

New Zealand Science Review

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Sir Paul Callaghan on:
'a place where talent wants to live'



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A forum for the exchange of views on science and science policy.

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Cover photo: Sir Paul Callaghan GNZM, FRS, FRSNZ is Kiwibank's 2011 New Zealander of the year, for his service to science in the fields of nanotechnology and magnetic resonance.

Instructions to Authors

New Zealand Science Review provides a forum for the discussion of science policy. It covers science and technology in their broadest sense and their impacts on society and the environment, both favourable and adverse. It also covers science education, science planning, and freedom of information. It is aimed at all scientists and decision makers, and the interested public. Readability and absence of jargon are essential.

Manuscripts on the above topics are welcome, two copies of which should be sent to: The Editor, NZ Association of Scientists, PO Box 1874, Wellington, or e-mailed to allen.petrey@xtra.co.nz

As well as full papers, short contributions, reports on new developments and conferences, and reviews of books, all in the general areas of interest of the journal, are invited. The journal also accepts reviews of a general nature and research reports.

Full manuscripts (with author's name removed) will be evaluated and authors will be sent copies of the reviewer's comments and a decision on publication. Manuscripts should not normally have appeared in print elsewhere but already published results discussed in the different, special context of the journal will be considered. They should preferably not exceed 2500 words.

To facilitate anonymous review, author's names on manuscripts and any acknowledgement of assistance should be on a detachable cover page. Manuscripts should be accompanied by biographies

of not more than 100 words on each author's personal history and current interests. Authors are also expected to supply a suitable passport-size photograph of themselves.

Manuscripts should be typed double-spaced with wide margins on one side of the page. Articles may be submitted in Word for PC, rich text format, or plain text, by e-mail, or on floppy disk or CD-R. Diagrams and photographs should be on separate files (preferably eps, tif, jpg, all at 300 dpi), not embedded in the text.

All tables and illustrations should be numbered separately – Tables 1, 2, 3, 4, etc., and Figures 1, 2, 3, 4, etc. – and be referred to in the text. Footnotes should be eliminated as far as possible. Diagrams and photographs will be printed in black and white, so symbols should be readily distinguishable without colour, and hatching should be used rather than block shading.

References should preferably be cited by the author–date (Harvard) system as described in the Lincoln University Press *Write Edit Print: Style Manual for Aotearoa New Zealand* (1997), which is also used as the standard for other editorial conventions. This system entails citing each author's surname and the year of publication in the text and an alphabetical listing of all author's cited at the end. Alternative systems may be acceptable provided that they are used accurately and consistently.

In this issue

In their paper, *Teaching, learning, and assessment of science investigation in Year 11: Teachers' response to NCEA*, Azra Moeed and Cedric Hall explore teaching practice and teacher understanding of science investigation, and the connectedness between learning, motivation to learn, and assessment.

The results from their case studies indicate that teacher practice of science investigation changed in response to the internal assessment requirements for the National Certificate of Educational Achievement (NCEA). The nature of this change raises issues of validity and reliability for the assessment of student learning of science investigation.

Paul Callaghan argues, in *Sustainable economic growth for New Zealand: An optimistic myth-busting perspective*, that vision is essential to any strategy aimed at enhancing prosperity. He believes that New Zealand is poor because we choose to be poor and are held by self-serving but dishonest myths.

His paper, originally prepared for the March 2011 workshop *StrategyNZ: Mapping our Future*, sets about 'busting' these myths and suggests that the way forward is to encourage small to medium enterprises that have the potential to grow through investment in research and development. He argues that one hundred inspired New Zealand entrepreneurs could turn the New Zealand economy around.

Jack Sommer and Chengxiu Sun, in their paper *Bioscientists in the 2008 Survey of New Zealand Scientists and Technologists*, explore differences and similarities of New Zealand bioscientists relative to the larger science community both in terms of their attributes and opinions on some important issues.

The data for this paper were extracted from this 2008 New Zealand survey (Sommer 2010) and the authors believe they will serve as a guide to greater understanding of the issues that engage the scientific community generally and bioscientists in particular. Such understanding, they argue, is vital to the advancement of a bio-based economy such as New Zealand's.

Their analysis also demonstrates specialised capabilities of the 2008 survey not previously developed. After first commenting on the origins and purpose of the 2008 survey, they reveal some of the distinguishing attributes and opinions of bioscientists compared to all other scientists. There are important messages in this analysis for both public policy and private action. There are also some conundrums to contemplate.

In *Technology-enabled advance in the worlds of statistics, machine learning and data mining*, John Maindonald indicates that advances in digital computing continue to have large effects on all aspects of life and society, including science. These advances are possible because we have computer languages that translate directly into computational steps that can be implemented in computer hardware.

John notes that the language implemented by the R system, a software environment for statistical computing and graphics, has become the environment of choice for implementing new statistical methodology and is playing an increasingly important role in making the new abilities readily accessible at the scientific workbench.

He then goes on to give us a sense of the power that the high-level commands of the R language puts in the hands of researchers who have the skills to use them. John concludes that there is every reason why scientists whose work involves substantial statistical analysis or other computation should start using R, or something better when it comes along, early in their education. He believes the ideal place to start is at senior secondary school.

Also in this issue is an obituary for Bill Robinson, who, in the words of IRL's Jeff Tallon, '...made New Zealand's greatest technological gift to the world in his lead/rubber base-isolation dampers'.

Two letters to the editor will be of interest to members. The first, from David Penny, puts forward the notion of a 'Phased New Zealand Superannuation', and the second, from Des Darby, continues the discussion on science restructuring commenced in the previous issue.

Finally, in what can only be described as an enthusiastic review, Hamish Campbell tells us about the new book by Bruce Hayward *et al.*, *Volcanoes of Auckland: The essential guide*. In Hamish's words 'It is a magnificent contribution [and]... highlights the relevance of earth science to modern New Zealand society, to our economy, and to environmental conservation.'

Allen Petrey
Editor

Sommer, J. 2010. 2008 Survey of New Zealand scientists and technologists. *New Zealand Science Review* 67(1). 40pp.

President's column

It's election year, and as I write this, the general election is only two months away. While there is much happening politically, one area seems strangely quiet. For the past few months, NZAS has been canvassing the political parties to learn about their science policies, with the goal of placing science policy documents on the NZAS website for members' information, comment and discussion. Almost none of the main political parties has had anything to say. The one exception is the Green Party, who came back to us with a detailed policy statement. The best any of the other parties has managed is a 'watch this space' or a 'here's what we said last time' message. This does not fill me with confidence that the idea of a knowledge economy, or investment in science and technology for economic growth, is really taken seriously at a political level in New Zealand. At least the Greens seem to be gaining in the polls! The upcoming NZ Institute of Agricultural and Horticultural Sciences Political Forum at Te Papa (4 October) is very welcome and may provide some insights, or at least some information.

Science funding has been in the spotlight again lately, around funding for postdoctoral positions in New Zealand and the scrapping of the FRST postdoctoral scheme in favour of the Rutherford Discovery Fellowships, which are aimed more at mid-career scientists. Melanie Massaro from Canterbury University garnered a huge amount of support in a short time (well over 500 signatories) for an open letter to the Royal Society and the Minister pointing out the dearth of opportunities in New Zealand for young post-PhD researchers.¹ The letter generated a very quick response, with the Ministry of Science and Invention announcing that a planned review of the Rutherford Discovery scheme was being brought forward (time frame yet to be announced). The Rutherford scheme itself is great, and the now-defunct FRST postdoctoral scheme was extremely valuable, too. It would be nice to see funding go into both stages of the science career structure, rather than have the usual situation of one or the other.

Things do not seem especially brighter in Australia. A recent report from the University of Melbourne² shows that more than one-third of younger scientists in Australia are planning to leave science in the next few years. The main reasons given were 'poor job security, a lack of research funding, low pay and endless red tape'. Most of the 5500+ polled were passionate and excited about the scientific research they were doing, but worn down and disappointed by 'the system'. Sounds familiar, and strongly echoes research done in New Zealand over the past few years by Lesley Hunt at Lincoln University. She found³ that while many Crown research institute (CRI) scientists felt a real commitment to their science, they felt very little commitment to their CRI and were 'doing science despite the system'.

All of this seems to me a symptom of changing times, and the huge economic imperatives on many aspects of society, imperatives that are much stronger than they were a generation ago. Science is a strange beast, capable of generating immense economic gains and improvements in the lot of humanity (indeed, *all* of modern society rests on the science and technology of the past century and more), yet science is a pursuit that cannot easily be measured in economic terms and that withers under a system of rational economic accountability and justification. Which is not to say that the science community should be granted unlimited funds from a grateful public to do whatever we please. Rather, a light hand in science management and genuine breathing space for serendipity to work its magic will bring more benefit to New Zealand than another round of science advisory boards and yet more funding structures with a short-term focus.

Now on to the good news! The modernised NZAS website (www.scientists.org.nz) is going from strength to strength. It has a great facility for discussion and news, commentary and general bloggy interaction. Have a look, if you haven't already, and post something – your latest work, reflections, questions, commentary, and responses to others. We hope that the website will prove useful for discussion around the general election and science policy – if only we had something to discuss (see above).

The NZAS annual awards ceremony is coming up fast. This year's event will be held on Thursday 10 November at Turnbull House in Wellington, and will see the presentation of the Marsden, Shorland, and Research Medals, and the Science Communicator Award. NZAS is having to think hard about the role and future of the Awards, in the changing science landscape – your thoughts on this topic are welcome, via the website or by e-mail. Following the Awards night, the Association AGM will be held on Wednesday 23 November, at the Thistle Inn in Wellington. Come along to the meeting, and have a drink or a meal while you're there.

James Renwick
President, NZAS

¹ See <http://www.scientists.org.nz/news/2011/09/disappearing-post-docs>

² <http://theconversation.edu.au/talkin-bout-my-generation-young-academics-on-why-so-many-eye-uni-exit-3476>

³ Hunt, Lesley 2009. Doing science in a culture of accountability: Compliance through resistance to alienation and estrangement. *Kouitui, New Zealand Journal of Social Sciences Online* 4(1): 25–40.

Teaching, learning, and assessment of science investigation in Year 11: Teachers' response to NCEA

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In New Zealand, the school science curriculum promotes open-ended science investigation, but the assessment regime in year 11 requires investigation with 'direction' and a more limited understanding of investigation. This case study research explored teaching practice and teacher understanding of science investigation, and the connectedness between learning, motivation to learn, and assessment. This paper presents the findings on teacher practice related to the teaching and assessment of science investigation. The results indicate that teacher practice of science investigation changed in response to the internal assessment requirements associated with science investigation for the National Certificate of Educational Achievement (NCEA). The nature of this change raises validity and reliability issues for the assessment of student learning of science investigation.

Introduction

Learning in scientific investigation is an important goal of science education, alongside the acquisition of scientific knowledge, understanding, and practice (Kanari & Millar 2004). The practical aspect of the subject has had a distinct and central role in science curricula internationally. Science educators have argued that there are benefits in engaging students in practical activities in science (Abrahams 2011; Hofstein 2004; Hofstein *et al.* 2008; Lunetta 1998; Tytler 2007; Woolnough 1991; Wellington 2005) and suggest that by carrying out an investigation students learn the related science concepts and understand better the nature of science (Hodson 1990; Roberts & Gott 2006).

Woolnough (1991) argued that scientific investigation promotes a holistic approach to learning science through the linking of scientific concepts to the process and outcomes of an investigation. In the view of Patrick & Yoon (2004), students gain most from science investigation when they 'discuss expecta-

tations, observations, conclusions, theories, and explanations before, during, and after conducting the activity' (p. 319). Millar (2004), in agreement with this view, argued that student learning in relation to science investigation needs to be seen as a recursive process rather than a constrained procedure. The notion of a recursive process was also clearly promoted in *Science in the New Zealand Curriculum* (Ministry of Education 1993):

The processes of investigation are not sequential. The process may begin at any point ... will tend to move backwards and forwards. Students should be reflecting on their decisions, actions, and findings and modifying their plans and actions as they are proceeding. (p. 47)

In New Zealand, Achievement Standard Science AS1.1 defines investigation as:

...an activity covering the complete process: planning, collecting and processing data, interpreting, and reporting on the investigation. It will involve the student in the collection of primary data. (New Zealand Qualifications Authority 2005, p. 3)

Investigation, as mandated by the New Zealand science curriculum, promotes a recursive process where the students consider and modify their plans as the investigation proceeds. However, the assessment process related to AS1.1 effectively requires a linear and sequential process because of its focus on one 'fair testing' type of investigation in which students control a single variable. In a New Zealand case study of science investigation, Hume & Coll (2008) concluded that students in year 11 were acquiring a narrow view of science investigation as fair testing, and that although learning was taking place, students' responses demonstrated rote learning and low-level thinking. A related concern was raised by Allen (2008), who argued that an investigation needs to be challenging for the student. If the

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activity is too simple or the answer is known in advance, there is little intellectual challenge left in the activity. The student then focuses on getting the right answer rather than carrying out a scientific investigation.

In a British study, Cleaves & Toplis (2007) researched students' views of learning and assessment of science investigation and reported that students considered that their teachers trained them to do investigation. Students said that the teachers told them 'this is what you have to do' (p. 92) and 'this is what you need to write' (p. 92) to get a good mark. Additionally, students said they were taught to repeat data collection; they knew that they had to do this but did not understand why. Students also said they learnt to comment about anomalous results; they considered that it was good to have anomalous results because if they could explain them they would gain a better grade. Cleaves & Toplis (2007) reported that students develop a view that investigation is a part of science that they have to learn in order to get marks, rather than a view that science is 'predicated upon investigation' (p. 92).

Assessment theory

The two main guiding principles that underpin assessment are validity and reliability (Hall 2007). As noted by Hall (2007, p. 6):

Validity focuses on 'fitness for purpose'. A valid assessment task is one that fulfils its intended purpose(s), such as fairly testing the course objectives and content, fostering student learning, and motivating further interest in the subject.

However, within the context of school science at the senior secondary level there are at least three key elements that need to be considered in judging the validity of the assessment of science investigation. Firstly, the intent and requirements of the New Zealand Science Curriculum need to be understood and interpreted appropriately by everyone involved in teaching and assessing science investigation. Secondly, the translation of the curriculum into the relevant National Certificate in Educational Achievement (NCEA) standards (AS1.1 for year 11) requires close scrutiny to see how well the standards maintain the integrity of the curriculum. Thirdly, the actual assessment tasks that are undertaken by students need to match well the intent of the relevant assessment standards and the curriculum from which the standards are derived. The literature reviewed in this section suggests that there are question marks surrounding all three elements. The present research looks at assessment practice for AS1.1 to uncover more fully what problems exist and the implications of these for future teaching and assessment practice.

In addition to validity, assessments need to be reliable. As noted by Hall (2007, p. 7):

Whereas validity focuses on 'fitness for purpose', reliability refers to the extent to which the assessment provides an accurate measurement of each student's understanding or learning'.

The point to note is that an assessment may appear to be valid because the material being tested focuses on important knowledge and skills. However, the results may not be reliable because the measurements fail to capture students' learning accurately, as may happen if tasks contain ambiguities, or markers interpret and apply criteria differently, or students behave inconsistently

(e.g. misinterpret a question or are influenced by factors related to health or emotional state). In general, reliability is commonly evaluated through evidence of the consistency and stability of results across assessors and over time (Harlen 2005). In relation to science investigations, students' performance can differ from one investigation to another depending on the content, complexity and openness of task, the processes used to observe and record students' performances, the consistency of markers in applying criteria, and factors related to the context of the assessment such as the teaching approach taken by teachers.

The relationship between validity and reliability is well demonstrated by Roberts & Gott (2003) commenting on Sc1, a similar assessment requirement in the UK to Achievement Standard AS1.1. They suggested that a validity issue arises where an assessment involves the observation by a single teacher of a large number of students carrying out a practical investigation. They noted that complex tasks could take two to four hours to perform, typically resulting in few investigations being carried out:

Sc1 has become routine, with a limited number of cases assessed. In some instances, Sc1 coursework has become so formulaic that performance is more akin to the recall of a complex protocol than the creative solution of a problem. (p. 104)

In other words what is being assessed is not actually what was intended to be assessed. In Gott & Duggan's (2002) view, to get a valid indication of a student's ability to carry out an investigation, results over a number of assessments (covering different types of tasks) would need to be combined. The point to note is that such a procedure might also improve the reliability of the results because it is based on several assessments of science investigation, enabling a more stable judgment to be obtained.

An important factor noted, or at least implied, in some of the literature reviewed in this section, is that the assessment of science investigation, because of its 'high stakes' nature, influences the teaching approach adopted in schools (this is often referred to as the 'backwash' effect of assessment). The risk that exists is that teachers 'train' their students to pass the assessment, thereby losing focus of the important understandings that students need to engage with (such as the relationship of science investigation to science knowledge more widely and the role of problem-solving in discovering or applying science knowledge). There is no denying that assessment has an important place in teaching and learning in school science. What is debatable is whether teaching to the test or task is a desirable outcome of an assessment system. The research of Cleaves & Toplis (2007) in the UK and Hume & Colls (2009) in New Zealand indicates that this approach is commonly adopted.

The New Zealand Science Curriculum (Ministry of Education 1993) promotes open-ended science investigation, where students have control over defining a problem, choosing the method, and arriving at solutions (Simon *et al.* 1992), but the assessment regime in year 11 requires investigation with direction, which is likely to be associated with a more limited understanding of investigation.

This paper reports research that studied teachers' response to this contradictory situation by investigating how year 11 science teachers practise science investigation. It was part of a larger

project that looked at the phenomenon of science investigation focusing on the key elements of motivation to learn, learning, and assessment (Moeed 2010).

Methodology

The research reported here adopted case study methodology, drawing on qualitative data to study the phenomenon of 'science investigation'. The intention was to understand investigation through those who practise it in their unique contexts and through the interactions that take place in that setting (Merriam 1998). The research involved a critique of the *National Curriculum Framework* and *Science in the New Zealand Curriculum*, a regional survey of year 11 science teachers, interviews with year 11 science teachers, and an in-depth study of one science class (see Figure 1).

Teacher survey

An anonymous postal survey was administered to year 11 science teachers in the Wellington region; 101 teachers completed the survey, representing a 61% response rate. Participants in the survey were drawn from coeducational schools (64%), boys' schools (17%), and girls' schools (19%). The teaching experience of participants varied – 40% had fewer than five years' experience, 14% between 6 and 10 years, 17% between 11 and 15 years, and 29% had 16 years or more. One respondent did not indicate teaching experience. Forty-six percent of participants were drawn from high socio-economic communities (deciles 8–10), 33% from middle socio-economic communities (deciles 4–7), and 21% from low socio-economic communities (deciles 1–3). Fifty percent of participants came from large schools (student numbers 800+), 32% from medium-sized schools

(500–799 students), and 19% from small schools (fewer than 500 students). Sixty-one teachers were female and 40 male.

The main survey themes relevant to the data reported here focused on:

- teacher practice of teaching science investigation
- change in teaching of science investigation since internal assessment for NCEA
- reasons for any change in practice
- preparing students for assessment including formative assessment
- the procedure for assessment of science investigation.

Teacher interviews

All ten teachers who taught a year 11 science class in a typical coeducational, medium-sized school situated in a middle socio-economic community were interviewed through a semi-structured interview. The main question themes were:

- teachers' views about teaching and learning science investigation
- teachers' approach to assessment
- change in the teaching of science investigation since internal assessment for NCEA
- the approach for assessment of science investigation for AS1.1.

Full details of the postal survey and the teacher interviews are provided in Moeed (2010).

Results

The regional survey results, and study school science teacher interviews showed that year 11 science teachers focused on training their students to undertake the fair testing type of investigation in preparation for internal assessment of science investigation. The approaches the regional teachers said they used included 'repetition', 'doing tasks similar to those assessed' and 'practising fair testing'. This approach was also adopted by the study school science teachers, who said they were 'training' their students to investigate and 'getting them to go through the hoops'. Some of these teachers reported an emphasis on students learning the skills needed to investigate. Thus procedural knowledge rather than procedural understanding and conceptual learning were deemed appropriate preparation for AS1.1.

Science teachers in the study school said that the teaching approach they took was contrary to how they would ideally teach science investigation but in the interest of students' achievement. Teaching 'what would be assessed was seen as a pragmatic solution to the dilemma they faced – there was little choice given the assessment regime in place. The training approach to teaching investigation was reinforced by teachers constantly using the template designed for AS1.1.

Teacher survey

Teachers were asked to indicate if they had taught science before the introduction of the NCEA and whether their practice of teaching science investigation had changed since its introduction

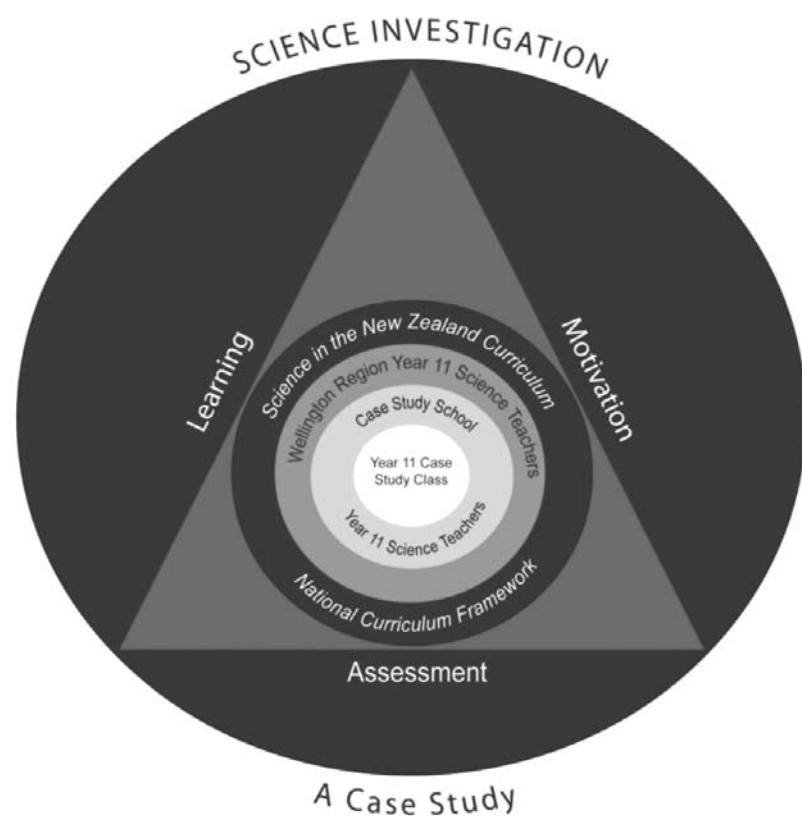


Figure 1. The case study of science investigation in year 11 science.

and, if so, to explain in what way. Sixty-six respondents (65%) had taught year 11 science before the introduction of NCEA. Fifty-five (83%) of these reported a change in their practice of teaching science investigation after its introduction. Eight of these 55 teachers reported doing more science investigations, 22 the same number, and 25 fewer.

Change in practice

Teachers provided multiple ways in which their practice had changed in relation to investigation and assessment. Investigation-related changes made up 66% of the responses. These included teachers saying that they did more complete investigations (31% of responses), and that the investigation had become compartmentalised (13% of responses). Twenty percent of the responses were assessment-related, a typical response being:

Investigations become an exercise in fulfilling criteria for credits. (Teacher 036)

A further 11% of responses recorded that teachers did more holistic investigation. One teacher said:

The process of doing a complete investigation can take up to three lessons. Kids do the planning task in one lesson and then wait to do the investigation (gather data) in the next lesson and then I either get them to write the report for home work or it has to be done in the next lesson. Sometimes they forget what they had done the last time. To me this complete investigation feels like more compartmentalised than complete. (Teacher 073)

A small number expressed concern that teachers were doing fewer student-initiated investigations. Although this was a very small percentage (6%), it is important as open-ended investigation is student-initiated and usually based on something that the student wants to find out.

Some teachers indicated that their practice included teaching the students the language required to get a particular grade:

Emphasis on small things, in other words do these things and you will get an A [Achieved], M [Merit] or E [Excellence]. (Teacher 069)

Concern was also expressed that there was less time available to do other practical activities.

The reasons for change in practice were coded under the five categories: learning; assessment; less time; student motivation; and future use. Reasons coded as learning included responses such as 'students need to learn to investigate in science because it is a practical subject' (Teacher 016). Assessment reasons offered included 'they need it because it will be assessed' (Teacher 023) or 'for achieving in AS1.1' (Teacher 032 & Teacher 079). Teachers who said there was less time to do investigation gave reasons such as 'each investigation takes several lessons to complete so there is less time for investigations' (Teacher 082). Some teachers said they did investigation as 'students like doing them', 'enjoy them' or they are 'more motivated when doing investigations' (Teacher 093). A few teachers reported reasons such as 'students need to know how to investigate for science in senior school' (Teacher 056).

Teachers who had taught more investigations since the introduction of the NCEA were concerned with assessment and student learning, but also said they had less time than before.

Those teachers who were doing the same number of investigations as they did before the NCEA had similar concerns about time; however, they stated that doing science investigation had motivational benefits (although these teachers did the same number of investigations, they said that how they taught investigation had changed). The teachers who were doing fewer science investigations were concerned about assessment and the lack of time but offered motivational reasons for not doing them (Table 1).

Table 1. Reasons given for change in practice in teaching science investigation after NCEA was introduced.*

Reason for change	Percentages for the responses by teachers who conducted, after NCEA was introduced:		
	More investigations	The same number of investigations	Fewer investigations
Learning	37	21	4
Assessment	42	41	50
Less time	21	18	40
Student motivation	0	15	6
Future use	0	5	0

* It should be noted that many teachers supplied more than one reason. The percentages are based on the number of responses made by each group, not the number of respondents.

Meeting assessment requirements was the most frequent reason given for change in the number of science investigations, whether the teachers were doing more, the same, or fewer than they had before the introduction of NCEA. The next factor was having less time. It is noteworthy that those doing more investigations considered enhancing student learning as the second most important reason. Learning becomes less important for those doing the same number of investigations but becomes still less when teachers choose to do fewer investigations.

More than a quarter of the responses (28%) indicated that teachers prepared their students for AS1.1 by doing tasks similar to those used for assessment and using the template from the Ministry of Education website, Te Kete Ipurangi (TKI).¹ Another quarter of the responses indicated that teachers used fair testing type tasks. Only 16% of responses recorded that teachers used formative assessment and gave students feedback as to how they could improve. Other responses indicated that they prepared their students by teaching them the skills of planning, interpreting and processing information, and reporting. Some indicated that they started preparing students from year 9 and familiarising them with the terminology used for AS1.1 (Table 2).

Separately from the data collected for Table 2, 78% of teachers carried out practice assessments in the form of a 'mock examination' or 'trial run'. Their reasons for doing these assessments were to prepare students and familiarise them with the assessment context, enhance investigative skills, and provide feedback to improve their performance. Some teachers indicated that through such assessments they could identify and address students' alternative conceptions. In their view, these assess-

¹ Te Kete Ipurangi (2005). Watch that car go. Retrieved 8 March 2010 from http://www.tki.org.nz/e/search/results.php?1%3Aelem=DC.Subject.Classification&1%3Aval=NCEA%3BNCEA%20Science&1%3Avalop=AND&1%3Asearchtype=term&2%3Aelem=TKI.Level&2%3Aval=NCEA+Level+1&2%3Avalop=AND&2%3Asearchtype=term&xsl_lang=en&xsl_path=/search/results_e.php

Table 2. Teachers' reported student preparation for AS1.1 (97 teachers made 189 responses).

Student preparation	Teacher responses	
	Number	Percentage
Doing tasks similar to those assessed	53	28
Practise fair testing	47	25
Formative assessment and giving feedback	30	16
By teaching skills needed for investigation	22	11
Start preparing students from year 9	18	10
Teach the science concepts	17	9
Do lots of practical work	2	1

ments increased student motivation and confidence. Since these trial tests represent a way of providing formative feedback to students, the relatively low figure for 'Formative assessment and giving feedback' in Table 2 (16%) should be seen as a response to a particular question about student preparation and not a figure about all forms of formative assessment.

Teachers saw disadvantages for themselves from carrying out formative assessments in terms of the workload associated with the preparation and marking (38% of responses). Some teachers (19% of responses) were concerned about the ethical issues in giving students too much help through formative assessment. Some saw assessment as demotivational if the task was too difficult.

Teacher interviews

When talking about the goals for student learning through investigation, all teachers ($n = 10$) focused on the fair testing type of investigation that is assessed in AS1.1. Overall, the goal was to teach a 'fair testing type of investigation' and foster the associated learning skills; however, concern was expressed that students were doing investigation for which they already knew the answer.

Teachers ($n = 10$) said that students learn the process skills of planning, gathering information, processing and interpreting information, and reporting findings, which are those identified in the assessment guide for AS1.1. Four teachers mentioned that they taught what students need to write in order to get an Achieved, Merit, or Excellence grade. Two teachers said they wanted the students to know that science is real and that we investigate all the time.

None of the teachers interviewed were satisfied with the process followed for the assessment of AS1.1 (following the requirement of fair testing, controlling variables and following steps to get to an answer already known). Their reasons were different but each expressed a genuine concern for their students which was obvious during the interview. They were 'despondent', 'upset', 'not impressed', 'uneasy', questioned the 'fairness', and 'pragmatic' – saying 'this assessment had to be done'.

All teachers said they taught students to investigate based on the requirements for AS1.1. All teachers gave students the opportunity to do at least one formative assessment (trial run), which was the school's science department's policy and was very similar to the task students were going to be assessed on.

One teacher explained that if the task for formative assessment was not sufficiently similar to the one used for AS1.1, most students would struggle and require a lot of help from the teacher. In his view, he was giving the students 'too much help'

for AS1.1. However, as the school was now using the format required for AS1.1 in years 9 and 10 (a simplified AS1.1 template), he felt that this could change the practice of having to teach to the AS1.1 assessment.

Change in practice

Only half of the teachers interviewed had taught before the introduction of the NCEA and so only those teachers could comment on this aspect, and all five said that their practice had changed, by:

- focusing on fair testing type of investigation
- teaching students to use the template for the assessment of AS1.1. One teacher prepared students to write their answers in the right place in the template
- using a learning task almost identical to the assessed task
- using the procedure required for assessment
- putting all learning tasks in the NCEA format
- doing formative assessment as a trial run and providing feedback about what to write to improve the grades.

Raising her concern, one teacher said, 'the requirement to do and write in a particular way is leading to the template approach in writing up the investigation'. Another concern was that of the subject context in which the assessment was carried out. Teachers had taught students how to investigate when they were teaching the same subject as the one in which students would be assessed (e.g. in physics). However, when it came to the actual assessment for AS1.1, more than half the teachers ($n = 7$) were teaching another topic and students were disadvantaged because the assessment was out of context. One teacher said:

I was teaching chemistry at this point but this college runs AS1.1 in the exam week, so I was teaching chemistry and somebody else is teaching physics and somebody else is teaching biology and the context of the assessment is a physics one. We are assessing out of context. It is not fair to my students.

All teachers said that once the assessment was over they did not give investigation the same amount of time (i.e. three lessons). Teachers ($n = 8$) said they asked students to investigate and just write the plan and results. Others ($n = 2$) said that they still insisted on fair testing and looking at the reliability of the data. Two teachers said that once the assessment was done, students were just not interested in doing practical work so they put the time into preparing for the examination. One commented:

To be perfectly honest we lead up a lot to that and then after that I'm still very insistent on reliability and fair testing, but things kind of start to flag a bit after that.

Discussion

Investigation in practice: Fair testing

The regional survey results and study school science teacher interviews showed that year 11 science teachers focused on training their students to undertake the fair testing type of investigation in preparation for internal assessment of science investigation. The approaches used by the teachers in the regional survey included 'repetition', 'doing tasks similar to those assessed', and 'practising fair testing'. This approach was also taken by the study school science teachers. Some of these teachers reported an emphasis on students learning the skills needed

to investigate. It would appear that procedural knowledge rather than procedural understanding and conceptual learning were deemed appropriate preparation for AS1.1.

Science teachers in the study school said that the approach they adopted to teaching science investigation was contrary to how they would ideally teach this curriculum area but in the interest of students' achievement and because students had to be assessed, teachers were pragmatic and continued to teach 'what would be assessed'. A view was that there was no choice. This training approach was reinforced by constantly using the template designed for AS1.1.

Regionally, and in the study school, more fair testing investigations were carried out when teaching physics or chemistry topics than biology or astronomy topics. According to Tytler (2007), such an imbalance occurs because it is easier to control variables in physics and chemistry. Evidence from this study suggests that in a fair testing investigation as practised in year 11, the design aspects of scientific investigation (planning) were reduced to the notion of variable control, where the student was making a comparison between two options and controlling variables to test a hypothesis. In the view of both Lunetta *et al.* (2007) and Tytler (2007), investigating in mainly physics and chemistry contexts is problematic, as potentially it could lead to students thinking that investigation is only done in these subjects.

A particularly influential factor for the focus of science teachers on fair testing is that the assessed investigation for NCEA Level 1 is a fair testing type of investigation. Although other types of investigation, including pattern seeking, classifying and exploration, are included in the curriculum, they are not specifically assessed in NCEA, which raises the issue that if other types of investigation are not formally assessed, they are less likely to be taught. More importantly, if students mostly experience fair testing they are likely to have a limited view of science investigation (Hume & Coll 2008).

Some teachers in the study school said that prior to the assessment of investigation they stopped the biology topic they were teaching and gave students practice through doing formative assessment (a mock examination) in a physics context that was very similar to the assessed task. The teachers then provided feedback to the students on how they could improve. This they justified by saying that they were ensuring their students were not disadvantaged because they were doing a biology topic whereas the assessment was set in a physics context.

Training for assessment involved an emphasis on what the students needed to write to achieve a particular grade, a practice noted also in the study by Cleaves & Toplis (2007). NCEA grades require a student to be able to describe their investigation to get an Achieved grade, explain their answer to get a Merit grade, and discuss their results to get an Excellence grade.

In Abrahams & Millar's (2008) view and according to research findings by Roberts (2009), both conceptual and procedural understandings are needed to carry out science investigation. Instead of developing these two kinds of understandings, students in this study were trained to perform in a way that matched the narrow focus encouraged by the NCEA assessment requirements for science investigation.

Changes in teaching practice after the introduction of NCEA

Teaching of science investigation for year 11 changed after the introduction of the assessment of practical investigation for NCEA Level 1. Of the region's year 11 science teachers who had taught before the introduction of the NCEA, 83% reported a change in their practice of teaching science investigation after the introduction of the NCEA.

Some regional teachers reported that since the introduction of the NCEA, they had changed the number of investigations they did in year 11 science. Teachers offered several reasons for the change in practice. Whether they did more, the same, or fewer investigations, the main reason offered for the change in practice was the need to meet the assessment requirements; concerns related to student learning were much less a factor. Another reason given was that complete investigation, a requirement of the assessment, was time consuming and took up to three lessons.

In the study school, a major change in practice following the introduction of the NCEA was the greater time devoted to teaching fair testing types of investigation in the first half of the school year as build-up to AS1.1. In the second half of the school year, after assessment, teachers said they reverted back to their pre-2002 practice of committing less time to fair testing and more time to other types of investigation and practical activities.

Study school teachers highlighted two related changes in practice. Firstly, they emphasised that students should learn the vocabulary required for AS1.1, for example 'independent' and 'dependent' variable and the 'reliability of data'. These are crucial ideas for understanding science investigation but the focus was more on learning the vocabulary rather than ensuring a deep understanding of the ideas. Wellington (2005) refers to the need for students to build the bridge between 'knowledge that' (observed phenomenon), 'knowledge what' (remembering facts) and 'knowing why' (understanding the reason for phenomenon occurring) (p. 107). In this instance, students learnt that they needed to repeat the trial several times but did not know why they should be doing so.

The second change to practice by teachers as a response to pressure to improve student performance, was training the students to become familiar with the template used for AS1.1. In the study school a simplified template was developed for use in year 9. One limitation of this template approach for learning investigation is that it was designed for fair testing types of investigation.

A noteworthy current assessment practice for over 75% of the region's teachers, and all of the school case study teachers, was to carry out formative assessment in the form of a mock examination or trial run, a practice also observed in the study class. Teachers said they saw advantages and disadvantages in using formative assessment of this kind. They reported that students valued the feedback that would help them to improve their performance. Teachers saw this as outweighing the disadvantages of workload, marking, administration, and management because it was helpful to students. Formative assessment in the form of a mock examination also helped teachers determine if

the intended learning outcomes were met. Teachers said that they gave feedback to students about what they could do to get an Achieved, Merit, or Excellence grade. Formative assessment, as applied by these teachers, was different from that described by Bell (2005) and Bell & Cowie (1999); these researchers stressed the importance of assessment 'during learning' that 'relies on teachers developing in their pupils an orientation towards learning as distinct from performance' (Cowie 2005, p. 3).

Reliability and validity issues with assessment of investigation

Reliability focuses on the accuracy or consistency of results across assessors and over time (Harlen 2005). For assessment of investigation, high reliability 'would entail students getting the same results all the time irrespective of when the assessment is carried out and who marks it' (Harlen, p. 246). Training the students to achieve in assessment may enable students to rewrite the same answers and get the same result if the same assessment task is used under the same conditions. Clearly, this would not be an appropriate indicator of student understanding of science investigation because it does not test students' understanding and behaviour on a range of different investigation tasks; such an approach might well produce high estimates of reliability (because of the consistencies built into the process) but the approach compromises validity. Some teachers in the study school said that even though a student may get an Achieved grade for AS1.1, they could not say if that student was capable of achieving it in a similar assessment. Validity can be increased by combining five to ten assessments of investigation from different contexts and by using a template and tightening the criteria (Gott & Duggan 2002). The high level of student achievement in AS1.1 in the study school and nationally (both 83%) suggests that the assessment task was comparatively easy for students in year 11. Another explanation could be that it was poorly implemented because students were trained and given too much direction.

Although the criteria have been tightened, the implementation, it appears, does not reflect this change for the most commonly used tasks for AS1.1. Both the task and marking schedule are available on TKI and are easily accessible to students. According to the New Zealand Qualifications Authority statistics, the same tasks have been used nationally for over eight years. Potentially, students can find out what the task is and prepare for it and write the expected answers indicated in the marking schedule to get an Achieved, Merit, or Excellence grade. In the study school, where assessment took place in three lessons spread over two weeks, students had ample time to find out specific information required and use it in their report before marking and feedback had occurred.

The assessment of science investigation as required by NCEA and implemented in the study school has had negative side-effects, including: encouraging a surface approach to learning; providing a narrow focus on fair testing types of investigation; teachers giving students training to perform in such an investigation; and teachers' narrow use of formative assessment and feedback. These negative side-effects highlight issues of consequential validity. The assessment of investigation as prescribed and implemented may be doing harm and is therefore open to challenge in terms of consequential validity (Crooks 1993, cited in Hall 2007).

It is clear that much of the preceding commentary on the validity and reliability of the science fair test investigation draws as much on themes in the relevant literature as on the data gathered here. What can be fairly said is that when constructed carefully, administered appropriately, and interpreted properly, assessment of science investigation provides an in-depth window into how students apply their knowledge and skills to carry out an investigation (Harlen 2005). The NCEA requirement of assessment of a single fair testing type of investigation using a tightly structured task is likely to have increased reliability because of the consistencies built into the teaching and assessment; however, constraints are clearly placed on validity because of the narrowness of what is assessed.

Conclusion and Implications

Year 11 science teachers changed their practice of teaching science investigation in response to the requirement of NCEA internal assessment of science investigation. Teachers mostly taught fair testing type of science investigation that was linear and sequential as required for assessment rather than teaching a variety of science investigations as required by the curriculum. They prepared their students through repetition, teaching the language required for assessment, and providing one opportunity for a trial run to give student feedback on how to improve their grades. The use of a template is likely to have made the assessment more reliable. This change in teacher practice has consequences for student learning of science investigation. Continuation of such practice is likely to result in students seeing science investigation as learning what they have to do to get a particular grade rather than developing an understanding that science is predicated upon investigation.

Acknowledgement

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Sustainable economic growth for New Zealand: An optimistic myth-busting perspective

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Long-term vision is something we tend to avoid in New Zealand, with the possible exception of Māori, who have greater reason to focus on the development of their assets for future generations of mokopuna. But I will argue here that vision is essential to any strategy aimed at enhancing prosperity. It is my belief that we are poor because we choose to be poor, and that what holds us back are self-serving but dishonest myths.

The first myth is that we are an egalitarian society, a great place to bring up children. However, in income disparity, child mortality, imprisonment rates, and most other negative social indicators, we are among the worst in the OECD. The second myth is that we are clean and green. In truth, the reality is altogether different. Like other developed countries we have despoiled our environment to eke out a measure of prosperity, and we therefore have no moral high ground from which to preach to others. Our valuable dairy industry severely impacts our rivers and lakes. Our pastoral industries are significant emitters of greenhouse gases. The third myth is that we, as New Zealanders, do not need prosperity, that we have 'lifestyle' instead. However, we complain that our health system

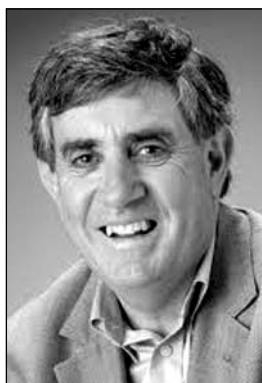
cannot afford to meet our needs and that our infrastructure is decrepit, and now we face significant economic stress following the Christchurch earthquake. Furthermore, the 'lifestyle' argument is hard to sustain, given that, although New Zealanders are the second hardest working in the OECD, when we look at how hard we work against how productive we are, compared with other OECD countries, we see that New Zealanders are amongst the least productive.

Fifty years ago more Australians migrated to New Zealand than *vice versa*, and the New Zealand dollar was much stronger than Australia's. Now Australia is 35 per cent richer than New Zealand, representing a \$40 billion per annum GDP shortfall for us. Let me illustrate that in a different way. There are 1.3 million FTE of jobs in New Zealand. In order to maintain our current per capita GDP we need a revenue per job of \$125,000. In order to match Australia we need around \$170,000. Tourism brings in around \$80,000 per job, and while usefully employing unskilled New Zealanders, it cannot provide a route to prosperity. By contrast the dairy industry brings in around \$350,000 a job. The problem with dairy is that environmental limitations prevent us from scaling it up at all, let alone by the factor of 5 or 6 we need to make up the \$40 billion per annum shortfall.

Interestingly, our largest export-earning sector is manufacturing (contradicting yet another New Zealand myth that everything is 'made in China'). At around \$250,000

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a job on average, these businesses thrive by producing goods that have a high profit margin and a high ratio of value to weight. The key to this kind of manufacturing is knowledge content, and that in turn is driven by investment in research and development (R&D). The poster child of such business is Fisher and Paykel Healthcare, with a \$500 million per annum of exports. If we had 100 such companies, our prosperity would be assured, and in a manner which is entirely sustainable. Such businesses generate no greenhouse gases, do not require land or energy, and do not dump nitrates in our streams. Out in the larger global economies, there are even more startling examples of sustainable businesses which are highly productive. Apple Inc earns around \$2,000,000 per job, while Google and Samsung earn around \$1,400,000.

The engine of such an economy is the pipeline of small and medium enterprises that have the potential to grow through investment in R&D. Herein lies New Zealand's failure to understand what drives real prosperity in the outside world. We have been stuck at a public funds investment in R&D of only 0.5 per cent of our GDP for decades, regardless of which party is in power. This is way behind our competitors. As an excuse, governments argue that industry investment is even less, but in my view, that simply reflects the existing bias towards low R&D business in our national business profile. For example, the food industry world-wide typically invests 0.5 per cent of revenue in R&D while the pharmaceutical industry invests 90 per cent. Our second failure arises from false analysis concerning a need to specialise. It is argued that because we are small, we must specialise by playing on our strengths. In the 1990s, a belief that we needed to build on our biological industries strength led to a disproportionate investment in biotechnology, for very little beneficial outcome. Out of our top 100 companies in 2010, only two are in biotech. Now politicians tout cleantech or smart foods.

The obvious and the politically fashionable products will undoubtedly be addressed by much bigger players than New Zealand in the world economy. The evidence shows that we will be good at what we are good at, and we need to be prepared for the fact that we are good at some unusual and unpredictable stuff. Where we will be successful is in the technology niches. Because we are only 0.2 per cent of the world's economy, we are subject to a 500 times multiplier which can make such niches highly profitable bases for businesses which are large on the New Zealand scale. Fisher and Paykel Healthcare dominate the world market for respiratory humidifiers. Rakon are world-class players in crystal-controlled oscillators. If we can, as we do now, have 10 such companies exporting between them nearly \$4 billion per annum, why not 100? Indeed, we have grown such companies despite a complete lack of awareness by the New Zealand public that we can do this sort of thing. These businesses are essentially invisible. They do not sell in New Zealand, but internationally. They do not sponsor the ballet or children's soccer. They make weird products that our kids and their parents do not understand.

We have it in our power to change all that. We have an excellent education system, as good as the Danes or Swedes. If we care for our environment and create a just, equitable and creative society, a 'place where talent wants to live', we can attract the best in the world, and provide opportunity for our most talented Kiwis to see their future here. Imagine what we could achieve if we built a strategy around, and made central to our thinking, the existing success of our emerging knowledge sector, gearing our education system accordingly. One hundred inspired New Zealand entrepreneurs can turn this country around. That is the challenge for us all.

Bioscientists in the 2008 Survey of New Zealand Scientists and Technologists

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Our paper explores differences and similarities of New Zealand bioscientists relative to the larger science community both in terms of their attributes and their opinions on some important issues. The most recent Survey of New Zealand Scientists and Technologists, from which data for this paper were extracted, will serve as a rough guide to a greater understanding of issues that engage the scientific community generally and bioscientists in particular (Sommer 2010). Such understanding will contribute to the advancement of a bio-based economy. The analysis demonstrates specialised capabilities of the New Zealand survey not previously developed.

We comment first on the origins and purpose of the 2008 Survey and then reveal some of the distinguishing attributes and opinions of bioscientists compared to all other scientists. There are some important messages in this analysis for both public policy and private action. There are also some conundrums to contemplate.

Origins

The 2008 Survey was organised and conducted by Sommer with invaluable support from a distinguished Technical Advisory Group made up of New Zealand scientists from universities, Crown research institutes, MoRST, and scientific societies. Principal sponsorship for the survey was provided by the New Zealand Association of Scientists and was supplemented by the Royal Society of New Zealand and MoRST. Although completed in late 2008, the report was released in early 2010 as a special issue of the *New Zealand Science Review* (Sommer 2010).

Sommer's direction of major surveys of US scientists in 1986 and 1988 (Sommer & Seltzer 1988) laid the foundation for the 1996 Survey of New Zealand Scientists and Technologists (Sommer & Sommer 1997). A more limited survey of New Zealand scientists conducted by the NZAS in 1994 (Berridge 1995) provided valuable insights for the 1996 Survey. With this

background, the 2008 Survey was developed and carried out via email in the last quarter of 2008. More than half of the 76 questions asked in 1996 were repeated in 2008, and 22 questions carried over from the 1988 survey serve as background for international comparison.

Fields of science

The 2008 survey is a 1 in 6 random sample of nearly six thousand New Zealand scientists, 80% of whom had attained a doctorate and 17% a masters-level degree in one of eight broad fields of science. The survey population was limited to this level of credentials and these broad fields of science to focus on the research scientist community and to permit comparison with elements of the 1988 and 1996 surveys mentioned above.

The survey sample was composed of 930 individuals for whom valid email addresses were available. The survey respondents numbered 361 after discarding several incomplete surveys. The response rate was just under 40%.

The bioscientist component of the survey sample was made up of those individuals whose highest degree was in Biological sciences and several others whose highest degree was in another field (e.g. Medical sciences and Agricultural sciences) but who identified Biological sciences as their principal employment over the five years leading up to the survey. These bioscientists made up 30% of the respondents, thereby providing a substantial basis for analysis. As shown in Figure 1, no other fields of science had as many respondents.

Sources of survey population

The survey population is composed of those employed by universities ($n=178$), Crown research institutes (CRIs, $n=142$), research associations, polytechnics, and museums, the last three of which have been grouped as 'Other' ($n=41$) (Figure 2). These are the research scientists most closely tied to public funding

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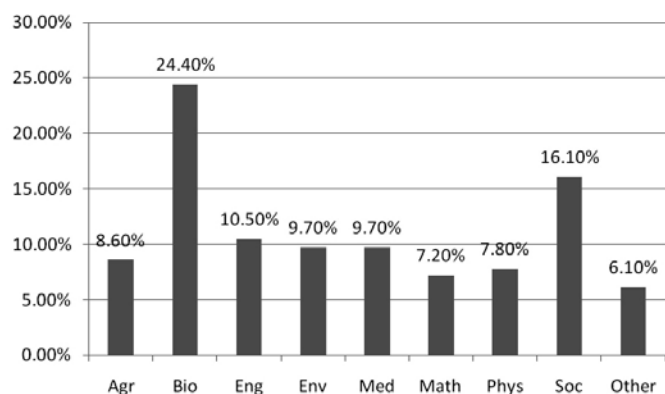


Figure 1. Primary field of scientific specialisation of survey sample. (Agr = Agriculture & Soil sciences; Bio = Biological sciences; Eng = Engineering sciences and Applied sciences & technologies; Env = Earth & Environmental sciences, and Natural Resources; Med = Medical & Health sciences; Math = Mathematics & Computer sciences; Phys = Physical sciences; Soc = Social & Behavioural)

sources. Regrettably, it does not include similarly qualified scientists in private firms who could have added as much as 10% to the existing database but who were difficult to recruit because demand for their services is market-driven.

Purpose

The functions of the survey are four-fold, and each is important.

- It provides an independent ‘voice’ for scientists not sifted, sorted or processed by institutional or organisational spokespersons in universities, CRIs, other government agencies, or scientific societies.
- It is a source of information for the development of science policy, public and private.
- It provides information that can be used to monitor the effectiveness of government science policy.
- It is a source for enhanced public understanding of science and technology.

A fifth function of the survey has emerged, that is as a source for hypothesising about the directions of New Zealand science. Our ability to distinguish responses of bioscientists from those of the rest of the science community supports each of these functions.

Voice

Scientists are highly independent and express concern that their views are not taken into consideration when science policy is formed. This point is backed up in the survey, where fewer than 1 in 7 scientists regard government science strategy development to be open and inclusive. Moreover, bioscientists were the *least* called upon among all fields to advise government during the five years preceding the survey. This is surprising given the size of the bioscientist population and past government expressions of support for a bio-based economy. This independent ‘voice’ for scientists provided by the survey can be a welcome alternative to carefully crafted institutional or organisational statements for policy purposes that are only lightly informed by workaday scientists. The ‘voice’ of the bioscientist is heard to be more strident on many issues than that of the rest of New Zealand’s scientists and technologists.

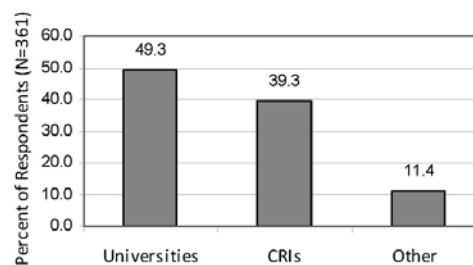


Figure 2. Sources of survey population.

Source of information for science policy

In general, scientists are reluctant to enter the world of political exchange, but the survey offers the possibility of ‘leverage without lobbying’. The 1988 Sigma Xi Survey performed this role effectively; the results were read into the United States Congressional Record *in toto* and provided a powerful science committee chairman with evidence used to formulate the agenda for legislative hearings during that session of Congress (Sommer 1991). Publication of the opinions of the membership of this global scientific honour society did provide ‘leverage without lobbying’. The New Zealand surveys of 1996 and 2008 are strictly non-partisan and they have established a source of unbiased information for science policy decision-making in New Zealand.

The 1996 New Zealand Survey established a benchmark of information on *Attributes* of the science community such as Age, Gender, Fields of Science, Income, Publications and Patents, and other data that make up the hard bits of evidence upon which policy can be formulated. The 2008 Survey provided a second data point for all of these attributes, thus initiating speculation on trends, and added a key new question on time spent on administrative duties versus time spent on research.

Release of the Report of the Crown Research Institute Task Force in 2010 indicates that the ‘voice’ of the scientific community is being heard and that the 2008 Survey had been helpful in the deliberations of the Task Force (Crown Research Institute Task Force 2010). Many of the Task Force recommendations address issues raised in the past two surveys. Dr Wayne Mapp, Minister for Research, Science and Technology at the time, cited examples from the survey as reasons for policy adjustments in his speech to the NZBio2010 conference in Auckland (Mapp 2010). The additional capability of probing the views of bioscientists introduces a subtlety that reduces the hazard of creating a one-size-fits-all policy.

Monitor of science policy

The 1996 and 2008 surveys contain questions developed from government policy statements of goals to be achieved over a period of years. For example, gauging the morale of the scientific community (and improving it) was a goal expressed in the 1996 MoRST document *RS&T2010* and reiterated in 2006 (MoRST 1996). The 2008 survey results give a second data point on the same *Attitude and Opinion* questions from 1996. The results are mixed on the morale issue but generally trend downward.

The 2008 survey contains new questions developed from MoRST’s *From Strength to Strength* statement that sets out a vision for 2020 (MoRST 2007). Future surveys can repeat these questions too, to provide those concerned with the management of science with some indicators of policy effectiveness. These goals were established under the Labour-led government that

was voted out of office as the Survey was being conducted. These goals will be reviewed under the new Ministry of Science and Innovation that has now replaced MoRST.

Enhanced public understanding

Although the press and other media often come in for criticism by scientists for their treatment of science stories, it is also recognised that this is the medium through which science is filtered to the public. Among the eight broad fields of science employed in the survey, bioscientists are the most critical of journalistic media, probably because biological sciences deal with complex issues where strong emotions are in play among the general public. Questions on how scientists view issues that concern the public present a kind of human interest dimension for a larger audience: genetic modification, stem cell research, global warming, and nuclear power development provide a window for the general public from a sometimes obscure world of scientific research.

A case may be made for a fifth function of the survey, and that is *hypothesis formulation*. Some curious results emerged from the comparative analysis of bioscientists versus the remainder that have led us to consider what could have contributed to their existence. We address a few of these results in this paper.

Because the 2008 Survey was taken at the termination of a government led by the Labour Party the next survey will follow a period of leadership by the National Party. This introduces a virtual ‘natural experiment’ and invites lively speculation over future survey results because a National-led government will have a clear baseline from which to work and an opportunity to relate their performance to that of a competing party.

With this background we turn to the focus of our discussion: Bioscientists versus all other scientists.

Are bioscientists different?

The answer is ‘No’ with respect to their reasons for becoming a scientist, their commitment to scientific research, their views on whether government should establish research agendas or demand specific results in advance of initiating research, and on a host of other issues explored in the Survey. We refer readers to the published results (Sommer 2010).

However, the answer is ‘Yes’ with respect to some important attributes and opinions. We will get to these differences in a moment but first consider an example of congruence of bioscientists with the remainder of the science community.

Most important issues facing scientists

When asked, ‘What are the most important issues facing scientists and technologists’, the top three reported by the entire sample ($n=361$) were Interruptions in research funding, Bureaucratic accountability, management and red tape, and Emphasis on funding applied research over basic research, in that order (Table 1).

Table 1. Most important issues facing science.

Lack of public understanding of science and technology	11.00%
Interruptions in research funding	25.40%
Over-politicisation of research	8.60%
Decline of student interest in science and technology	11.90%
Bureaucratic accountability, management, and red tape	24.00%
Emphasis on funding applied research over basic research	15.80%
Fraudulent development of data and its use by scientists	1.10%
Other	2.30%

Bioscientists responded in the same order as the entire sample but with a special emphasis on Interruptions in research funding – 28.6% versus 21.2% for non-bioscientists.

This congruent ordering and ranking is interesting, but it is made more so because this result repeats that of the 1996 Survey of New Zealand Scientists and Technologists. More interesting still, the results of both 1996 and 2008 New Zealand surveys repeat those of the 1988 Sigma Xi survey in the United States. (Sommer 1988b). *In all three surveys, Interruptions in research funding was the most important issue for bioscientists, and in each survey their concern exceeded that of all other fields of science.* This persistence across time, space, and scientific communities is a conundrum that we have not yet resolved.

Consider some differences between the bioscientists, who made up 30% of the 2008 survey respondents, and the rest of science community in terms of selected attributes, below. Later we reveal differences in their opinions on some sensitive questions that have policy implications.

Attributes

Gender and Age

Bioscientists mimic the larger science community in terms of gender, with 27.5% female compared to 29.4% female in other fields combined, but the important datum for gender is the increase in the proportion of women in the survey sample from 22.8% in 1996 to 28.8%. This information alone is an important contribution to science policy deliberations as well as for academic institutions and human resource managers in firms.

Bioscientists are younger, their mean age being 46 and other scientists 49. Forty-three per cent of bioscientists are under 45 years old compared to 37% of other scientists (Figure 3). Throughout the survey results we find that younger scientists, bioscientists included, have some different opinions from older scientists.

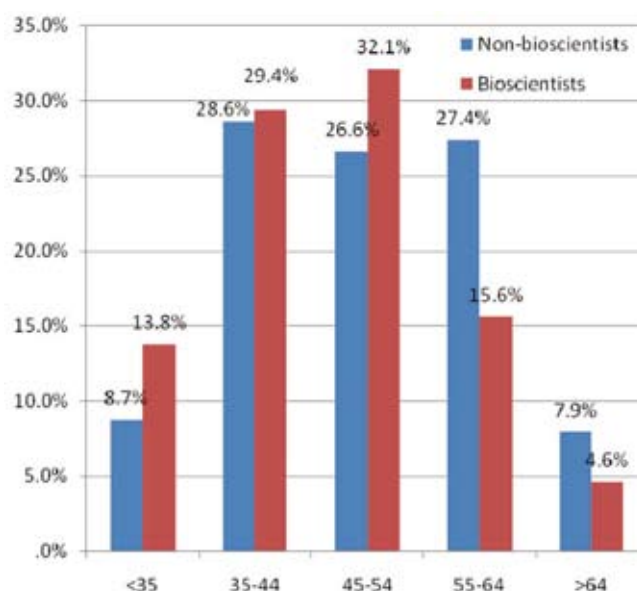


Figure 3. Mean age of bioscientists v. all others surveyed.

Work location

Work location is another important difference: among survey respondents Crown research institutes employ 58.7% of the bioscientists, universities 28.4%, and other venues 12.8% (Fig-

ure 4). The remainder of the science community reverses this order: 31% are in CRIs, 58.3% in universities, and 10.7% in other positions. On average, CRI scientists have higher salaries than those in universities.

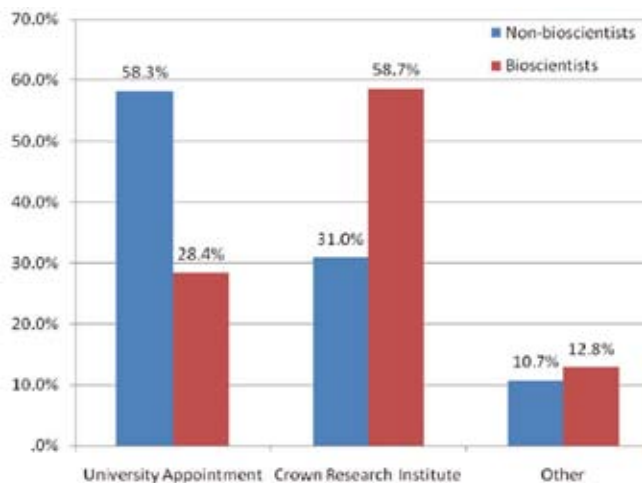


Figure 4. Work location of scientists surveyed.

Personal income

Age difference contributes to differences in annual personal earned income, which average about NZ\$10,000 less for bioscientists than others, making bioscientists among the lowest paid fields, approached only by agriculture and soil scientists (Figure 5). In contrast, medical and health scientists are amongst the most highly paid.

The relative youth of bioscientists contributes to the difference in level of qualifications (hence income), where 71.5% of the bioscientists hold Ph.D.s compared to 82.2% of the other scientists. Some young bioscientists are still working on their doctorate.

Given the demographic composition of this population of research scientists, one can expect the income profile to change over the next five years.

Research budgets

In terms of span of control over research budgets, bioscientists have an advantage (Figure 6): 53.1% are responsible for research budgets over NZ\$100,000 compared to 33.7% for other

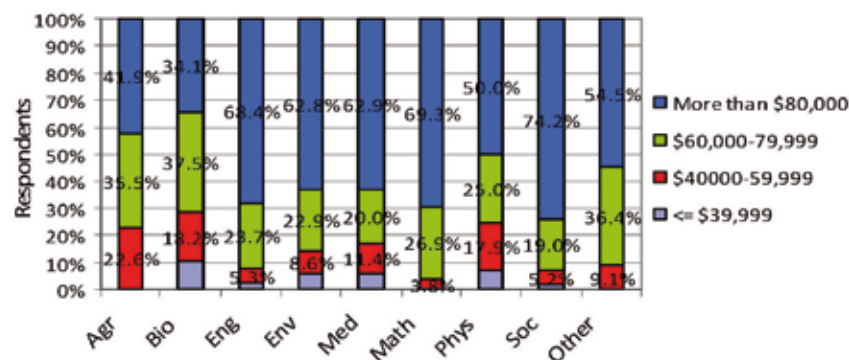


Figure 5. Personal income by field of science. (Agr = Agriculture & Soil sciences; Bio = Biological sciences; Eng = Engineering sciences and Applied sciences & technologies; Env = Earth & Environmental sciences, and Natural Resources; Med = Medical & Health sciences; Math = Mathematics & Computer sciences; Phys = Physical sciences; Soc = Social & Behavioural)

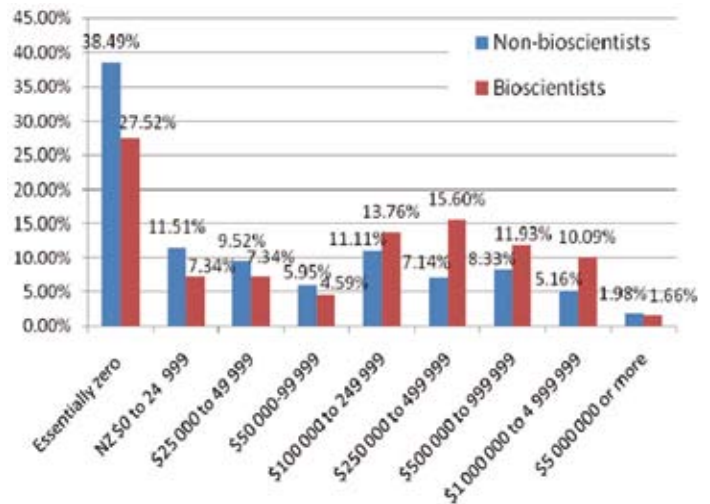


Figure 6. Research budgets.

scientists, and only 34.8% of bioscientists have budgets under NZ\$25,000 compared to 50% for the others.

Note the high percentage of individuals who have essentially no research budget to speak of. It comes as no surprise that concern exists across the entire research community that funding for science is inadequate and skewed toward certain individuals or groups.

Sources of research funds

Individuals were asked what has been their principal source of research support over the past five years. For nearly half of all bioscientists the Foundation for Research, Science and Technology (FRST) was their main source of funds (Figure 7). By contrast, FRST was the main source for only a quarter of all other scientists. Moreover, a follow-on question asked from which organisations had one received any funding over the past five years: 65% of bioscientists and 43% of all other scientists identified FRST.

This concentration of funding in one place is not mitigated by the variety of alternatives found in other science systems, where multiple government agencies, private foundations, and, more importantly, private industry complement government sources. New Zealand's Marsden Fund provides modest but welcome support for basic or 'blue sky' research but it, too, is limited to a small proportion of funded scientists. Universities fund much of their research through government/TEC's Performance-Based Research Fund (PBRF).

Exacerbating this situation is confusion over the funding guidelines of FRST and changes in priorities that can threaten the career of an individual or a whole research team. One survey question sought to discover what applicants for FRST support thought of the bidding process and found that nearly half of all grant recipients felt they did not have enough knowledge of the system to make an informed application (Sommer 2010, p. 18-19). Moreover, only one in ten scientists thought the FRST award process works well and bioscientists were among the most critical (ibid. p. 17).

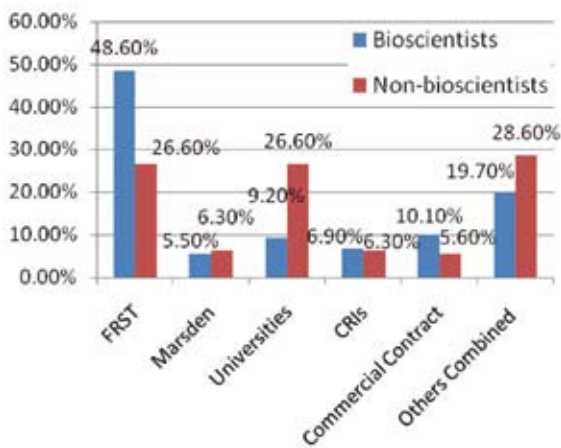


Figure 7. Funding sources.

One consequence of lack of diversity of funding sources in New Zealand is an ever-present sense of dependency on government and lack of control over one's career. Uncertainty prevails. Animosity was directed at FRST by many in the science community, but it was particularly acute among bioscientists.

To quote one of the many narrative submissions by survey participants, a 52-year-old male bioscientist employed at a CRI wrote:

FRST has become a surreal system in the Kafka mould, with values and objectives that are against the operation of good science. When asked, I counsel young people to steer clear of science careers in New Zealand.

A 51-year-old female bellwether bioscientist at a university commented:

I have found that mainstream ideas get funded by FRST. New and original ideas are not favourably looked at. The funding seems to be controlled through 'old boys' networks'. The outputs seem to be mediocre in comparison to funding levels. Small businesses struggle and substantial funding is not directed towards these businesses.

Moreover, to indicate that bioscientists are not alone in their views, a 55-year-old male university engineer said:

I have no faith at all in FRST. Its 'foresight' process and reinvention of the English language as a substitute for real insights into potential research gains are jokes worthy of Fawcety Towers. It would be laughable if it was not so damaging to science in New Zealand.

Regrettably, these comments are not isolated instances of a voice crying in the wilderness, but the animosity directed at FRST is likely to be dissipated, or possibly redirected now that the organisation has been restructured as part of the Ministry of Science and Innovation, as of November, 2010. The challenge for government, of course, is to dispel these concerns of obfuscation and mismanagement of the research investment process.

Research versus compliance

The amount of time meeting administrative responsibilities such as grant application writing and reporting versus time spent on research has implications for productivity and it has been a universal source of irritation for scientists. The distribution of responses to this question is shown in 10% intervals, with

a peak of 25.5% (mean of all respondents) saying they spend 20–30% of their work time complying with administrative matters (Figure 8). Bioscientists dominate the upper end of the distribution, where more than half of their work time is not in actual research. If this is the penalty for managing larger grants, or perhaps multiple small grants, one might wonder about diminishing rates of return to research!

On this point another survey respondent commented:

Administration and reporting continue to stifle science research efforts. Little or no independence by or within CRIs is leading to a mediocre research environment for all but a few science workers.

Self-reported time estimates are certainly not hard data *per se*, but responses to this question, as with almost all of the others, become more useful with further iterations of the survey. This is a dimension of the life of scientists in New Zealand that bears continued monitoring.

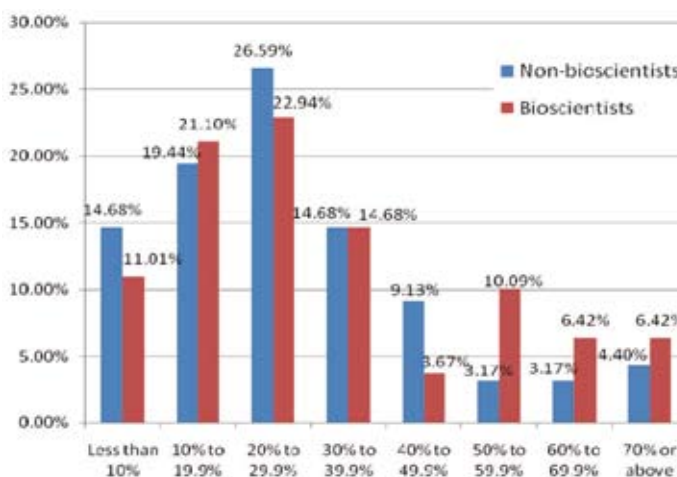


Figure 8. Time budget for compliance activities.

Attitudes and opinions

Job security

There is no question that New Zealand scientists have an 'attitude', as revealed by their opinions expressed in several questions. Respondents were offered direct statements to which they could Agree Emphatically, Agree, Neither Agree nor Disagree, Disagree, Disagree Emphatically, or remain Undecided. One statement concerned the important issue of job security:

I feel my job is reasonably secure for the next five years.

Bioscientists differ from other scientists, with 51.3% agreeing compared to 65.0% of non-bioscientists (Figure 9). Bioscientists disagree more, 31.2% to 21.0% for all others, but much of this difference may be accounted for by the stage of career of these more youthful individuals. It is worth noting that the difference between these two groups is lodged in the most strongly held views.

Management of science

The restructuring of New Zealand science over the past two decades (1989–2008) created great uncertainty, and much of the search for vibrant programmes to meet the priorities set by government appeared frenetic, or even frantic. Widespread discontent over alarming shifts in government priorities left a

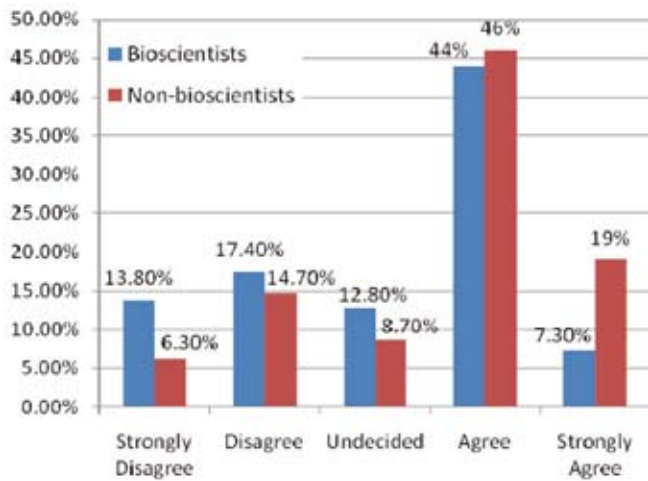


Figure 9. Job security.

‘flavour of the day’ taste in the researcher’s mouths, and scientists were heard to complain that more resources are spent on new and clever names for initiatives and persuasive charts and diagrams than on making the system run effectively.

So, how did scientists respond to a question that sought an opinion about the guidance systems put in place to manage science? The statement read:

The management systems in New Zealand science are appropriate for the effective advancement of research.

Bioscientists begged to differ: only 2.8% agreed with the statement and 73.4% disagreed (Figure 10). Contrast this with 11.1% agreement and 60.8% disagreement by non-bioscientists. Not one of the respondents Strongly Agreed with the statement, the only such question in the survey to fail to record such a response.

Since 1996 when this question was first asked, the needle on this monitoring device moved into more negative territory. This result indicated a challenge then, and that challenge remained in 2008. The current government is moving to address important structural issues in the organisation of New Zealand science as it seeks to move the needle back to the positive side (Key 2010).

Career recommendation

On another bellwether issue the following statement confronted survey respondents:

The way things are going with scientific and technology careers in New Zealand today, I would recommend such careers to New Zealand youth.

Again, the bioscientists demurred (Figure 11): only 23.8% agreed compared to 42.5% non-bioscientists, and 58.7% of bioscientists disagreed compared to 33.7% of all other scientists. Troubling as this may seem it is an improvement over 1996.

The persistent discontent of bioscientists should be a cause for alarm, especially in light of the fact that bioscientists make up one-fifth of the under 35 age cohort of New Zealand’s scientists.

These three key questions indicate that bioscientists possess a substantially different, and more negative, outlook on matters of policy relevance than the rest of the science community.

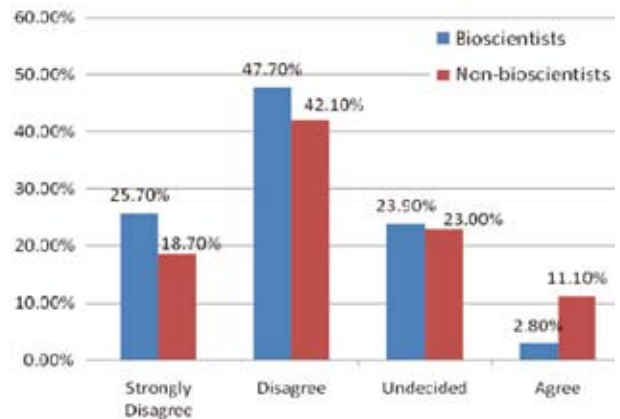


Figure 10. Effectiveness of management systems.

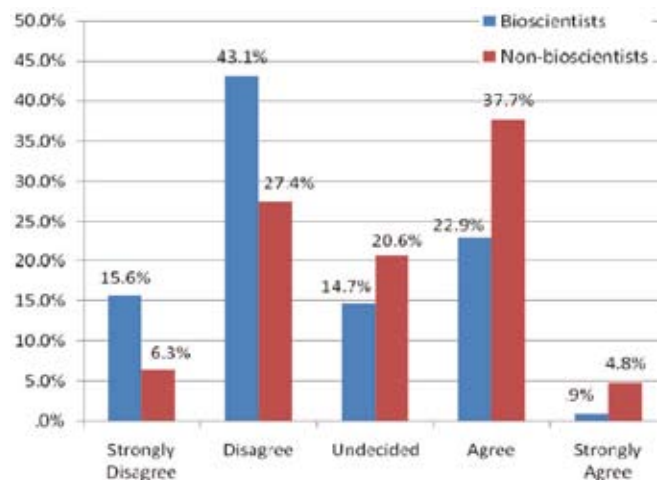


Figure 11. Recommending careers in science.

These differences contribute to the negative assessment of the morale of the scientific community mentioned in the *RS&T 2010* document.

Even with this negative assessment, bioscientists (25.7%) have not sought to leave New Zealand much more than those in other fields (23.8%), according to their response to a direct survey question. Of course, the survey could not account for bioscientists, or others, who had already left the country.

What’s up?

With these disturbingly negative views, one can ask, ‘What, if anything, is up?’ There are a few positive changes from 1996 that bioscientists shared with the remainder of the science community.

Even with the viewpoints expressed on bellwether questions of job security, efficacy of management, and lack of enthusiasm for recommending a career in science, aggregate *job satisfaction* improved although bioscientists were slightly less satisfied than other scientists.

Some other indicators of goals pointed upwards (Table 2). Memberships on boards of directors of companies increased dramatically. Access to equipment and availability of staff support improved and inter-institutional collaborative opportunities increased. There was a doubling of the percentage of Māori participating in the survey. In the 2008 Survey these questions

were framed around 'the past five years', whereas in most cases those in 1996 were framed around 'since the restructuring' or 'ever', for example, patents appeared to decrease slightly in 2008 but the period compared was 'the past five years' to the 1996 'ever'.

Table 2. Rising indicators 1996–2008.

Indicator	Yes (Agree or Strongly Agree) 1996	Yes (Agree or Strongly Agree) 2008
Research collaboration	18.10%	40.20%
Board of Directors	1.20%	5.20%
Māori origin	0.70%	1.70%
Patent	13.60%	12.50%
Access to equipment	13.60%	69.60%
Staff support	9.60%	47.90%

It is important that the media report on positive developments rather than focusing solely on the negative.

Some controversial issues

The general public is confronted daily with confusing and sometimes frightening issues seemingly requiring advanced scientific knowledge. Even with the best of intentions, print and electronic media exaggerate the potential risks of these issues. Expert opinions based on current understanding of the science behind the issues helps to engage media outlets and enhance public understanding of science and technology.

Consider two issues on which bioscientists have special expertise, genetic modification and stem cell research.

Scientific opinion on genetic modification

Confronted with the statement: *My understanding of the science of genetic modification of organisms leads me to believe they pose sufficient threat to the ecosystem to warrant suspension of research endeavours*, almost three-quarters of bioscientists disagreed compared to just over half of non-bioscientists.

We understand that consensus is not conclusive in science, but it is reassuring to the journalist community and to the public at large to know what experts think, even when contrasting viewpoints are also held by other scientists.

Scientific opinion of embryonic stem cell research

In the aggregate response to the statement: *I believe that embryonic stem cell research should be suspended while other stem cell sources are researched*, older scientists and female scientists agreed more than their counterparts but real differences showed up with respect to fields of science.

Bioscientists registered pronounced disagreement relative to most other scientists. Seven in ten bioscientists disagreed.

An interesting result came from those in the Medical & Health Sciences who disagreed more than others (71.4%), even bioscientists, and were also among the strongest in agreement (17.2%), a result made possible because they were more resolute in their opinion than all others.

Statistical evidence on science as a career

Several issues of importance for New Zealand science have been subjected to more in-depth statistical analysis. Specifically, multiple-regression techniques have been employed to sort out significant factors in the areas of career advice and job security.

Career advice

The regression model shows that both Field of science and Work location are significant predictors of enthusiasm to recommend a career in science to New Zealand youth (Table 3). Specifically, bioscientists were less likely to recommend a career, relative to scientists from all other fields; scientists working in universities, relative to all other work locations, were more likely to recommend a career in science. Interestingly, Gender also emerges as a factor, as female scientists were more likely to recommend science careers than males.

Table 3. Enthusiasm to recommend a career in science.

	B	Std Error	Beta	t	Sign.
Bioscientists (1 = Bioscientists)	-0.316	0.099	-0.194	-3.206	0.002
Gender (1 = female)	0.241	0.102	0.144	2.36	0.019
Income	0.009	0.021	0.029	0.44	0.66
Work location (1 = University)	0.248	0.097	0.164	2.565	0.011
Age	0.042	0.04	0.062	1.03	0.304

Job security

This regression model shows that bioscientists were less likely to feel secure about their job relative to non-bioscientists (Table 4). In addition, income was a significant predictor of one's feeling about their job security; not surprisingly, scientists earning more income felt more secure about their position. When we considered the relationship between work location and job security, we found that scientists in CRIs were feeling less secure. However, when we control for age, gender, income, and field of science, the relationship between work location and job security disappears.

Table 4. Feelings of job security.

	B	Std Error	Beta	t	Sign.
Bioscientists (1 = Bioscientists)	-0.232	0.108	-0.124	-2.149	0.032
Gender (1 = female)	0.195	0.107	0.104	1.827	0.069
Income	0.12	0.023	0.325	5.192	0
Work location (1 = University)	0.039	0.101	0.023	0.382	0.702
Age	-0.061	0.046	-0.076	-1.325	0.186

In closing

Results presented here support the four functions of the Survey of Scientists and Technologists and they make audible the specific voices of age, gender, work location, and field of science. Most emphatically, the voice of the bioscientist has been singled out amidst the cacophony of data, permitting us to peer into important differences within aggregate information.

Our disaggregated information has helped to make specific what are the unvarnished concerns of bioscientists within the entire New Zealand science and technology community. The voice of the bioscientists is certainly clear enough on important issues and raises questions for the direction of public policy.

Whether the bioscientist's voice will be acknowledged by the public, press, and policy domain is an open question but there are results of sixty other survey questions that may amplify the urgency to hear this voice.

Most of what we have had to say has been a descriptive report on the 2008 Survey with special reference to bioscien-

tists. What we have reported about this foundational field of inquiry that supports a bio-based economy in New Zealand's future indicates there is much work ahead for those who would manage science.

Will public policy under a National-led government direction seize the opportunity to move the morale needle back from negative territory into a positive realm?

What are the prospects?

Prospects for a less troubled science and technology community in New Zealand are on the rise as recommendations from the Crown Research Institute Task Force Report move towards implementation by government. Five features of the proposed changes hold out the possibility to raise morale as well as productivity:

- Devolution of decision-making away from central government to CRIs on the science needed to address broad public priorities should enhance consultation between scientists and managers in those organisations thus reducing the sense that they are excluded from decisions about the direction of their scientific research. This initiative will also address the time-intensive issue of 'bureaucracy and red tape'. Given the concentration of bioscientists in CRIs, the result of this policy initiative should reduce anxiety and animosity within the field.
- The promise of more stable funding by increasing the proportion of funds that are Core funds and less reliance on Contestable funds addresses, to some degree, the sore issues of 'Interruptions in research funding' and 'Time spent on administrative rather than research activity.'
- Moving the system from *competition toward collaboration* by inducing opportunities to collaborate across institutional boundaries should promote synergies between CRIs and universities and with the private sector.
- Increased focus on technology transfer, combined with greater freedom for the individual scientist to innovate should result in a more dynamic environment for contributions to the New Zealand economy.

- Appointment of a Chief Scientific Advisor sent a loud message that the Prime Minister is serious about government commitment to science.

If these initiatives are backed up with implementation there is no guarantee that all in the science community will benefit to the same degree nor will changes occur without dissent. It does seem likely that bioscientists will modify their opinions on the issues we have identified insofar as they are able to capture the fruits of their research in terms of recognition of their contribution to scientific advancement and in financial reward.

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Technology-enabled advance in the worlds of statistics, machine learning and data mining

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Advances in digital computing continue to have large effects on all aspects of life and society, including science. These advances are possible because we have computer languages that translate directly into computational steps that can be implemented in computer hardware. Here, I draw attention to changes that are affecting the theory and practice of data analysis, with a focus on methodologies that feature in expositions of data mining and machine learning. The R language and system is playing an increasingly important role in making the new abilities readily accessible at the scientific workbench.

The computer language revolution

Human language makes possible the rich fabric of human culture, of which mathematics and science are a part. Computer language provides a powerful mechanism for describing computational tasks, now with the bonus that talk translates directly into action. These tasks may now, with the software and hardware that is available in 2011, include text processing, mathematical tasks, image and auditory processing, communication, and much else besides. The scientific and mathematical imagination has been stimulated to conceive and carry out tasks of previously unimagined complexity.

Application oriented language

There are huge advantages in working with a language or languages whose terminology closely mirrors what specialists find appropriate when describing a computation. Here, note the language implemented by the R system, which has become the environment of choice for implementing new statistical methodology, and for much else besides. Figure 1 demonstrates the use of R code for plotting and for fitting a regression line. The inset shows R code that gives a simplified version of the figure. Relative to languages such as Fortran, C and Java, R is very high level. Many of the R packages rely heavily on code that has been written in C or Fortran. These earlier languages remain important, but their role has changed.

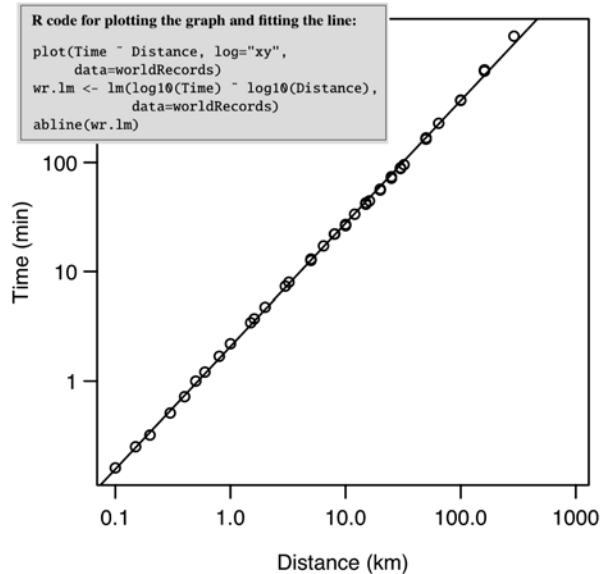


Figure 1. Record times for road and track races, as at August 2006, are plotted against distances. Logarithmic scales have been used on both axes, with equal distances showing a change by a factor of 10. The slope of the line is 1.125, indicating that the relative rate of increase of Time is 1.125 times that for Distance. The data (in the dataset worldRecords) can be made available, from an R session, by installing the DAAG package for R and typing library(DAAG). Code is shown that gives a simplified version of the graph. The supplementary materials include further investigation of these data. (Although the line appears a good fit, two of the points deviate by more than 12% from it. Relative to times that vary by a factor of around 9000, a change by a factor of 1.12 appears slight.)

The R system has many attractions. It is free. It is open source, so that anyone can inspect the underlying code and check that its commands do what they claim. It is readily and

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seamlessly extensible, so that its abilities can be the basis for computations that are tailored to the demands of pretty much any area of science or commerce. Witness its use by Google and others for mining web data. Its 3300+ ‘packages’ extend the base system to give access to an unsurpassed and widening range of abilities. The R Task Views web page (<http://cran.r-project.org/web/views/>) gives an idea of the range. Extensive tutorial and expository material is available on the internet. There are more than 100 books that expound R, or that describe its use for a particular area of application. A Python specialist could perhaps use Python to illustrate similar points. There is, however, no direct equivalent of the R Task Views web page, suggesting a more limited penetration into field and laboratory bench science.

Abilities that are immediately available in R make it possible to bring together data from different sources, do preliminary checks, extract analysis output in various alternative forms, apply checks to the output, provide graphs and tables, and use output (perhaps combined with other data) for further analysis. Access can be provided, from R, to programs that were initially designed to run as independent programs. Thus, note the R interface to the Weka data mining software (Witten & Frank 2005). Note also the extensive spatial analysis abilities, most of them added since 2003. These have relied heavily on interfaces to other systems, including the widely used GRASS system that must be installed outside of R. Bivand *et al.* (2008) give an overview, now somewhat dated, of what is available. There is currently no R equivalent of the impressive graphical interface to GRASS that the QGIS system (www.qgis.org/) provides.

Point and click interfaces are well suited to some tasks. In general, however, analyses that meet high professional standards will require some use of steps that are spelled out in computer language. The grunts and gestures on which non-human apes rely severely limit what can be communicated. Point and click interfaces overcome these limitations, to some extent, by using language to indicate where and to what end the user can click or type. For use for statistics courses at school and beginning university level, note the R-based iNZight GUI, developed by Christopher Wild and Dineika Chandra at Auckland University (<http://www.stat.auckland.ac.nz/~wild/iNZight/>).

The focus of the discussion will now narrow somewhat, to consider statistical or (though I have reservations about the term) data mining analyses.

Data analysis challenges

Data, data everywhere

Alongside advances in computing hardware and software there has been, over the past decade, a steady growth in the scope and detail of datasets that are available for scientific use, in large part because of advances in automatic data capture. This is not without problems. The size of the collection does not guarantee quality, or relevance to some particular question, or representativeness. Nonetheless, the massive datasets now available open new vistas, and will be a large part of the future of science.

Genomic data provide much more detailed information about some parts of the genome than about others, much more information about some species than about others. Some of this has to do with ease of collection, some with perceived relevance to questions of biological interest, and some with accidents of

circumstance. This matters more for some purposes, less for others. How should the different pieces of evidence be weighted for purposes of taxonomic classification? Is a taxonomic tree the right way to characterise biological relationship. What of horizontal gene transfer? Is there risk that traditional tree-structured classification systems will force the data into an alien mould?

An interesting development, with large potential implications for the handling of data analysis, has been the development of the Kaggle platform (<http://www.kaggle.com/>) for data prediction competitions. This allows organisations to post their data and have it scrutinised by teams that relish such a challenge. Maindonald (2005) argued for making it standard practice to expose to open scrutiny all datasets that are the basis for scientific claims. The kaggle initiative may be even more effective in serving the same purposes.

Extensive computation, and large datasets

Increasingly, advances in science seem likely to rely on a mix of extensive computation that brings together existing scientific theory in new ways, and the use of very large datasets. The Lytro camera (<http://www.lytro.com/>), due to come on to the market later this year, demonstrates how well-understood physical processes, combined with the power of modern computation, can be marshalled to create a radical innovation in the marketplace. With this camera, the picture is taken first and focused later, so that the only shutter lag is that due to the human operator. Global Climate Models provide another example. They use extensive computation to account for many different physical processes, different in their importance and in the precision with which their effects can be modelled. They rely on data from many different sources.

New traditions of data analysis

The invention of new names that reflect specific application areas has a long tradition – theory of errors, psychometrics, biometrics, biostatistics, geostatistics, chemometrics, and so on. The word *statistics*, used to describe the theory and methodology that underpins the analysis of data, is perhaps 200 years old. Problems in robotics, in speech and image recognition, and in related areas of engineering have spawned the discipline of *machine learning*. The term *data mining* has come from the computing community. Machine learning, prior to about 1980 on the fringes of Artificial Intelligence, has moved to occupy a central place. It has moved from an initial focus on symbolic logic to use a theory and methodology that are thoroughly statistical. There is nothing in Bishop (2006) that would be markedly out of place in an advanced statistics course. Its traditional focus has been robotics and pattern recognition in an engineering context, but that may be changing.

Expositions of data mining often place emphasis on the methods, or algorithms, that it offers. Its only theoretical basis is that of the statistical theory to which some data mining texts make vague reference. It may be best seen as a name that emphasises the new challenges that arise from the very large datasets that are now presenting themselves for management and analysis. Data mountaineering might now be a better description. See Maindonald (2006).

Features of data analysis challenges

However described, the analysis challenges have common features. I will illustrate with a subset of a dataset that has been widely used for demonstration in statistics and data mining texts.

It relates to glass fragments that were collected in the course of forensic work. Numbers of pieces of glass of each of the glass types that are included in Figure 2 are:

- Window float (70)
- Window non-float (76)
- Headlamps (29)
- Containers (13)

Variables are percentages of Na, Mg, . . . , plus refractive index. In all there are 214 rows of data (observations) by 10 columns (variables). The aim is to find a rule that predicts the type of any new piece of glass. Figure 2 is a visual summary of the result from the use of a simple form of classification methodology, with the name *linear discriminant analysis*.

First, two points about the graph:

- It reflects the performance of the methodology for classifying the data used to develop the model. This may lead to an overly favourable view of its performance.
- As there are four groups, there are three dimensions of separation. Separation in the third dimension requires a second graph. In this respect, use of Figure 2 on its own gives an overly unfavourable view of performance.

Ideally, the classification accuracy should be estimated for new data that reflects the context in which results will be used. With data that accumulate over time, historical accuracies for forecasts that were made one year ahead may give a good indication of the accuracy of prediction for the following year. Here, it is necessary to make do with the data that we have, noting the accompanying caveats. With such a small dataset, a split between training and test (and perhaps validation) sets would be a poor use of the available data. Hence the use of cross-validation, which uses repeated splits into training and test data.

A simple version of cross-validation leaves data values out one at a time, fits (trains) the model using the remaining data, and makes a prediction for the omitted point. When the process is complete, predictions are available for all points that are independent of the data for the point. Use of such a *leave-one-out* cross-validation process gives, for the present data, a 70% accuracy. The accuracy is, however, different for the different glass types. Table 1 tells a more complete story. The classification accuracy is highest (86%) for headlamp glass, as Figure 2 might suggest.

Questions, for any use of the results (e.g. to identify glass on a suspect), are:

- How/when were the data generated? (1987)
- Are the samples truly representative of the various categories of glass? (To make this judgement, we need to know how data were obtained.)
- Are they relevant to current forensic use? (Glass manufacturing processes and materials have surely changed since 1987.)
- What are the prior probabilities? (Would one expect to find headlamp glass on the suspect's clothing?)

Table 1. Different accuracies for different types of glass.

Actual	Predicted (cv)			
	WinF	WinNF	Con	Head
WinF	0.71	0.29	0	0
WinNF	0.26	0.67	0.07	0
Con	0	0.46	0.46	0.08
Head	0.03	0.07	0.03	0.86

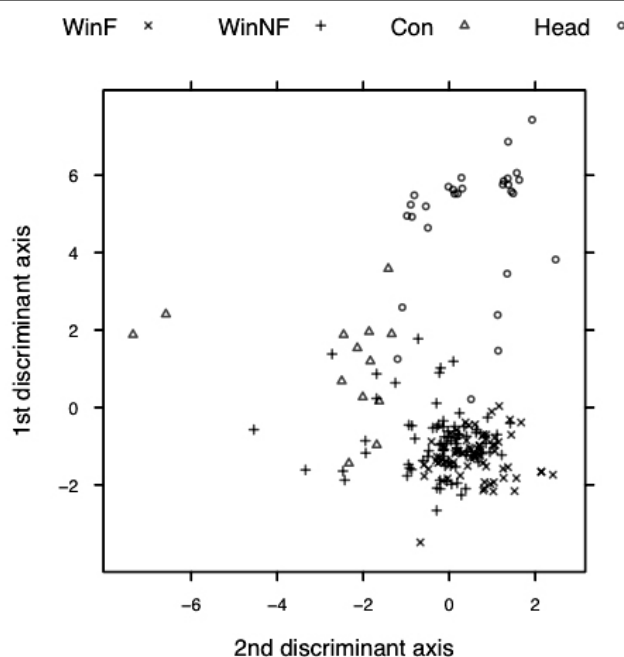


Figure 2. Visual summary of the result when the linear discriminant analysis methodology is applied to a forensic glass dataset, as described in the text. As there are four types of glass, there are three dimensions of separation, and the figure shows the two-dimensional projection that best distinguishes the four types.

These data are probably not a good basis for making judgements about glass fragments found, in 2011, on a suspect's clothing. Too much is likely to have changed since 1987. This 1987 source population is unlikely to be a good match for the glass fragments that one might expect to find now in 2011.

In practice, the only available data may be from a population that is a less than perfect match to the population to which results are to be applied. All available checks should be applied to investigate the closeness of the source/target match. Issues of this sort are crucial once one moves from such engineering applications as robotics where the data that are needed may be generated at the time of use, to an area such as forensic data analysis.

Structures of variation

Data often have a structure. For example, data on mortality rates of patients in critical care might be collected across some hundreds of hospitals. A result that generalises across hospitals must account for variation between hospitals. An algorithm that uses historic data to detect email spam becomes, unless regularly updated, increasingly less effective as time proceeds. In commerce, financial shocks wreak havoc with assessments that are based on pre-shock data. Taleb (2004) makes this point forcefully and at length. Issues of this type are widespread. None of the software I know that has a data mining focus addresses this issue, short of making summary information for each hospital the unit of analysis. The machine learning literature shows some awareness of such issues; cf. Bishop (2006). Books that have statistical learning or data mining in their title, whether written by statisticians or computer scientists, mostly ignore it. The otherwise excellent text by Clarke *et al.* (2009) gives the issue a passing mention that grossly downplays it, then proceeds to ignore it.

Are the new methods better?

Trees, neural nets and Support Vector Machines (SVM) have been the stock-in-trade of Data Mining and Machine Learning, for data such as were used to create Figure 2. Do they do better than the more traditional linear discriminant analysis approach that was used above? Sometimes! Beware though of exaggerated claims, such as have appeared in some of the Support Vector Machine literature. See Ambroise & McLachlan (2002) and Zhu *et al.* (2006).

A generally preferable alternative to leave-one-out cross-validation is k -fold validation, where $k=10$ is a common choice. This splits the data into 10 parts, then leaves out each of the 10 parts in turn, fits the model to the remaining 9 parts, and makes predictions for the omitted data. At the end of the process, predictions are available for all the data. Different splits of the data into 10 parts will give different accuracies. This can be useful, because re-runs of the cross-validation process provide an indication of the statistical uncertainty in the accuracy estimate. R's `rpart` function for tree-based classification gave accuracies for the forensic glass data that varied between 71% and 76%. Support Vector Machines, used as implemented in the `svm` function in R's `e1071` package and without any tuning, gave accuracies between 76% and 81%. Note again that these accuracies are for the population from which the original sample was taken. The only obvious continuing relevance of the forensic glass data is to forensic archaeology!

Where there are large numbers of variables, some preliminary variable selection may be needed. As noted in Ambroise & McLachlan (2002), this complicates the estimation of accuracy. The same is true for the tuning that SVM commonly requires to work well. There must be new selection or tuning at each cross-validation fold.

Tree-based classification, which mimics the classification keys that are used by botanists, differs more radically from the mainstream of statistical methods than any of the other methods mentioned. Figure 3 is an example. Splits are optimised over existing nodes, over variables, and (for each variable) the

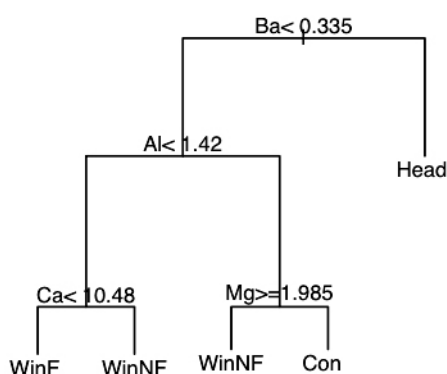


Figure 3. The inverted 'tree' is a visual representation of the classification rule given by R's `rpart` function (in the `rpart` package), for the forensic glass dataset. The tree has been pruned back to remove branches whose inclusion, as estimated by cross-validation, reduced classification accuracy. At each node, the left branch is taken if the condition is true, and otherwise the right branch. The tree that is shown gave an estimated cross-validation accuracy of 74%.

threshold for the split. Because `rpart` has a built-in procedure that assesses the cross-validation accuracy following each new split, the tree that is formed will vary from one run to another. The tree that is shown had an estimated cross-validation accuracy of 74%.

Random forests

The random forests method (Breiman 2001) warrants mention for two reasons – as a classification method it is hard to beat, and it introduces some novel ideas. It has relatively recently started to attract attention in the data mining literature. Its disadvantage is that it functions pretty much as a black box. Getting insight into why it delivers its results may not be easy.

When classification trees are formed, each individual split is optimal, given previous splits. The tree that is finally formed may be far from optimal. The random forests methodology aims to overcome this by simulating the taking of repeated random samples from the source population, with a tree formed for each such sample. More than 500 such samples might be taken. The classification is decided by a majority vote over all 500 or more trees.

The effect of taking repeated random samples from the source population is simulated by taking from the source sample repeated bootstrap samples that are of the same size as the source sample. In a bootstrap sample, each sampled observation is put back after it has been taken, so that it is available for selection when the next observation is taken. The end result is that some sample values, on average slightly less than 37% of the total in a large sample, are left out, while the same proportion of those that remain are repeats. For each split of bootstrap sample (called a *bag*), there is also a random sampling of variables – taking the square root of the total number of variables often works well. For each such sample, a tree model is fitted to the in-bag data and predictions are made for the *out-of-bag* (OOB) data. For the forensic glass data, this method gave accuracies in the range 85–87%.

Maindonald & Braun (2010) have an introduction to classification trees and random forests that is aimed at non-specialists.

Which method is best?

Predictive accuracy, as measured by cross-validation, estimates accuracy for the population from which the sample was derived. Differences of a few per cent between different methods are unlikely to be of much practical consequence. This is especially true in the common situation where the source population is unlikely to be a very precise match to the target population. It is often hard to get a good handle on the differences that matter for the intended use of results! Comments in Nilsson (2010, p.425) do not go quite far enough:

Some methods work better for some problems than for others, but often these differences are only marginal, and most people in the field agree that having lots and lots of data is, in the end, more important than the particular machine learning algorithm used.

Many analysts will find a choice between linear discriminant analysis and random forests all that they need. Even more important than having lots of data is to have data that are immediately relevant.

Statistical learning methods

Statistical learning methods automate the choice of an optimal model from some suitably large class of models. The random forests method is a good example. It can be extended for use with continuous outcome data also, but is not for this purpose a method of choice.

Consider now Generalised Additive Models. As implemented in R's *mgcv* package, these can fit smooth curves with automatic choice of smoothing parameter. Figure 4 was based on data from 155 sites in the flood plain of the river Meuse in the Netherlands. It shows contours of equal estimated lead contamination, averaged over effects from flooding frequency and soil type, as a smooth function of distance from river and height above river. The methodology does not completely protect against over-fitting, so that checks are desirable. Based on the use of ordinary cross-validation, accuracy is about 14% less than for a model that fits $\log(\text{zinc})$ as the sum of smooth functions of elevation and distance, plus effects due to flooding frequency and soil type. Figure 4 may thus be an over-interpretation of the data. See Wood (2006) for extended discussion of the methodology.

Note that the methodology tries to find a fitted surface such that deviations from the surface appear as close as possible to statistical noise. If the residual variation can indeed be reduced to what looks like noise, the fitted surface should be effective for spatial interpolation. If there is remaining spatial pattern, some form of *kriging* may give improved spatial predictions. For an account of kriging as available in R packages, see Bivand *et al.* (2008).

Resampling methods

A feature of the discussion to date has been the heavy reliance on

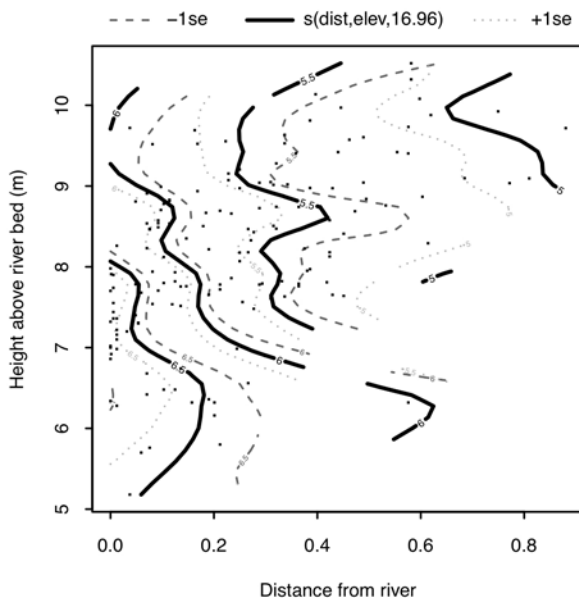


Figure 4. Contours of equal estimated lead contamination in the floodplain of the river Meuse in the Netherlands, averaged over effects from flooding frequency and soil type, as a smooth function of distance from river (scaled to lie between 0 and 1) and height above river. The contours, based on data from 155 sites, were derived using R's *gam* function, in the package *mgcv*.

cross-validation or similar assessments of accuracy. These can be used when theoretically based assessments are not available or are of doubtful validity. The role of bootstrap sampling in random forests was noted. In modern statistical methodology, various forms of bootstrap sampling have wide-ranging applications, providing alternatives to methods that rely more strongly on theoretical assumptions.

Finally, note the use of simulation. As the term is used here, this refers to the generation of repeated simulations of data that follow a theoretical model. The model is fitted to each set of simulated data. The results give insight into the distribution of fitted model statistics under the theoretical assumptions. Simulation is sometimes called the parametric bootstrap, reflecting the fact that the resamples are taken from a theoretical distribution rather than (as with the bootstrap) from available sample data. It gives information on the properties of the theoretical model, where cross-validation and bootstrap methodology provide information on the behaviour of the fitted model under repeated sampling.

Careful analysts will use simulation to check out the properties of any methodology that departs from the strict assumptions of the classical theory, as reflected for example in the output from regression software (including R's *lm* function). The classical theory assumes a single known model. If the model is selected from a wide class of models, or there is extensive variable selection, there may be serious bias in the choice of model and/or the model fit. Figure 5 uses extensive simulation to illustrate the extent of such effects. Data are pure noise; there is no relationship between explanatory variables and the dependent variable. When three variables are taken out of three, the nominal p-values for the three coefficients are spread out around 0.5. The solid line is designed to go through the median of the p-values. Notice that when the number of variables is around 18 or greater, the median nominal p-value will on average be around 0.05. These nominal p-values thus become seriously misleading.

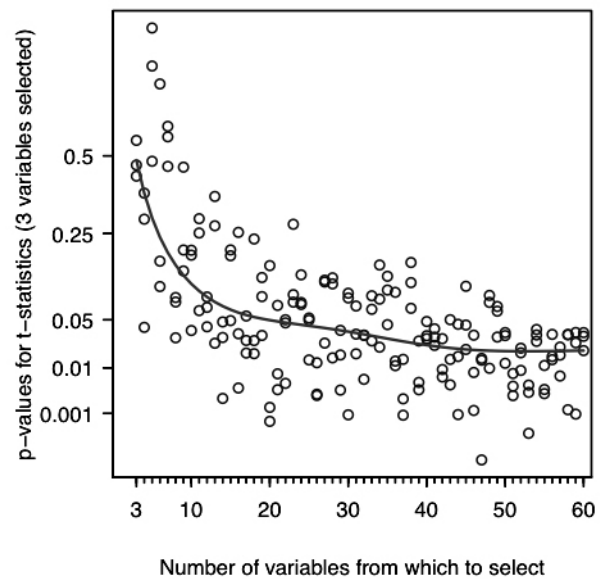


Figure 5. p-values, versus number of variables available for selection, when the 'best' 3 variables were selected by exhaustive search. The fitted line estimates the median p-value.

This illustrates well the light that simulation can shed on a methodology. The backward and forward and other variable selection methods that have been widely used for several decades are well designed to give specious results, unless simulation or another method that achieves the same effect is used to adjust for model selection bias.

The wider world of statistical methodology

The methods that have been described in this paper are a small part of what is available in R. They have been chosen for attention because they are widely used in the data mining and machine learning literature, because it is easy to illustrate their use and usefulness, and because they provide a good context in which to demonstrate the importance of computationally intensive methods. Resampling and other computationally intensive methods have moved into the statistical mainstream, reducing somewhat the former reliance on theory.

While describing those methods, I have tried to give a sense of the power that the high-level commands of the R language puts in the hands of researchers who have the skills needed to use them. There is every reason why scientists whose work involves substantial statistical analysis or other computation should start using R, or something better when it comes along, early in their education. The ideal place to start is at senior secondary school level. There is a wider educational value. Anyone who claims to be well-educated should have some sense of the extent to which advances in science and the technology are a result of the new power that computer language has placed at the fingertips of those who are suitably skilled. I find support for this general view in Bishop (2010). Bishop contrasts Information and Communication Technology (ICT), widely taught in British schools, with Computer Science, using the car as an analogy. ICT, which focuses on spreadsheets and word processing and other such applications, is analogous to learning to drive, while “computer science would be the equivalent of understanding how the engine and other elements of the car work, as well as how to design new cars”. Actually there are a large number of places, increasingly important in science, that a driver who knows only spreadsheets and word processing is unable to go.

The history of R

In 2008, Associate Professor Ross Ihaka from the University of Auckland was awarded the Royal Society of New Zealand’s Pickering Medal for his work on the development of R, undertaken in collaboration with Robert Gentleman while he also was at the University of Auckland. It implements a dialect of the S language that was developed by John Chambers and others at Bell Laboratories. The introduction to Chambers (2008) has a good summary of the history.

Supplementary materials

The website <http://www.maths.anu.edu.au/~johnm/nzsr/taws.html> will have links to information and references that are

relevant to this paper, including R code for all the graphs, supplementary graphs and calculations, and links to further relevant web pages.

Executables that will install R can be downloaded from <http://cran.r-project.org> (in New Zealand, use the mirror site <http://cran.stat.auckland.ac.nz/>). Lillis (2011) has extensive further details on R. For citation, refer to the current version of R Development Core Team (2011).

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Obituary

William (Bill) Henry Robinson (1938–2011)

Engineer/physicist who developed lead/rubber earthquake dampers

Bill Robinson, world-renowned scientist, earthquake engineer, Antarctic researcher and science manager passed away on 17 August 2011, aged 73. He was suffering from cancer.

WHR, as he was often known, completed an engineering degree at Ardmore, Auckland and then a PhD in Metallurgical Physics at the University of Illinois at Urbana-Champaign under H.K. Birnbaum. He went on to Sussex University investigating ion-channelling in crystals before returning to New Zealand in 1967 when he commenced his career at the Physics & Engineering Laboratory, DSIR, in Lower Hutt. Bill went on to eventually become the Director of PEL and then of DSIR Physical Sciences.

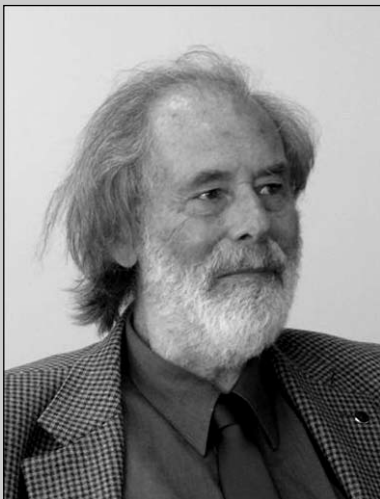
I first met Bill in November of that year, 44 years ago, when I also commenced work at PEL, at that stage as a student 'Professional Trainee'. He was my boss and mentor for the next 25 years and remained a close friend subsequently. I learned a great deal from his research style which combined quirky left-field thinking with a disciplined, practical approach. I guess that came from his training which was a meld of engineering and physics. 'Never go straight into the lab in the morning. Always go to your desk, plan your day and think about what is the best thing to do in the lab. Then you can go to the lab'.

Bill was versatile. He is of course known for his work on earthquake dampers, but he undertook extensive research into the physical and mechanical properties of sea ice in the Antarctic; he dabbled in cosmology, setting up equipment to search for gravitational waves; and he probed the piezoelectric and mechanical properties of materials using ultrasonic oscillators.

Nothing was too difficult for Bill to tackle. If extrusion dampers could be used to protect structures then they could also be deployed in motor vehicles for the same purpose. Bill demonstrated this in a cordoned-off road by the Hutt River by mounting earthquake extrusion shock absorbers on an old Vanguard utility vehicle and propelling it at 45 kph into 30 tonnes of concrete. If single crystals of ice a few cm in length could be investigated in the lab, then, with a bit of instrumentation, hectares of sea ice in the Antarctic could be similarly investigated by flying a Hercules aircraft close to the ice surface. This made the cover page of *Nature* in 1988. For that matter, Bill instrumented out the Erebus Ice Tongue extending many kilometres into McMurdo Sound to measure its vibrational properties, hoping to be able to predict when the glacier-fed ice tongue would break away.

For Bill science was a marvellous adventure, and he was great fun to work with. On one occasion we were testing a Pb-extrusion damper in the drop tower ('Twiggy') at Auckland Engineering School on Symonds Street. A weight was dropped down a column stretching the full length of the 12-storey office tower to smash onto the damper at about 100 km/hr. After the first deafening impact, Bill turned to me and said 'Cor, this is lethal. What's more it's...' and here he searched for the right word, 'dangerous'. Like so many interactions with Bill it was very funny at the time. Actually this experiment confirmed that these Pb-dampers displayed essentially the same behaviour over a million-fold range of strain rates.

As noted, WHR became Director of PEL. In this position he initiated a set of management reforms that, if extended throughout the DSIR, might have saved it from being disestablished in 1992. Before these reforms, we had little idea what it cost internally to carry out any activities. By introducing project systems and project accounting (all very obvious nowadays) it quickly became apparent that some activities were too costly to maintain. And Bill was brave enough to terminate a number of these.



Bill invested heavily in our discovery of high- T_c superconductors, taking the full risk as far as DSIR Head Office was concerned. In the early days he and I trekked around the boardrooms of many of New Zealand's leading companies, giving demonstrations and discussing the commercial opportunities. This led eventually to the formation of partnerships that are still in place more than twenty years later.

Not long after this Bill suffered a brain haemorrhage that left him seriously incapacitated. But his fighting spirit saw him back on campus the following year developing his dampers commercially. He set up Penguin Engineering Ltd (a fond reference to the PEL he once directed) and in 1995 he founded Lower-Hutt-based Robinson Seismic Ltd, which is recognised around the globe as a leading innovator in seismic protection and damping devices.

WHR was awarded the Cooper Medal in 1994 and New Zealand's top science and technology honour, the Rutherford Medal, in 1998. He was also awarded the Mechaelis Medal for Physics, an honorary DSc, and both a Fellowship and Gold Medal for Technology of the Royal Society of New Zealand. In 2007, he was appointed Companion of the Queen's Service Order for services to engineering.

I like to think that Bill Robinson has made New Zealand's greatest technology gift to the world in his lead/rubber base-isolation dampers. As a generic technology, it now sits in more than US\$100 billion worth of buildings and structures around the globe. For a period, this type of technology was being incorporated into 70–80% of all new large buildings and structures in California and Japan. These dampers were proved to be highly successful in the 1994 Los Angeles earthquake and 1995 Kobe earthquake in Japan. Most famously in New Zealand his dampers sit under our national Te Papa Museum and were retrofitted into Parliament Buildings. Bill was affectionately known in Japan, China, India, Italy and Turkey both for his technology and his charm, and despite his physical challenges he travelled often in these countries for speaking engagements.

Bill Robinson was a warm, amusing and highly creative scientist, inventor and science manager. He is greatly missed amongst his peers, his family, his friends – and his clients and collaborators, who span the globe.

Dr Jeffery Tallon

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Letter to the editor

Phased New Zealand Superannuation?

Everyone knows that we live longer than a few decades ago, and that most of us have more years of active life before the inevitable sets in. Isn't it obvious that, as long as we are good and healthy, we should work at least part-time a couple of years longer? Or wouldn't it be a good idea for many of us to work a bit less, year by year, until we retire. Life expectancy is rising, and our general health is better than it used to be, and there are more job opportunities that do not require heavy physical work. So most of us could really work that little bit longer.

We all know that there is both good news and bad news about aging. Perhaps the Bad News is that the proportion of our population over 65 is increasing all the time, thus increasing the cost of supporting us. This increased aging is sometimes called the Old-Age Dependency Ratio (the number of elderly people at an age when they are generally economically inactive, compared to the number of people of working age). It continues to rise, and for most countries is expected to be 40–50% in a few decades. Ouch! At the same time, the younger section of our society is correspondingly decreasing, and they are paying the taxes to support us.

But the Good News is that the older of us have, on average, more years of active life. So life expectancy is increasing, and so is our health. If we factor this in (and let's call it Prospective Old-Age Dependency Ratio, or POADR for short), the POADR

is rising at only about half the above rate. So that is good news which we should use.

Well, maybe I should declare my position a bit more. I am now 72 (shudder) but still work (officially) 40% time. Until I was 70, I declined to register for New Zealand Superannuation (NZ Super) because I was still working. There were other stages of my life when our family had much greater need of public support than then. Well then, let's think sensibly about some options

So my suggestion is three-fold.

Part 1. Eligibility at age 64 for those in real need of it

We are civilised, and civilised societies look after all their members. To help show that we are serious about supporting everybody who needs it, we could lower the age of eligibility of NZ Super by a year – to age 64. Only those on some form of disability pension would go on to the NZ Super at that age. However, it is important that we reiterate to everyone that a civilised society looks after everyone who has a real need. There is no additional cost from this move – but it is making an important point about a civilised society.

Part 2. Phasing in NZ Super over 4 years

Rather than changing the age of basic eligibility, I would prefer a phased increase in the proportion of NZ Super be the 'norm',

while retaining eligibility for 100% NZ Super if not working. A couple of schemes are given below.

Part 3. Reward those who delay taking NZ Super until they are at least 70

Some people are happy to put off registering for NZ Super for several years; they are still working constructively and happily. This could be encouraged, and I think it would be worth a good reward. For those who ‘opt out’ from receiving a benefit until they are least 70, then an additional one year’s NZ Super would be both good and affordable. It is affordable because, even with it, they have saved us four years of public funding. How it is spent would not be the government’s business, but one possibility I could imagine would be to do some modifications to houses so that there is easier access as we get older. No matter what, it has saved us all significant funding, and is well worth a reward.

Yes, there are those who might be aiming to opt out of taking NZ Super, but then things go wrong: their health gets worse, or the financiers cause a major slump and jobs dry up. They can still just register and pick up immediately from the appropriate point for their age group. None of us knows precisely what the future holds for us, so the in-built flexibility of the system is important.

However, I do not think that it is a sensible (rational?) use of public funds to give money to people who are working more or less full time. As such, the age of receiving NZ Super need not be maintained at what was appropriate 50–60 years ago.

If we are working longer, there will have to be some safeguards built in to check we are still up to it. I know of one disastrous case where one unfortunate individual had lost his short-term memory, covered up pretty well, but the longer term the results were fairly disastrous for his employer. So if we are going to keep working somewhat longer, at least part-time, then we do need safeguards that productivity and innovation are maintained. Perhaps we don’t need to do exactly the same job as earlier – lots of people might be glad of a little less responsibility – retiring gently.

From experience, I think that many people do not like sudden big changes. We all anticipate something of what the future

might hold for us. So for the majority, one option is to establish a steady transition, where we change the amount of NZ Super the majority will get as they age. Perhaps it could be as follows:

	65	66	67	68	69	sum
2012	1.0	1.0	1.0	1.0	1.0	5.0
2013	0.8	1.0	1.0	1.0	1.0	4.8
2014	0.6	1.0	1.0	1.0	1.0	4.6
2015	0.6	0.8	1.0	1.0	1.0	4.4
2016	0.6	0.8	0.8	1.0	1.0	4.2
2017	0.4	0.8	0.8	1.0	1.0	4.0
2018	0.4	0.6	0.8	1.0	1.0	3.8
2019	0.4	0.6	0.8	0.8	1.0	3.6
2020	0.4	0.6	0.6	0.8	1.0	3.4
2021	0.4	0.4	0.6	0.8	1.0	3.2
2022	0.2	0.4	0.6	0.8	1.0	3.0

However, I think it’s probably better to get it over and done with. I would prefer the following.

	65	66	67	68	69	sum
2012	1.0	1.0	1.0	1.0	1.0	5.0
2013	0.8	1.0	1.0	1.0	1.0	4.8
2014	0.6	0.8	1.0	1.0	1.0	4.4
2015	0.4	0.6	0.8	1.0	1.0	3.8
2016	0.2	0.4	0.6	0.8	1.0	3.0

This is simpler and faster, and on average results in the same average 2-year rise in the average age at which most of us get NZ Super. But remember, there are those on Part 1 who need it earlier, and those on Part 3 who put it off. Let’s have a sensible discussion. The world is changing, and we do have a brain.

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David has asked members for comment on his views on New Zealand’s Superannuation, which the Association will be pleased to publish.

Editor

Science restructuring raises serious issues

I read with interest in *New Zealand Science Review* [Vol 68 (2,) 2011] the above article originally written by Dr Peter Pockley in 1992. Being based in Australia, he made frequent reference to CSIRO in discussing the then current break-up of DSIR into ten Crown research institutes. I appreciate your reprinting it now at a time when mergers of the CRIs have been discussed.

In 1992, Dr Pockley focused, in part, on the costs of restructuring and the on-going administration of distinct institutes.

... I asked how much it will cost for the creation of separate boards, premises and administrations for the 10 Crown Research Institutes

If [a single organisation] had been structured in separate divisions or institutes along 'sectoral' lines similar to the CRIs, the organisation would have shared common services and existing buildings and avoided the costs of setting up separate CRIs.

Further, in a note appended to this reprint, Dr Pockley now writes:

... if the suggested amalgamation of CRIs into three 'mega' units is an improvement on the earlier, literal decimation of the DSIR, why not go the whole hog and re-create a single, wide-ranging national research organisation (like Australia's enduring CSIRO)...

We all share concerns about the overhead costs of running Crown-funded science, whether at the Ministry or institute level. However, it is important that assumptions made about cost structures are tested when they can be.

In this context I wish to point out that perusal of the 2009/10 Annual Reports of the present eight CRIs reveals they operated with proportions of staff categorised as 'Management and General Support' varying from 17% to 24%, with the overall average being 19%. These staff are differentiated from the majority of staff who are categorised as 'Research and Research Support', and so can be understood to be what scientists would refer to as 'administrative overheads'. While CRI sizes range from 317 to 824, with an overall total of 4127 staff, inspection reveals that there is no correlation ($R=0.025$) of administrative overheads with institutional size.

Following Dr Pockley's comparison with CSIRO, perusal of that organisation's Annual Report for 2009/10 reveals that the proportion of staff categorised as 'General Services, Administrative Support, and General Management' is also, perhaps remarkably, 19% of CSIRO's total 6680 staff.

It is important to note these comparable proportions of administrative effort. The proportionality would appear to apply to a much larger number of staff than in any CRI, and it supports the idea that the proportion of effort spent on administration is not necessarily smaller in a larger institution. It points to other factors, such as organisational culture, or perhaps geographical distribution, as being the determinants of the proportion of effort spent on administration.

Most importantly, it shows that for the CRIs there is no strong argument to create larger organisations solely on the basis of an assumed gain in administrative efficiency.

Arguments, if made at all, about mergers of CRIs or their size must therefore be based on other criteria. Campbell *et al.* [*McKinsey Quarterly*, June 2011], for example, propose the consideration of three questions to determine the merit for centralisation of management:

- (i) Is it a legal requirement, for example, in terms of financial reporting, or health and safety?
- (ii) Does it add significant value? For CRIs this could be financial value (for example, a 10% increase in retained earnings for investment in capital equipment) or scientific value (for example, opening of new science pathways for the benefit of New Zealand).
- (iii) Are the risks low, for example, of business rigidity, reduced motivation, bureaucratic hierarchy, and distraction?

Any restructuring of the science system should be considered under criteria such as these.

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Bruce W. Hayward, Graeme Murdoch and Gordon Maitland

Volcanoes of Auckland: The Essential Guide

Review by Hamish Campbell, Senior scientist, GNS Science, Lower Hutt
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Essential? A guide to a bunch of volcanoes in Auckland? I dashed home with this book safely stowed in my briefcase, feeling dubious. To be essential means affecting the essence of something – that which defines its very being, that which makes it and is perforce important. It can also mean absolutely necessary. I tentatively dipped into the book over my usual refreshing mid-afternoon cup of tea with the children safely stowed from another day at school. Such is my routine.

I was gripped from the start and could not put it down. I read it all in two sittings – one in daylight the other in bed – and thus I found my only serious criticism of the book's presentation. The pale grey font reserved for figure captions is best viewed in daylight and proved almost invisible in the soft light afforded by my bedside lamp. I imagine that publishing houses like Auckland University Press never sleep, so this failure probably remains to be market-tested.

The same (i.e. never sleeping...) may be true of the senior author, who is very well-known in both New Zealand and international earth science. His 'output' is prodigious and always first class. He has carved a niche with his expertise in paleontology and micropaleontology in particular, specialising in the study of foraminifera, single-celled animals that live in water and are an incredibly important lower link in the food chain. He uses quantitative analysis of mainly fossil foraminifera but also modern species in solving geological and environmental problems. In so doing, he has become a natural science megastar who has championed the worlds of conservation and environmental change.

This book, no doubt largely researched and executed in his spare time, is what we have all come to expect from Bruce Hayward: well-organised, focused, balanced, thorough, scholarly. Furthermore, it is very easy to read and comprehend. It represents substantial commitment and attention to detail over many years, building on the work of two earlier generations of geologist, namely Ernie Searle and Les Kermode, to whom the book is dedicated. It has that feel of being mature, up-to-date, authoritative, complete, and it leaves the reader well-satisfied and very pleased to own a copy. To be both content and smug... what more could you want? To be informed and also stimulated, perhaps. Yes, these attributes as well!

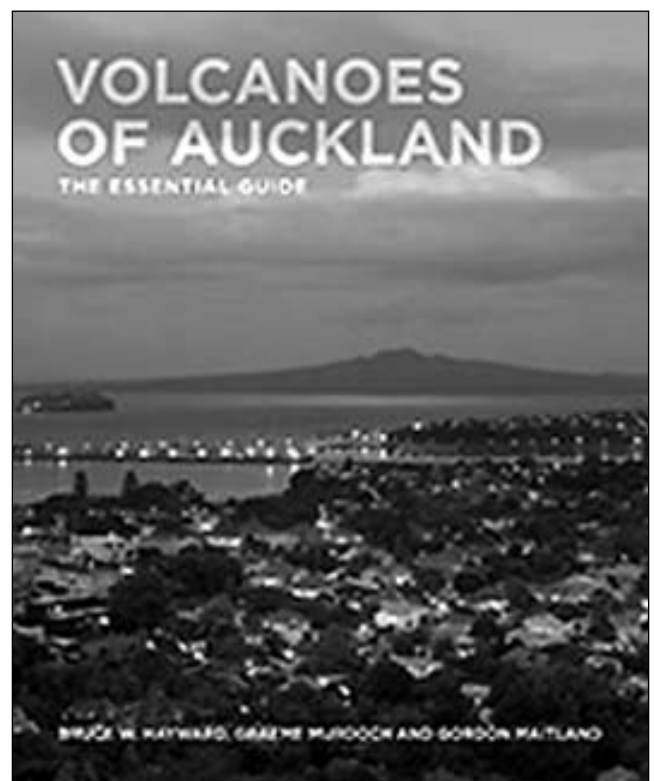
The book is in three parts. The first is a comprehensive geological account of what is known about the Auckland Volcanic Field and in particular the nature of the volcanism; the what, when,

how, why, who, and the future. The second is all about 'Human Interactions with Auckland's Volcanoes' and it is in this part that we have Graeme Murdoch's substantive and fascinating account of pre-European Māori connections with the Auckland Volcanic Field. The third is a 'Guide to Auckland's Volcanoes', an illustrated account of all 50 volcanoes that collectively comprise the Auckland Volcanic Field. This third part is 122 pages long and is neatly organised geographically into volcanoes of the 'Waitemata Harbour and North Shore', 'Central Auckland', 'Eastern Auckland' and 'Southern Auckland'.

The main text finishes with consideration of 'Incorrectly Identified Volcanoes' and 'Waitakere – Auckland's Oldest Volcano'. And as with any book worth its salt, it comes with a Contents page, Introduction, Glossary, Selected Bibliography, Acknowledgements, and an Index.

The book is superbly illustrated with coloured maps supplied by Geographx, aerial photographs taken by Alastair Jamieson in 2009, and supported by other photographs and diagrams from various named sources and not least Bruce Hayward himself. I counted at least 364 photographs all up, of which about 68 are new aeriels. Many are intriguing historic photographs that have been carefully selected by Gordon Maitland from the Pictorial Collection at the Auckland War Memorial Museum. There are 44 maps and 20 diagrams. All illustrations are pertinent, all relevant, all revealing. I found little wanting, although the professional geologist in me wishes there were a more formal and closer photo of Les Kermode. By the way, I was struck

Hayward, Bruce W.; Murdoch, Graeme; Maitland, Gordon 2011. *Volcanoes of Auckland: The Essential Guide*. Aerial photography by Alastair Jamieson. Auckland University Press, Auckland. ISBN 978 86940 479 6 About 27 x 22.5 cm, 234 pages, 364 photographs, 44 maps, 20 diagrams \$NZ 59.99



by the uncanny similarity in the faces of Sir George Grey and George Fowlds on p.85.

As with much of arable New Zealand, Alastair Jamieson's fine aerial photographs reveal fine sculpturing of many if not all of Auckland's soil-clad grass-clothed volcanic cones by the fancy footwork of that other mammal, sheep. So commonplace to us kiwis but not so to those people from sheep-less countries. Some explanation for non-kiwis would be helpful in a second edition.

The editor in me struggled hard to find any mistakes of any sort, and failed. This handsome book is damned near faultless and I have to conclude that it is indeed essential: it is absolutely necessary. To know New Zealand, it is necessary to embrace and know Auckland. Every New Zealand home should have this book.

Volcanoes of Auckland: the Essential Guide does fine justice to Auckland and its 'unique' identity as a major city built on an active volcanic field. It expertly explains and sets the scene for a broad non-geological public audience.

In so doing it also describes, perhaps unintentionally, an aspect of the industrial history of a typical modern city. It just happens to be the city of Auckland, founded in the mid-1800s.

I suspect that this book will be snapped up for higher education purposes to be used by students not so much in earth sciences but of physical geography, environmental law, conservation studies, urban design and planning, landscape architecture and Māori studies. Why? Because it is all about construction and development of a city in a highly desirable bit of real estate through quarrying (mining) of its immediate landscape: the 'essential' exploitation of relatively easily-won rock materials from many of its iconic and not-so-iconic volcanic cones.

The authors have acted with restraint in being as non-judgemental as they possibly can be with respect to 'town planning' decisions over the years, but nevertheless a constant conservation message is discernible and well-expressed. To this end I especially like the section on p.89 on 'Restoring Damaged Volcanoes'. Why not? And on p.90 it is suggested that this book may serve as a substantive document in the seeking of World Heritage Status for the Auckland Volcanic Field.

On a philosophical note, wisdom suggests that we humans are only really involved in two principal activities: one is growing and the other is mining. A third major activity might be conservation: keeping things as they are for posterity.

I think that this book is a valuable account, text-book even – and perhaps unintentional – of the tension between exploitation through mining and conservation that pervades modern sophisticated civilised societies everywhere. In this regard this book provides substantive insight.

It has to be said that we Kiwis are rather schizophrenic when it comes to mining: we are happy to purchase and use modern technology (cars, computers, phones, machines, etc.) that are made from materials, particularly metals, that are largely won from mining activities in foreign countries, but we are loath to mine in our own country, unless it is absolutely essential. I am thinking of materials necessary for 'economic and social infrastructure' such as roads, buildings, etc. This is what Auckland has done. What else could it do?

This question is not addressed in the book, and perhaps it should be in a second edition. Where is Auckland getting its rock resources now? I imagine that Auckland is now sucking in 'essential' rock resources for construction purposes from many other quarries (mines) throughout the North Island, and some of them at considerable distance away. How much? What is Auckland's annual consumption? I wonder, and at what environmental cost? This book helps us understand that quarrying (mining) is an essential attribute for growing cities. Perhaps Bruce might tackle Wellington next.

To end on a geological note, it is evident from the book that there is still much to learn about the Auckland Volcanic Field. For instance, precise timing of eruption has only been established for a few volcanoes; 32 of the 50 have some age control, but for the majority the age remains imprecise. Consequently, as yet we earth scientists cannot present a really accurate eruption sequence. Secondly, we still have an uncertain understanding of why the volcanic field is where it is, and what factors control the distribution of volcanoes: it appears to be rather random but may reflect an underlying 'structural control' (see p. 31). Thirdly, we have little understanding of the extent of volcanic rock at depth; what this book is all about are the visible features at the surface. Fair enough, but in time geophysical research may enable us to visualise lavas at depth that became 'frozen' on the way up and hence never made the surface.

In a second edition, a diagram showing how sea-level has changed through the past 250 000 years would be useful. This is the assumed age of the Auckland Volcanic Field, and it spans the past two to three glaciations. In many of the descriptions sea-level is referred to at the time of eruption and it is especially relevant to the lower-lying explosion craters.

This book is inspirational in many ways and I now wish that something similar might be produced for the volcanic cones in the Dunedin and Waipiata Volcanic Fields in Otago, or the volcanic field preserved in the Chatham Islands.

The authors should be proud of this book, as should the Auckland Council, who helped sponsor its production. It is a magnificent contribution. Above all it highlights the relevance of earth science to modern New Zealand society, to our economy, and to environmental conservation.



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