of NZ states that the central aim of Primary Science Education for year 0 to 6 is to nurture students interest and curiosity and to develop positive attitudes towards science. Exploring their natural world should be central. For years 7 to 10 it should continue to provide a wide range of experience but study some topics in depth.It should also increase in complexity as they explore real issues that affect their world.To do this they will need both a **body of knowledge** and a **way of thinking**.

According to the Science Academy **Citizenship** is being able to say what science is, say what the strengths and weaknesses are and ask informed questions about science issues.
As well as this there are "Five Foundational Capabilities";

1. Gather and interpret data
2. Use evidence
3. Critique evidence
4. Interpret representations
5. Engage with science

A breakdown on what these actually look like can be found on here on TKI.

There are also many ways to explore communicating science through Mathematics as well as addressing The Key Competencies e.g. using symbols and texts. A balanced programme will have a mix of hands-on and literacy based activities. The onus is on the teacher to be explicit about the science being learned and the purpose for each activity or approach. This is especially true of the *ideas about science.*

The four underpinning Big Ideas about science are;

1. Science assumes for every effect there is one or more causes.
2. Scientific explanations, theories and models are those that best fit the facts known at a particular time.
3. The knowledge produced in science is used in some technologies to create products to serve human ends.
4. Applications of science often have ethical, social, economic and political implications.

In an attempt to get teachers to focus on the important content in Science the Science Capabilities were developed. Rose Hipkins explains in www.newzealandscienceteacher.co.nz ; "The capabilities were developed to show some explicit ways to "join the dots" between all of the following:

- the content strands of the science learning area
- the 'overarching' Nature of Science (NOS) strand
- the statement in the front of NZC that outlines why all students should learn science
- the key competencies
- some existing resources designed to support learning in science."

How do we decide what content knowledge the students need?

The issue is that in the overcrowded curriculum teachers need to make hard decisions about what they put in and what they leave out. By default teachers tend to teach what they feel confident about and if their science content knowledge and experience is poor then only the low hanging fruit will be picked. If thinking scientifically and becoming scientifically literate is the goal then learners need a sound understanding of a range of science concepts and a useful vocabulary to be able to work with them. They will also need experience in a number of ways scientists work.

According to [Harlen(ed) 2010 Key](#) content of the science programme are defined in fourteen big ideas. These can be addressed in a wide range of engaging contexts at various curriculum levels.

Ideas of Science

1. All material in the universe is made up of very small particles.
2. Objects can affect other objects at a distance.
3. Changing the movement of an object requires a net force acting upon it.
4. The total amount of energy in the universe is always the same but energy can be transformed when things change or are made to happen.
5. The composition of the earth and its atmosphere and the processes occurring within them shape the Earth's surface and its climate.
6. The Solar System is a very small part of the millions of galaxies in the universe.
7. Organisms are organised on a cellular basis.
8. Organisms require a supply of energy and materials that they are often dependent on or in competition with other organisms.
9. Genetic information is passed down from one generation of organisms to another.
10. The diversity of organisms, living and extinct, is the result of evolution.

Ideas about Science

1. Science assumes that for every effect there is one or more causes.
2. Scientific explanations, theories and models are those that best fit the known facts at that time.
3. The knowledge gained by science is used in some technologies to create products to serve human ends.
4. Application of science often has ethical, social, economic and political implications.

Using this approach the authors believe that learners will see the connection between science learning and how it relates to understanding their world. They point at the way science can become a list of disconnected mini studies where students only motivation to engage is the passing of exams.

What Skills and Dispositions Do Our Students Need for Success at High School?

Feedback from past pupils has been consistent in that for the first term or two they feel less-well prepared for High-School Science than for other subjects. Most high-schools begin their science programme with an introduction to the science lab and a focus on safety, vocabulary, the nature of science and fair testing. e.g. Generic Learning outcomes for the first unit in Year 9 -

- Name several characteristics of science
- List the safety rules for working in Science Laboratories
- Identify safety Hazard (HAZCHEM) symbols
- Identify common Laboratory equipment
- Draw Laboratory equipment in a Scientific manner
- Label the parts of a Bunsen burner
- Carry out simple experiment using a Bunsen burner
- Measure volume and length accurately
- Read scales accurately
- Construct graphs using tables of data
- Plan and conduct a simple investigation
- Fair Testing
- Independent and dependent Variables

In reviewing the Yr9 programmes the key things that are different to what is typically found in Primary Schools are;

- The children work in purpose built labs with specialist teachers and equipment.
- The recording expectations are significantly higher.
- Science is initially less integrated and more specialist, although this changes once expectations and routines are established.
- More time is given to drawing conclusions, planning and recording than hands on data collecting.
- The Nature of Science is more strongly emphasised

High School teachers said that they typically started at level 3 of the curriculum for the first term's work. This points to quite a mismatch of understanding the level-expectations as Primary aim to have their students working well into level four when they finish year 8.

High Schools are going through their own dilemma in moving towards 21st century learning of integrating the context they choose to be cross curricula such as following a local issue such as recycling and integrating Mathematics, English and Science into it. This will provide more relevance and purpose to the learning but potentially leave some aspects of science not covered.

General observations from High School Teachers of Year 9 Students;

Positives	Negatives
Most Students have had experience with fair testing. Eager to engage with Science Positive expectation of enjoyment Stronger in Biology. Work well socially together. Ask questions. Able to form hypotheses for testing. Complete homework activities. Children generally come with positive expectations and experiences in science.	Inconsistent starting points in Science Poor understanding of the Nature of Science. Children generally have poor science vocabulary. Little previous experience of laboratory. Non-specific understanding of many science concepts. Many hold basic misconceptions that are difficult to shift. Many hindered by poor literacy and numeracy skills. Many students lacking resilience and risk averse, thus needing reassurance. Weaker in Physics and Chemistry. Conclusions and explanations at a low level. Poor recording in Science using graphs and tables. Assessment data sent from contributing schools on Science is of little use. Many Science Fair entries have shonky science behind them. Observation/inference not clear. Many students not "honest" about their results and will put a spin on them to match hypothesis. Accuracy of measurement and language needs emphasised. Most students arrive with the misconception that Fair testing is the only way scientists know about the world. Sometimes lack confidence. Gender stereotype that males do science. Students often cannot identify their previous science learning experiences.

So what could primary schools do to improve our transition to high school science?

- Make a better and more explicit job of teaching the Nature of Science and Science Capabilities
- Improve the science content in teaching topics going deeper
- Build vocabulary and enhance accuracy of language
- Ensure children have quality science learning in Physical and Material World areas
- Have senior children visit and work in a lab before they attend High School
- Ensure students develop capability in reading, understanding and responding to science texts
- Teach tables, graphs and how to create them and extract information from them
- Use outside-expert help to ensure science is not flawed as misconceptions are difficult to replace with scientific thinking
- Teach students to be resilient in the face of challenges
- Teach difference between inference and observation
- Provide a wide range of science experiences learners can draw from
- Extend student's understanding of how scientists investigate beyond fair testing and into classification, seeking patterns, modelling and researching

Conclusions

- **There is a tension around whether to focus on covering content or developing an understanding of Nature of Science.**
- **There is a tension around whether to go broad or deep.**
- **There is more to do than time allows.**
- **The outcome should be that our learners are engaged with science and are equipped to be informed citizens.**
- **Success at High Schools require resilient, literate, numerate and thinking students.**
- **High Schools expect students who know how to work in a scientific way.**

What Can We Learn From English Practice?

The aim of the English Science Curriculum is stated as follows; “A high-quality science education provides the foundations for understanding the world through the specific disciplines of biology, chemistry and physics. Science has changed our lives and is vital to the world’s future prosperity, and all pupils should be taught essential aspects of the knowledge, methods, processes and uses of science. Through building up a body of key foundational knowledge and concepts, pupils should be encouraged to recognise the power of rational explanation and develop a sense of excitement and curiosity about natural phenomena. They should be encouraged to understand how science can be used to explain what is occurring, predict how things will behave, and analyse causes.”

It goes on to explain that children will;

- develop scientific knowledge and conceptual understanding through the specific disciplines of biology, chemistry and physics
- develop understanding of the nature, processes and methods of science through different types of science enquiries that help them to answer scientific questions about the world around them
- are equipped with the scientific knowledge required to understand the uses and implications of science, today and for the future

The curriculum then begins to specify the curriculum content and mandate Key-Stage mastery content. Key Stage 1 is y1 and 2, Key Stage 2 is yr 3,4,5 and 6 and Key Stage 3 is yr 7,8 and 9. Schools are required to publish their science schemes year by year online. They have limited choice around what will be covered, but can schedule when and how. The curriculum for example stipulates what concepts and knowledge will be covered at each year level.

The curriculum has core mandated material and then non-statutory guidance on what will make a full programme. The curriculum is specific and clear about what must be taught and the expectations it has for its delivery. It is divided into two main sections, *Working Scientifically* and *Programme of Study.*

Here is an example of learning specified for year 5 and 6 for Working Scientifically;

“During years 5 and 6, pupils should be taught to use the following practical scientific methods, processes and skills through the teaching of the programme of study content:

- planning different types of scientific enquiries to answer questions, including recognising and controlling variables where necessary
- taking measurements, using a range of scientific equipment, with increasing accuracy and precision, taking repeat readings when appropriate
- recording data and results of increasing complexity using scientific diagrams and labels, classification keys, tables, scatter graphs, bar and line graphs
- using test results to make predictions to set up further comparative and fair tests
- reporting and presenting findings from enquiries, including conclusions, causal relationships and explanations of and a degree of trust in results, in oral and written forms such as displays and other presentations
- identifying scientific evidence that has been used to support or refute ideas or arguments”

An example of England’s Programme of Work is that year 4 pupils cover five science topics and under the topic of Electricity learn to;

- identify common appliances that run on electricity
- construct a simple series electrical circuit, identifying and naming its basic parts, including cells, wires, bulbs, switches and buzzers
- identify whether or not a lamp will light in a simple series circuit, based on whether or not the lamp is part of a complete loop with a battery
- recognise that a switch opens and closes a circuit and associate this with whether or not a lamp lights in a simple series circuit
- recognise some common conductors and insulators, and associate metals with being good conductors

At the end of each Key Stage there was a National Exam to measure school’s performance against the curriculum. The exam is text based and mostly multi-choice or closed answer. An example can be found here.

There is an expectation that teachers will deliver two hours per week of science learning and that the science programme is available online. According to a 2015 BBC article ⅓ of teachers lacked confidence in teaching science and that 36% were unable to deliver the two hours of science mandated per week. The government is investing heavily on professional development with initiatives such as TigTag, a free to UK Teachers video resource and online training.

Comparison Summary of Science Teaching in NZ and England

Area	New Zealand	England
Curriculum Choice	High level of choice for schools and teachers. Enabling and empowering for teachers.	Low level of choice. Prescribed and internally audited.
Curriculum Emphasis	The Nature of Science and future oriented learning	Content knowledge 50% and citizenship 50%
Ministry Provided Curriculum Support	TKI Science online Building Science Concepts MOE Books ARBs Interactives Exemplars Learnz virtual field trips	Specific multi.media support Ministry books Free-lance books
Inservice for Teachers	Very little with our current emphasis on literacy and numeracy - Optional with 2 advisers for Otago Primary and Secondary	Extensive Inservice opportunities
21st Century Learning	Strongly encouraged High ability to integrate Student centred Ability to move beyond school gate Flexible and permissive Focussed on Science Citizenship for life Values and Attitudes important	Hard to integrate with pressure from key-stage exams in Numeracy, Literacy Curriculum driven by school scheme with little flexibility Very little evidence of technology being used
Pisa Results	3 places below UK	3 places above
School Set up	Years 1 to 8 are primary with generally science taught by non specialist teacher No access to laboratory	School starts at age 4 to year 6 as primary with generalist teacher; year 7 and upwards often have specialist science

		teacher.
Equipment	Varies from school to school but often chaotic and teachers need to source equipment and materials.	Varies from school to school but often chaotic and teachers need to source equipment and materials.

In reviewing literature around the English Curriculum there is a pride and determination to improve science outcomes for students. It seems that the English approach to curriculum is underpinned by a belief that by being prescriptive and through a strict auditing process they will ensure every student will have access to quality learning in science.

Interesting observations from my visits to English schools are;

- English teachers spend much more time talking to whole classes and following extremely specific learning intentions with less differentiation.
- English students sit passively and listen for longer periods of time than I would expect; a class of 4 year olds sat for a 30 minute literacy lesson that morphed into a science lesson.
- English students were started at 3 to 4 years of age into literacy, numeracy and science with formal lessons and high expectations. In one school I attended 100% of 3 year olds were below or well-below expectations for language and through tightly structured programmes by key-stage 1 they were 90% at expectations. (Incidentally the school had toilet trained 28 of the 32 three year olds that had entered that year)
- In the schools I visited the students literacy seemed one to two years ahead of NZ by the age of 11. Students that were 6 seemed able to write in sentences and were using their literacy in Science
- Students who had been in both NZ and English systems much preferred the NZ way of education and in one case had really struggled to assimilate back into an English School and consequently had changed to a more liberal school on returning to England. Pupils interviewed said they felt they learned more in the NZ schools, but parents felt they children's learning had slowed in NZ. As this was a small sample, it would be interesting to look into this further.

- In England there is a strong hierarchy with a low trust model of top-down checking on everything. Typically the science lead teacher looks at the teacher's science lesson plans, correlates this to checking on the student's work books and by talking to the students in the room. While part of the role is to support teachers, a fair part of it is to ensure the curriculum is covered as described.
- Common practice in lesson delivery was evident in the clear learning intentions being used and the lesson structures as follows; sharing of prior learning/reviewing, sharing of learning intention, the explanation and exploring through discussion/questioning/demonstration, the activity (if applicable) and then Plenary. Teachers typically gave students an opportunity to posit theories as to why things were so, and went on to explain.
- Vocabulary was front and centre in all the classrooms I entered. The language for the unit was on the wall and a part of each lesson.
- Wall displays were mandated in most of the schools, with each class responsible for ensuring an attractive display of the current topic for the term is on display. This was also echoed in the public areas of the corridors with best examples of student learning and their investigations up on display.
- Student work books were almost universally used as evidence of learning. So much so that in one school students had to select their best work from the previous book and stick it in the front of their new book; "My Best So Far", The challenge is to ensure nothing falls below that standard. This also was done in transition from one teacher to the next.
- Safety in England Schools is taken extremely seriously with a manual for science safety that outlines rams for almost every situation. e.g. if the children are working with soil, gloves and facemasks are to be worn.
- Recording in Science seemed to have the same high expectation as in other areas of literacy, "If they can do it in the morning there is no reason they can't do it in the afternoon."

Positives of the English Approach

If every teacher of year 3 children will be doing a unit on magnets for example, this means there is an economy of scale in being able to produce supporting material and provide specific professional development.

It also means children can move from school to school and have the same previous learning experiences.

Vocabulary and knowledge steadily builds.

Transition from primary to High School is more predictable and more even between contributing schools.

Teachers have clear understanding and expectation as to what is is expected and when.

Children get between 1.5 and 2 hours a week of science.

Teachers and Schools are accountable for progress in Science which is externally audited.

Negatives

High Stakes testing drives “teaching to the test” learning which tends to be knowledge based and lower-order thinking.

Emphasis on contexts rather than the Nature of Science.

Students, Teachers and Principals are incredibly stressed.

Little opportunity to follow student’s interests or local issues.

Science tends to be a separate subject and not integrated into a holistic approach.

Teachers feel less in control of their classroom programme.

The Cambridge Curriculum

Cambridge Curriculum - Some New Zealand private schools have opted for the Cambridge Curriculum, generally because it is more prescriptive and has external exams to ensure content is delivered. In reviewing the curriculum there is significantly more emphasis on specific knowledge in the various curriculum areas. It is much closer to the English Curriculum. It sets learning out in two main areas, Skills and Knowledge, with approximately two-thirds of the programme on Knowledge. An example of a long term plan for year 3 Science can be found here.

An independent article that examines this in more detail is available in Educational Review Magazine.

I personally feel that if followed closely, children would get a good grounding in Science and teachers would have a clear programme to follow, however it relegates science to a separate subject and would make integration extremely difficult. The scope and time pressure is significant.

What Do Students Tell Us?

Overall the pattern in NZ schools is that children in year 0 to 4 have a markedly more positive attitude to science than at year 8; it drops off even more as students progress beyond year 8. We know most students are achieving in science at level two but there is significant drop off at levels 3 and 4 of the curriculum (NMSSA 2012)

For this study I have prepared two questionnaires to gather student voice;
http://kwiksurveys.com/s/sp01btygdywvk4b517900
http://kwiksurveys.com/s/labtsui1z3kn3zb521354

One of the issues with students talking about their learning in science is a perception that science is only happening when the test tubes, bunsen burners and microscopes are out. There are many times in science when the learning is integrated with reading and writing activities.
In developing understanding of these concepts, teachers need to constantly make links to children’s learning and what scientists do and how they think. e.g. Number 2 from above can be explored through how we preserve food and how our understandings of the science behind this has changed through the ages. Children may only see the science in the hands-on experiments,

and miss the import concept that Science Knowledge changes as we learn more and that our theories and understandings are not always correct.

In response to the question, “What makes a good science lesson?” students identified the following;

- Working in small groups of 3 to 4 people they liked.
- Hands on and practical activities
- Establishing the right balance between support and challenge
- Having choice
- When it’s fun
- Having a purpose, challenge or leading to something
- Having access to enthusiastic experts
- Using interesting Youtube clips/videos
- When couched as a mystery or problem to solve
- When support is given around vocabulary
- The right mix of demonstration and hands-on
- When opportunity is given to do prior learning or research
- When teachers give hints and tips instead of explaining
- Start with easier lessons and build to more complicated
- Having enough time
- When teachers allow children who understand what to do to get started
- When children get to take something home or can show their learning
- Anything involving food
- When the learning is related to the topic rather than one-off lessons
- Writing down the key ideas
- When it is interactive
- Listening to explanations of why things work the way they do
- When students get a chance to play with the equipment

In response to the question what makes a poor lesson;

- When there is a lot of writing
- Where the teacher does it and they watch
- When it is just a list of instructions to follow
- When they don’t understand what they are doing and why
- When it is over-explained before the children do the activity
- When there isn’t enough time to get it finished
- When the equipment is wrong for the task
- When the experiment doesn’t work
- When there are social issues in the group
- When it is explained in a superficial way and not done in enough depth
- When teachers are impatient and not prepared to explain it again
- When teachers don’t get around the groups to support their learning
- When the groups are too big

- When we do things we have done before

In response to the opportunity to share their own thoughts the following thinking was prominent;

- Time flies when you're doing science
- It's a really fun way to learn about the world around us.
- I like the way we learn new things I didn't know about before
- Students generally enjoyed Chemistry and like explosions, burning and spectacular reactions.
- Several students felt that primary science was at a too simple a level and they weren't challenged
- Teachers can make fun things boring if they don't plan it well
- I like when I get a choice and I get to make a presentation about my learning
- Having work that challenges me is important
-

Science Fair

Many schools run Science Fair as a major part of their approach to teaching Science either annually or biannually. It is an excellent programme in that it ticks most of the boxes for 21st century pedagogy; Student directed learning, individualised learning, cooperative learning, real-life purpose, technology and open-endedness are all key to success.

Unfortunately it can easily become an exercise in presentation with shonky science if not scaffolded correctly. There can be a tendency for the standard to become beyond the grasp of most children as the ownership of the learning transfers to over-zealous teachers or parents with their eyes on the prize. The complexity of the science fair is a challenge for students and recognising this many schools have redeveloped the structure around them to be localised and maintain the process to reflect the needs and developmental stage of the the learners.It reduces the focus on the presentation and keeps the focus on scientific process and method.

Often Secondary Schools commented that they appreciated being asked to judge the Science Fairs, but were frequently disappointed with exhibits that had poor or incorrect science concepts underpinning them. The solution they offered was to get expert help early in the process. They also were concerned that some children arriving at year 9 were under the impression that "Fair Testing" was the only way scientists worked.

What Does Best Practice Look Like?

How do we go about teaching science effectively?

Excellent Teachers

- Provide challenges and high expectations
- Provide hands-on opportunities

- Engage their students emotionally
- Listen to their students
- Have a high level of understanding of the subject matter and the pedagogy to teach it
- Use stories to build connections

Students Learn Best When

- They are engaged emotionally and intellectually
- When they have an opportunity for hands-on learning
- They know what they are learning to master and see the purpose
- They make connections to prior knowledge
- They have opportunity to work cooperatively in small groups
- They get regular and timely specific feedback relating to the learning
- They revisit the learning in a different context
- There are stories they can relate to

How Should We Choose a Topic?

There are four approaches to selecting contexts and content for learning;

1 Start with the key knowledge and build an engaging context around that.
2 Start with an engaging science topic and build your key knowledge into that where it fits.
3 Start with a real issue or problem and explore the science needed to solve it.
4. Develop a strong curiosity in your students to understand how the world works

Approach	Strength	Weakness
1 Key Knowledge	Possible to get good coverage Manageable Measurable Resources available Easy to follow for teachers Science treated as separate learning area Can be delivered adequately by most teachers. Key content is defined Harlen(ed) 2010 Principles and Big Ideas of Science Education	Reduces science to a list of “facts and understandings” Potential to disengage students De-emphasises deep understanding of the Nature of Science Lack of integration and cohesion Stand alone
2 Engaging Science Topic	High interest and engagement Plans available from other sources Potential for students to develop positive attitudes to science.	Science knowledge and understandings haphazard More difficult to manage consistent coverage of content

		Potential to sideline science for engaging activities Needs a higher degree of science teaching expertise
3 Real Issue	Real time/real life science with a purpose and an application Relevant A chance to engage real scientists Potentially engaging and empowering Easy to integrate with Health or Social Science topic	Science aspect can be watered down and lost Hard to get a breadth of coverage Lack of resources and local support Takes careful management to ensure it remains child-centred Relies on outside school support Needs a high degree of science teaching expertise
4 Developing strong curiosity	This is a key overriding disposition that will drive real learning Children who ask genuine questions will develop a wide set of learning strategies Scientific knowledge and concepts begin to make more sense and have purpose	Difficult to measure Difficult to genuinely and consistently get this happening across the school Ensuring breadth of the programme and content knowledge is difficult

Whole Game Approach - David Perkins (2009) argues that schools frequently attempt to make complex ideas accessible to learners by breaking them down into little pieces but as a consequence the “big picture” often gets lost. He suggests that junior versions are a way of providing “threshold experiences” that make challenging knowledge and practices accessible even to young students without losing the holistic nature of the activity. According to Perkins, a “whole game” is generally some kind of inquiry or performance.

This is one approach that is scaffolded and yet holistic and likely to facilitate deeper understanding of the Nature of Science.

Science Fair - Many schools regularly participate in Science Fair Competitions where often the standard of formal competition is so high that it is beyond the scope of most children without huge intervention of adults. Often for it to be successful it relies on much home support and for many unsupported students it can quickly become about presentation and attractive displays. It may become impossibly elitist. Another pitfall is a lot of time can be wasted if children are working with a flawed science concept that goes unrecognised.
However with a little modification and some clever planning it can become more child-centred and less about competition, and more about children engaging with science. It is an excellent opportunity for student agency and self-directed learning. It is entirely consistent with a 21st Century Learning approach.

Children need strong guidance and support throughout each step of the process to be successful and to come away with a positive attitude about science learning. It must also be recognised that while it can be engaging, child centred, self-directed and powerful, it is not the full science curriculum on its own and will need balanced with other approaches.
Data from the survey showed there were many who liked this approach 36% rating it as extremely enjoyable, 27% very enjoyable and 28% O.k.and 14% who disliked or detested the Science Fair. The main reason for not liking the Science Fair was a feeling of not being successful or not understanding what they were meant to be doing.

Digital Learning - Using the tools and technologies available to us to enhance or drive learning. This ranges from using cameras as recording devices through to virtual field trips. It gives children access to scientists and real contexts in real time, eg Citizen projects as listed in the useful URLs section. It also gives rise to high quality scientific measuring devices such as decibel meters, frequency oscillators and time-lapse photography as affordable apps on our smart devices.

5 Es Instructional Model - This model moves learning through five sequential stages. Engage, Explore, Explain, Elaborate and Evaluate. It mirrors what Scientists do, and ties in well to the Nature of Science. A planning and explanation of this approach can be found here.

Assessment

What do we assess and how?

Whatever is assessed becomes important. The most important things in learning are often the most difficult to assess. For example you can easily assess children’s knowledge and recall but it is much more difficult to gather valid data on childrens’ mastery of the Nature of Science strand, their resilience, science for citizenship or mastery of concepts.

In short, we need to ensure that what we are assessing are the key things we are trying to teach; therefore if your focus is in Science Citizenship then gather data on children to show this. If it is on the Nature of Science, ensure you are gathering data on that.

We have exemplars and ARBs that will help us level student work appropriately, but in the end we will need to develop RUBRICs that reflect achievement in the area of focus. In this example year 6 students during a unit on Flight observed a paper spiral spinning gently above a candle.

Skill	Developing	Achieving	Excelling
Able to use scientific	Able to describe what	Able to describe	Able to describe

knowledge and ideas to explain a newly observed phenomena	is happening and make suggestion as to why it is so. Does not compare to other situations or known scientific knowledge. *"The spiral is spinning because the the wind is making it turn"*	clearly what is happening, using scientific vocabulary and ideas, and can relate it to another situation. *"The spiral spins because the air above the candle is being heated. Hot air rises and it is making the spiral turn like a propellor"*	clearly and use more than one scientific idea or concept to explain what is happening. *"The candle is burning and is producing heat, which is heating the air. The air is rising and as it strikes the surface of the spiral the spiral, moves away. There is little friction so it spins."*

These RUBRICs are very time consuming to create and specific to students and their learning situation. Often, for gathering information we rely on students writing their thinking, which limits the success of a portion of our class; usually boys.

Here is a link to an example of an assessment rubric produced by Henrica Sheiving of Otago that attempts to level investigation in science as well as vocabulary. https://docs.google.com/a/papakaio.school.nz/document/d/1WRqZAJnS39nIxaqnK_zCS5G_wk3X_slyfaZmMUemFhw/edit?usp=sharing

NZCR has produced Science Thinking with Evidence booklets which is a normative assessment tool around the Nature of Science. It is recommended that schools use it for years 7 and 8 to identify strengths and weaknesses in individuals and cohorts as well as teaching programmes. It is a very good way of gathering formative assessment and clearly identifies next steps for learning in science.

Evaluation - "*The unexamined life is not worth living,"* could be rephrased to *"The unexamined lesson was not worth taking."* To improve our success in teaching science we need to continually and critically evaluate our work as teachers much like scientists. We need to go beyond, "How well did that unit or lesson go?" to "What did I do that helped the children learn?"
"How could I have structured the lesson better?"
"If my key outcome was …….. then how many of the children did not achieve this, and why not?"
"What will I do tomorrow to get a better outcome?"
"What have I learned from this?"

So Let's Get Down to Structuring the Programme.

*We have a general idea of the **what** we want to teach and assess, but it is now time to go back to the Essence of Science Statement to ensure we are driven by the **why**. These are the key underlying objectives of a balanced science programme.*

1. *We prioritise learning to think, investigate and understand the world like a scientist.*
2. *We are building understanding of how the world works by developing students concept knowledge across the four context areas; Living World, Planet Earth and Beyond, Material World and Physical World.*
3. *We are developing the core skills of; Gathering and Interpreting Data, Using evidence, Critiquing evidence, Interpreting representations and engaging with science.*
4. *We are engaging students in science and developing them as scientific citizens.*

Guidelines

- Teachers must have at least a basic understanding of the the science topic they are teaching and a very good understanding of how scientists work
- Teachers must be clear about the learning intentions and success criteria and communicate these effectively to the students
- Teachers must provide effective feedback to students on their learning
- Teachers must allow time for students to go through the whole process, and opportunities to do it again with their improved knowledge and skills
- Teachers must provide opportunities for hands on learning whenever possible
- Student's natural curiosity should be celebrated and fostered
- Teachers must facilitate opportunities for students to ask questions and suggest reasons or solutions
- Teachers must be explicit about when they are doing science so that students see the relevance and variety of science beyond the laboratory
- Wherever possible, integrate learning across the curriculum; especially with English and Mathematics
- Contexts must be engaging for the students and have a relevance to their lives that they can understand and appreciate
- Contexts should be evenly spread across the four areas of science
- Teachers should mindfully teach the scientific vocabulary that underpins the science learning
- Experts should be used
- Use of science texts and videos should be included
- Learning may often involve field trips
- Teachers should gather data on what the children know at the beginning of a topic and target their content aspect of their lessons accordingly
- Teachers should use observation, diagnostic tool from NCER or Arbs to inform their teaching

- Teachers should include Communicating in Science in their programme but not let it become a barrier to learning science
- Teachers should be well organised and have tried the experiment or activity before they begin teaching it in a classroom
- While “jam-jar” science is acceptable, using scientific equipment is more motivating for students
- Teachers who are unsure of a an aspect of science should seek support before they begin teaching it
- Teachers must take care that if they are taking science through an integrated unit that the science aspect of the inquiry is not watered down but remains clearly “Science” in the heads of the learners.

Keys to Making It All Work

Teachers First - If you want change you need to start with engaging your teaching staff. This could be done through staff meetings or teacher only days. Keep it hands-on and fun. Get the staff to carry out an experiment and follow it through, modeling the kind of questions and approaches you would use to develop the Nature of Science concepts with children.
Make sure there is enough equipment and the lesson plans for teachers to go back to their classes and do the same lesson.

Structure/Organisation - Teachers need permission and time to focus on Science, so consider making Friday Science Day for a whole year. Some schools devote a term to science and then have special science days in the other terms. One model that works is to have a two tier approach; The major unit where a topic is investigated in depth, and the one-off hands-on investigations. These work best if they are in response to students’ genuine inquiry.
The challenge with integrated or inquiry units that the science is often watered down or lost.

Another structure that has merit is to team three or more teachers up and have them rotate the children through their science topic; e.g. One teacher investigates Sound, another light and the third heat. They run a series of lessons then swap the children over. That way the teachers get to practise and hone their teaching of science and as well as this the lessons they plan and the equipment they gather is more worthwhile and has better pay-back for the time invested. It also means teachers can gather feedback on their teaching and act on it with the new group of students.

5Es - If this is the best approach with children it is also the best approach with adults. Engage, Explore, Explain, Elaborate and Evaluate. It mirrors what Scientists do and ties in well to the Nature of Science. Here is an example with a planning sheet.

Backwards mapping - New Zealand teachers generally dislike being told exactly what to teach and when and how. Therefore one way to get curriculum coverage is to highlight and date a spreadsheet showing which areas of science have been covered and through which contexts. By reviewing this over three years it becomes obvious the contexts that need attention.

Provide resources - Many teachers shared that a barrier for them is the time it takes to gather the resources they need. To overcome this, a well-stocked and well ordered storage area is essential. One way of doing this is to approach it from a "just in time" method where teachers are encouraged to get more than what they need for a particular experiment and the excess is stored ready for next time. Another is the "just in case" method where a science area is stocked with a range of staples for science investigations.
Whichever method is used, there needs to be much forethought go into where and how things are stored as well as what should make up the basic inventory. Who is responsible for maintaining the area and stocks, as well as how can it be kept safe for children, are all things to consider.

If schools want high quality science they must be prepared to pay for the consumables and the teacher-aide time to ensure what is needed is available when it is needed.

TKI provides an inventory as well as spreadsheet to manage it as it is used and replaced. This is an ideal job for a teacher aide or parent volunteer to maintain. Having a well stocked Science Storage Area is key to making science more accessible for teachers.

A list of items needed to start the staff building their own science kit. Start with; vinegar, baking soda, cornflour, citric acid, oil, food colouring and a big bag of salt,containers, tissues, lunch size snaplock bags, paper clips, icecream sticks, birthday candles, toys such as cars, jars with a lid, spoons, measuring spoons and measuring jug and blue tac.
Then add magnets, magnifying glasses and eye droppers (available cheaply at the Science Shop Online.) From this start you can just keep adding when someone introduces a new investigation. To make everyone confident you can model the investigation in the staffroom or put the instructions with the kit.

Student Voice - Feedback from students consistently links enjoyment with achievement. If they feel they are enjoying the science, they believe they are learning. To make it enjoyable, the children list the following four things as key;

1. Being able to work in a social group
2. Hands on experiences (especially burning, exploding or chemistry)
3. Novelty
4. Going deeper

The list the following as detractors from their enjoyment;

1. Working with people they don't get along with
2. Groups are too big
3. Too much recording
4. When things don't work

Involve real Scientists - Access to experts brings the science curriculum to a whole new level. It gives a real-life purpose for learning, provides students with role models, and promotes

science as a career. The Royal Society of New Zealand runs a six month fellowship for ordinary classroom teachers to work along scientists in a particular field. They come away refreshed, enthused and empowered to drive science education in their schools. They get access to curriculum experts and leadership training to make them effective in bringing about change. Along with this there is LEARNZ which provide virtual field trips especially for New Zealand schools.
The University of Otago has an outreach group that sends scientists to schools on a regular basis to develop interest and enthusiasm in science. As well as these there are Citizen Science projects to get involved in in most areas through DOC, Regional Council or conservation groups.

Action Plan for Papakaio School as a result of Sabbatical
Make progress on the following fronts;

1. Curriculum Statement
2. Staff Development
3. Science equipment storage
4. Liaison with High Schools for transition

Staff Meeting Plan

Staff Meeting	***Outcome***	***Resources***
Sharing Sabbatical Findings	*Staff are aware of big picture of how our school curriculum, National Curriculum and lessons we can learn from England fit together.*	*Experiment - how many drops can we put on a coin.* *Prezi - Summative version of my findings.*
The Nature of Science	*Staff are able to articulate what the nature of science looks like at their level and how the Nature of Science is central to the teaching of science.* *Staff are equipped with background reading and prompts to help keep this focus.* *Staff become explicit in their teaching Nature of science each science lesson.* *Staff understand the purpose and importance of NoS and how it contributes to successful transition.*	*Curriculum jig-saw activity.* *Readings from TKI re NoS* *Experiment - Hovercraft* *WALT designer app for NoS*

Science Capabilities	*Staff are able to articulate what the Science Capabilities are and their place in the curriculum.*	*TKI Article Introducing Capabilities* *Rose Hipkiss explanation of Science Capabilities* *Walt designer tool for Capabilities*
Body of Knowledge	*Staff are able to articulate how and where the contextual areas of science fit in and the content knowledge.* *Staff hear of various approaches from schools in teaching science.* *Staff review our school-practice and come up with a curriculum approach that is manageable and promotes best practice in science learning.*	*Curriculum Statement* *Presi on school approaches* *The Apple goes Brown Experiment*
Effective Pedagogy in Science	*Staff are introduced to the 5E approach to science.* *Staff review student voice and look at their practice in the light of this.* *A planning template for science lessons is shared.*	5 Es Instructional Model Video 5 E Reading Hand-Out *5E Planning Sheet* *Floating Egg Experiment - Video - Note this video is a poor example of teaching science, - analyse this. Full of inaccuracy!* *https://explorable.com/salt-water-egg-experiment - a much better description and outline.*
Assessment Staff Meeting	*Teachers understand their responsibility to establish Prior Knowledge and have strategies for this.* *Teachers understand that assessment should be on the NoS rather than specific context knowledge.* *Teachers see the relationship between the NoS and the Capabilities and how they help with assessment and Learning intentions* *Teachers become explicit in teaching the Nature of Science.*	Experiment - Bubbles - http://www.sciencebuddies.org/science-fair-projects/project_ideas/Chem_p025.shtml or http://www.sciencemadefunkids.net/experiments.cfm?Exp=11 and http://www.wral.com/lifestyles/goaskmom/blogpost/11570936/ ARBS https://anethicalisland.wordpress.com/2013/05/03/events-in-instruction-event-3/ a chart of ways to activate prior knowledge http://www.thinkport.org/technology/template.tp - find a graphic organiser for teachers KWOL to fill re Assessment

		Exemplars TKI - Relating NoS and Capabilities Rubrics - https://docs.google.com/a/papakaio.school.nz/document/d/1WRqZAJnS39nIxaqnK_zCS5G_wk3X_slyfaZmMUemFhw/edit?usp=sharing
Resources	*Teachers have knowledge and access to key resources; TKI, Pinterest, etc from this document.* *Teachers have had time to explore and book-mark ideas.* *Teachers know the storage system and how we can grow and maintain our science resources.* *A shopping list is drawn up.* *A code of conduct agreed on access.*	Spinners and Darts Exp This document is shared. Explore TKI Visit our Science storage cupboard.

Hands-On Resources for Teachers

This is a list of places to go for Science Resources that I have come across as recommended by teachers. I have used a 3 star rating with 1 being mildly useful, 2 useful and 3 Extremely useful. I particularly draw your attention to my Pinterest account which has direct links to hundreds of hands-on experiments grouped into the Strands.

Resource	Description	Location	Rating
TKI - Science Online	NZ MOE Teaching and Learning Site	http://scienceonline.tki.org.nz/	3
Connected Series	MOE Connected booklets are in most schools stored alongside the School Journals	http://www.downthebackofthechair.co.nz	3
Building Science Concepts	MOE Published booklets. Lesson plans, background and overviews	http://www.downthebackofthechair.co.nz	3
The Science Learning Hub	A very good breakdown of units and extremely practical. Looking for a context for science learning?... then I	http://www.sciencelearn.org.nz	3

	would start here.		
Assessment Resource Bank	Assessment tools to help level and assess science achievement. A good pre-test or assessment tool that has some level of nationally normative function *logon/password - arb/guide*	http://arb.nzcer.org.nz/	3
LEARNZ	Virtual field trips supported by experts using technology for links	http://www.learnz.org.nz/	3
InstaGrok	A search engine that sets out searches in a web style. Suitable for y5 students up or teachers lifting their personal knowledge	http://www.instagrok.com	2
Pinterest Gary's Science Experiments	A collection of hands-on science experiments for primary school. A large number of experiments gathered and people to follow, with ideas for things to do grouped into the strands.	https://www.pinterest.com/garyshirley6/science-experiments/	3
Creative Ideas for Kids - Pinterest	A great site for hands-on experiments for Primary School	https://www.pinterest.com/LSSchachter/creative-science-ideas-for-kids/	3
Science Activities - Pinterest	A great site for hands-on experiments for Primary School	https://www.pinterest.com/vhrules/science-activities/	3
Physical Science - Unschool the teacher - Pinterest	Very good ideas for practical Physical Science activities	https://www.pinterest.com/unschoolteac/science-physical-science/	3
Science and Discovery for Kids - Pinterest	Very good ideas for Science activities	https://www.pinterest.com/thesugaraunts/science-and-discovery-for-kids/	3
Early Learning in Science - Pinterest	Very good ideas for Science junior activities	https://www.pinterest.com/jdaniel4smom/early-learning-science-activities/	3

STEM Education - Pinterest	K12 collection of science and technology projects.	https://www.pinterest.com/k12inc/stem-education/	3
Science Learning Hub	A wealth of ideas and articles on current science issues and learning	http://sciencelearn.org.nz/	3
Science Kids	A child centred site with experiments and articles. A magazine. New Zealand based	http://www.sciencekids.co.nz/experiments.html	3
Explorables - Kids Science Projects	An extensive list of very good science experiments with very good science explanations as well as realistic ways of carrying out experiments.	https://explorable.com/kids-science-projects	3
WickEd	Interactives developed by NZ MOE to support the learning of science concepts. A good support for units. Note a password is needed, but all NZ Schools will have their own access via password.	http://www.wicked.org.nz/	2
Science Post Cards	12 stories that link to science and literacy. Child centred and very good.	http://www.sciencepostcards.com/	3
Primary Resources UK	A mixed bag of grab and use resources. Some gems and others.	http://www.primaryresources.co.uk/	2
Scholastic Science Magazine Articles	Science articles for kids	http://magazines.scholastic.com/	2
The Science Shop Online	A great place to buy your science needs	http://www.thescienceshop.co.nz/	3
Steve Spangler Science	Go to the Lab Tab and there are a huge number of really good experiments. Videos available of them being done too.	http://www.stevespanglerscience.com	3
Science Bob	Look for experiments and ideas. A good source for 1 off engaging experiments for the classroom	http://www.sciencebob.com/index.php	3
Bill Nye the Science Guy	A You-tube channel with lots of fun experiments to see. Best if you go to You Tube and complete your own “Bill Nye the Science Guy” search	https://www.youtube.com/results?search_query=bill+nye+the+science+	3

		guy	
Myth Busters	This is a great source of real life science when the science tests real beliefs. Truth or fiction?	http://www.discovery.com/tv-shows/mythbusters/full-episodes/	3
ASAP Science YouTube Channel	Brilliantly produced, fast moving and relevant. Great role models for kids. Warning; some topics are not suitable for children.	https://www.youtube.com/channel/UCC552Sd-3nyi_tk2BudLUzA	2
TKI The Nature of Science	Links to excellent teaching units that are set up to teach explicitly the Nature of Science in the NZ context.	http://scienceonline.tki.org.nz/Nature-of-science/Nature-of-Science-Teaching-Activities	3
TKI An Inventory for equipment	A well organised list of what should be available in every school to support science learning. As well as the list it has a spreadsheet that can be used to maintain the equipment supply.	http://scienceonline.tki.org.nz/Teaching-science/Science-equipment/Equipment-list	3
Otago University Outreach Program	OU has a number of resources available. It also sends scientists out to schools for “Hands on Science”	http://www.otago.ac.nz/sciences/school-resources/	3
Royal Society of New Zealand	A really supportive organisation aimed at making science a popular career choice. I recommend you look at the Fellowship for teachers as it is life changing	http://www.royalsociety.org.nz/teaching-learning/science-teaching-leadership-programme/	3
Schooltime Games	Online site for children to play games that help science concepts	http://schooltimegames.com/Science.html	2
NZ Science Teachers Online Magazine	A very good place to read current articles on science teaching for years 0 to 13.	http://www.nzscienceteacher.co.nz/	3
BBC Science Clips	A very good site that has age areas and very good activities well explained.	http://www.bbc.co.uk/schools/scienceclips/ages/10_11/changing_circuits.shtml	3

PB Kids Zoom Activities	Great little experiments with bright instructions and a blog to give results. Excellent for those really keen students	http://pbskids.org/zoom/activities/sci/	3
Sci Show	Youtube Videos explaining science issues all around us. Fast paced and now in the delivery. Even a Sci Show channel for kids to explain their own findings.	https://www.youtube.com/channel/UCZYTClx2T1of7BRZ86-8fow	3
Royal Society of New Zealand information resources for students	This is child friendly technical science information sheets on a wide range of real NZ and Global topics. Worth a look when selecting a context	http://www.royalsociety.org.nz/teaching-learning/resources/alpha/	3
Royal Society of New Zealand information resources on current issues in the media	An excellent list of discussion and background scientific information on current events that have science base e.g 1080	http://www.royalsociety.org.nz/teaching-learning/resources/gamma/	3
Royal Society of New Zealand Crest Award Programme	A science badge homework programme with awards and guidance. CREST is an international awards scheme designed to encourage years 0-13 students to be innovative, creative, and to problem solve in science, technology and environmental studies.	http://www.royalsociety.org.nz/teaching-learning/crest/	3
Royal Society of New Zealand funding application page	Funding application for an environmental science initiative for Primary Schools. Funding applications yearly at beginning of year,	http://www.royalsociety.org.nz/teaching-learning/funds-for-schools-and-students/	2
List of BP Technology Challenges	Hands-on practical challenges that are often ideal for engaging children in problem solving using science concepts.	http://www.starters.co.nz/bpchallenge-index	3
Science Teaching with Lydia	A useful list of teaching ideas for science in the classroom	http://excellenceinteachingscience.blogspot.ca/	2
Science Buddies	A really good site for being able to start with a question and investigate. Good for starting a big investigation.	http://www.sciencebuddies.org/	3

Good Eats	A Channel that explores the science behind our food. Try the Popcorn one and there are plenty more. Subscribe.	https://youtu.be/uk5aq2Q6QW8	3
Using Questions to develop Capabilities	A power-point in google format showing how to use questioning to develop Science Capabilities	https://docs.google.com/presentation/d/1nQ0XFJdqGHcxJObcAeT42t5zBXuhX46ZT6NHSrk9pZ0/edit?usp=sharing	3

Science Apps for IPADS / etc

Science Apps		
Weather - various	compass	Elements 4 D
Science learning hub	Geonet quake	
Book creator	Newtons cradle	
Notability	NZ fauna	
Educreations	Constellation star viewer	
Brainpop	Science glossary	
Stop motion	Emf meter	
Turbo scan	Decibel meter	
How stuff works	Flitesy's exposure meter	
Magneto meter	Perlin draw	
Loughborough meter	National geographic kids	
Sonar ruler	Fun kids science experiments	
pinterest	New Zealand marine life	
Learn science video	Wind tunnel lite	
Nature Watch NZ	Tides near me	

Courtesy of Bevan Newlands

Resources and References

Please note I have deliberately set out the bibliography in this format, as not only does it recognise my sources but it gives urls for those wishing to review the sources themselves. It also gives a brief description to save time.

Resources	Description	Url

Constructing Your Primary School's Science Curriculum	A must have resource if you developing a Science curriculum. It will gives a well-thought-out and challenging underpinning understanding of why, what and how.	Book available from NCER Press - Authors Ally Buul, Chris Joyce and Rosemary Hipkins
Imagination Education Research Group	A philosophy around effective learning using emotional and imaginative engagement. Very good examples and lesson plans available.	http://ierg.ca/
The Five Science Capabilities of NZC	Capabilities unpacked - gather and interpret info; Use evidence to support ideas; critique evidence; make meaning of scientific representations; engage with science	http://scienceonline.tki.org.nz/Introducing-five-science-capabilities
Rose Hipkiss Article on Science Capabilities	A very good article explaining the reason for the overlay of the 5 science capabilities	http://www.nzscienceteacher.co.nz/curriculum-literacy/key-competencies-capabilities/unlocking-the-idea-of-capabilities-in-science/#.VVPhJZI4bTY
Self Organised Learning Environment Examples	Brief grab-bag of shared ideas of questions and approaches used by teachers to promote learning in science. Great resource for busy teachers.	http://tedsole.tumblr.com/
ESA Book Catalogue	A list of homework style texts available that help describe the breadth of science curriculum areas at each level.	http://esa.co.nz/search?type=product&q=Science+Year+8
Essential Principles and Big Ideas of Science Education	Key science concepts/learning selected by academics as being engaging, relevant, universal and connecting across many contexts.	http://www.interacademies.net/File.aspx?id=25103
Building Science Concepts Booklets MOE	Excellent booklets that cover a range of contexts being explicit about the science understandings within and the sequences of explicit teaching.	http://scienceonline.tki.org.nz/What-do-my-students-need-to-learn/Building-Science-Concepts
Academic Writing on Our Science Curriculum	A raft of academic titles that inform decisions around science curriculum	http://www.nzcer.org.nz/research/science-education
A Full game Approach to	A download for a junior programme approach of "Full Game" an analogy for	http://www.nzcer.org.nz/research/publications/junior-versi

Teaching Science	how teeball is a full game but a junior version of softball.	on-whole-game%E2%80%9D-science
LEARNZ	A virtual field trip with access to experts and experiences through online contact. Take a trip without leaving the school.	http://www.learnz.org.nz/
Teaching and Learning Resource Initiative	An academic paper on how ICT opportunities can enhance teaching and learning in science	http://www.tlri.org.nz/sites/default/files/projects/9271_otrel-cass-summaryreport.pdf
Marine Meter Squared	A Citizen Science Project for schools and scientists to work together on.	http://www.mm2.net.nz
The Monarch Butterfly NZ Trust	A citizen Science Project for schools and scientists to work together on.	http://www.monarch.org.nz/monarch/introduction-to-research/taggingtransects/
Garden Bird Survey	A very good bird survey citizen science project.	http://www.landcareresearch.co.nz/science/plants-animals-fungi/animals/birds/garden-bird-surveys
Digital Technologies and Future Oriented Science Education	A MOE discussion booklet	http://scienceonline.tki.org.nz/New-resources-to-support-science-education
Key Stone Science Tests	Here are free examples of English Key Stone Science Tests	http://www.mytestpapers.com/exam-papers/science-year6.htm
Aims and Goals for Science Education Editorial *New Zealand Science Teacher*, 107 October 2004. By Ian Milne President NZASE	A very good description of what we should be trying to achieve in Science	http://nzcurriculum.tki.org.nz/content/download/563/4014/file/ian-milne-nzst.doc
Sir Paul Callaghan Science Academy	The group behind the Science Road Show, sponsored by MOE and Fontera. A full approach to developing young scientists and addressing the need for sound science programmes.	www.scienceacademy.co.nz

5E Science Teaching Approach	Video - A very good overview of what 5 E Learning is about. Good for Staff Meeting	http://www.bioedonline.org/videos/supplemental-videos/5e-model-for-teaching-inquiry-science/
NZCER what science should look like in 21st Century	An in-depth paper on 21st century learning in science.	http://www.nzcer.org.nz/system/files/primary-science-education-21st.pdf
Royal Society NZ Teaching Resources	Very good list of units and supporting material for use in classrooms.	http://www.royalsociety.org.nz/teaching-learning/resources/alpha/

Appendix

Questions asked in my student surveys.
Are you a boy or a girl? M/F

What are your grades like at school? 1 to 5

How much do you like science at High School? 1 to 5

How much did you like science at primary school? 1 to 5

Think about your first term at high school. How well-prepared for Science at High School did you feel you were from Primary School? 1 to 5

How much of the following science ideas/areas did you cover at primary school; 1 to 5
All things are made up of Atoms and small particles.
Objects can affect other objects at a distance
Forces and energy;e.g. acceleration and speed, friction, weight
Energy - e.g. heat, light, sound
Earth Science - e.g. Rocks, volcanoes, landforms, weather, water cycle, glaciers etc
The Universe - e.g.solar system, space, orbit
Body Science - e.g. How lifeforms work, blood cells, body systems
Living World - e.g. Plants and photosynthesis, life cycles, food webs, rocky shore
Genetics - How genetic information passed from one generation to the next
Diversity of Life - e.g. classification, evolution of species, adaptation of species

What were the good things about Science teaching at your primary school?

How could science teaching be improved at your primary school?

What were some of your favourite topics/lessons at primary school?

Primary School Students

Which School do you attend?
How good do you think you are at science?
How much do you like science at school?
Which of the following things have you learned about in science at school?

- All things are made up of Atoms and small particles.
- Objects can affect other objects at a distance
- Forces and energy;e.g. acceleration and speed, friction, weight, pullies
- Energy - e.g. heat, light, sound, electricity
- Earth Science - e.g. Rocks, volcanoes, landforms, weather, water cycle, glaciers etc
- The Universe - e.g.solar system, space, orbit, earth
- Body Science - e.g. How lifeforms work, blood cells, body systems
- Living World - e.g. Plants and photosynthesis, life cycles, food webs, rocky shore
- Genetics - How genetic information passed from one generation to the next
- Diversity of Life - e.g. classification, rocky shore, evolution of species, adaptation of species

Have you participated in a Science Fair?
If so how good do think it was it for your science learning?
How much did you like learning science this way?
Think of a science lesson or topic that went really well for your learning. What are the main things that made it successful for you?

Think of a science lesson or topic that didn't go so well for your learning. What were the main things that made it unsuccessful for you?

Table of Appreciation
I would like to thank all the Ako, dedicated teachers and educators who contributed to this investigation.

School	New Zealand
Papakaio	North Otago
Weston	North Otago

Five Forks	North Otago
St Kevins	North Otago
Waitaki Girls	North Otago
Waitaki Boys	North Otago
Glenavy	South Canterbury
Waihi Preparatory School for Boys	South Canterbury
Karori Normal School	Wellington
Onslow College	Wellington
	England
Wellington School Hanslow	London
St Elizabeth's School	London
Maidstone Grammar School for Girls	Kent
Templars School	London
Coventry	Chelsea
Bathampton School	Bathampton

Personal Conclusions

It took four weeks and two days before I lost that weighty feeling of responsibility and constant sense of standing in the middle of a circus ring spinning plates, knowing that there are too many to keep going no matter how hard I try. I passed that burden of responsibility to my D.P. Sean Wansbrough and between him, the amazing staff and the BoT the plates kept spinning and I was able to walk away and to chant my new mantra, "Not my circus, not my monkeys". Being the driven person I am, I had to often-times remind myself to stop worrying about school issues and focus on the here and now and enjoy the opportunity.

So what have I gotten out of the sabbatical?

- My creative drive back
- Ability to use google docs enhanced
- Ability to use kwik survey
- Ability to use Prezi
- Ability to use Pinterest and a fantastic bank of experiments
- A number of networking contacts

- A deep respect for TKI and the people who put together the Science Community
- An appreciation for my staff and BOT who just carried on
- An appreciation for my DP who stepped up and managed the school so well
- An appreciation of our secondary colleagues and the things we can learn from them
- An appreciation for the freedom and opportunities we have in the NZ Curriculum
- A clear way forward to ensure our students leave Papakaio confident and capable in science
- A chance to refocus and develop a 5 and 10 year plan
- To know what it feels like not to be in a hurry or under pressure
- A chance to reconnect with my family in a deep and meaningful way
- A fantastic opportunity to tick several things off my bucket list
- Answers to my questions around science teaching

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