



Exercise & Sport Science as a rigorous science education: A discussion for teachers of the discipline

Final Report to Ako Aotearoa, New Zealand Centre for Tertiary Teaching Excellence

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Abstract

A previous study that included a focus group with a final-year cohort of Bachelor of Science students majoring in Exercise & Sport Science at a New Zealand university reported that none of the participants considered themselves to be 'scientists' (Hughes, 2010). An international review of Exercise Science programmes by Ives and Knudson (2007) agree that graduates of undergraduate programmes in Exercise Science are not as prepared as they should be in order to provide professional and comprehensive advice on exercise and human performance.

The purpose of this project was to guide tertiary teachers of Exercise & Sport Science in ways that could improve the rigor of Exercise & Sport Science as a scientific discipline and lead to better learning outcomes for undergraduates. The study set out to firstly define a rigorous science education at an undergraduate level. This was a qualitative study involving twenty-two experienced tertiary educators from a spectrum of science disciplines, countries and institutions. From the results of phase 1, six criteria for a rigorous science education were formulated from a process of thematic analysis.

The objective of phases 2 and 3 of the project was to analyze Exercise & Sport Science in the context of a rigorous science education. In phase 2, interviews were undertaken with lecturers from inside and outside the Division of Exercise & Sport Science. Qualitative data was analyzed through a process of thematic analysis. In phase 3, the six themes were used to develop a quantitative survey. This was circulated among graduates and lecturers of Exercise & Sport Science from one New Zealand university as a case study. The instrument underwent validity and reliability testing. Survey data was analyzed using SPSS; including descriptive statistics, along with independent and paired samples t-testing.

The key observation from this study is that Exercise & Sport Science has the potential to be a rigorous science education. In some instances, this was already seen to be the case. However, in other instances, there was seen to be room for improvement. A key recommendation is for programmes purporting to be Exercise & Sport Science to undergo an audit against the six teaching-oriented criteria proposed in this study, which have been labeled: Programme & Pedagogy; Generic Skills; Acquiring Knowledge; Applying Knowledge; Challenging Knowledge; and Investigating Knowledge. It is suggested that programmes unable to meet these criteria are differentiated from those that are.

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Background

The history of Exercise & Sport Science

The origins of exercise science date back to around 450 BC when Greek scholars such as Hippocrates, Plato, Aristotle and Socrates explore physical activity in a scientific fashion (Berryman, 2003). The field of Exercise Science as an academic discipline has originally arisen from the study of Physical Education (Potteiger, 2011). It gained momentum through the physiologic laboratory at Harvard University, which led to the establishment of the first college degree programme in Physical Education. Graduates of this programme received a Bachelor of Science degree in anatomy, physiology and physical training (Potteiger, 2011).

This study focuses on the plethora of undergraduate degrees available in Exercise & Sport Science today and whether they merit the title 'Science'.

- University of Auckland, BSc majoring in Sport and Exercise Science
- Massey University, BSc majoring in Exercise and Sport Science
- University of Otago, Bachelor of Physical Education majoring in Exercise and Sport Science
- Auckland University of Technology, Bachelor of Sport and Recreation majoring in Exercise Science
- Waikato Institute of Technology, Bachelor of Sport and Exercise Science
- Southern Institute of Technology, Diploma in Sport and Exercise Science
- University of Canterbury, Bachelor of Education (Physical Education) papers in Exercise Science
- Universal College of Learning, Bachelor of Exercise and Sport Science
- Eastern Institute of Technology, Bachelor of Recreation & Sport designed for people aiming to become highly qualified professionals in exercise science

For the purpose of this study, we have taken our definition of Exercise & Sport Science from (the British Association of Sport & Exercise Sciences (BASES) as the application of scientific principles to the promotion, maintenance and enhancement of sport and exercise related behaviors (BASES, website). The sub-disciplines of Exercise & Sport Science are typically considered to be exercise physiology, biomechanics, motor control, and exercise / sport psychology (Exercise & Sport Science Australia, website). As an outcome of undergraduate education in Exercise Science, graduates should be able to assess, design, and implement individual and group exercise and fitness programs for individuals who are apparently healthy and those with controlled disease (Commission on Accreditation of Allied Health Education Programs, website).

Is Exercise & Sport Science a rigorous science education?

Exercise scientists publish in scientific journals, including some of the most prestigious. The esteemed science journal *Nature* regularly publishes articles from the exercise sciences including titles such as, ‘Obesity: Be cool, lose weight’ (Farmer, 2009); and ‘The role of exercise in PGC1alpha in inflammation and chronic disease’ (Handschin & Spiegelman, 2008). Smith (2002) cites the excellent Research Assessment Exercise (RAE) ratings achieved by Exercise & Sport Science in the United Kingdom; while Baldwin & Haddad (2010) report the results of a PubMed search with the word ‘exercise’, which retrieved 82,826 peer reviewed articles published in the past 10 years. This included 3836 papers linked to genetics; 7357 for obesity; 6312 for diabetes; 18,562 for muscle; 4038 for bone; 24,033 for metabolism; 4505 for nervous system; 6954 for hormones; 2644 for brain function; 3426 for circulation; 1281 for immune system; and 5734 for respiratory (Baldwin & Haddad, 2010).

Nonetheless, the scientific rigor of Exercise Science as a profession does not necessarily translate to a rigorous science education at an undergraduate level. Laylock, Smith & Liefeyth (2006) describe a demonstration conducted in a third year module, which contributes to the BSc (Hons) in Exercise & Sport Science at a university in the United Kingdom. While the Head of School, applauded the demonstration for its ingenuity given laboratory limitations, the tutor reported that the quality of quantitative data collected was compromised; and, while students displayed a level of engagement, they reported that it was “limited in terms of science” (Laycock, Smith, & Liefeyth, 2006).

Similar limitations were reported by a final-year cohort of Bachelor of Science students majoring in Exercise & Sport Science at a New Zealand university. It revealed that none of the participants considered themselves to be ‘scientists’ and that this was a label attributed to post-graduate students of Exercise and Sport. From discussion, it also emerged that none of the participants felt prepared to pursue a scientific career and, broadly speaking, did not aspire to do so (Hughes, 2010).

Tommy Boone, the founding President of the American Society of Exercise Physiologists, might argue that Hughes’s findings in New Zealand emphasize his point that an undergraduate education in Exercise Science is meaningless preparation for the workforce because the career opportunities for Exercise & Sport Science graduates do not require university degrees. Boone believes that students wanting a rigorous science education should major in Exercise Physiology because Exercise Science does not have sufficient scientific depth to warrant its continuation as a science and is, “nothing but physical education without the licensure” (Boone, 2010).

Based on their international review of Exercise Science programmes, Ives and Knudson (2007) agree that graduates of undergraduate programmes in Exercise Science are not as prepared as they should be in order to provide professional and comprehensive advice on exercise and human performance. However, in contrast to Boone, they argue that it is the, “narrowing of the exercise science curriculum to focus on exercise physiology, at the expense of other sub-disciplines in kinesiology” (pp 103, Ives & Knudson 2007), that has reduced the effectiveness of Exercise Science graduates. Their recommendation is that Exercise Science programmes should require an applied

biomechanics course that includes a laboratory component; and an advanced biomechanics course that is elective. In addition, the inclusion of at least one motor behavior course was recommended. Ives and Knudson's primary concern is that graduates of Exercise Science are not consistently the first-choice candidates for jobs in, "evaluating human movement and programming effective physical activity for all populations" (pp 108, Ives & Knudson 2007). There are two main sources of competition: (a) from people with less rigorous preparation and; (b) from graduates in other health sciences who have incorporated Exercise and Sport in to their training. Ives and Knudson conclude that Exercise Science must evolve to remedy this problem (Ives & Knudson, 2007).

Another point made by Ives and Knudson (2007), but more emphatically by Ammonette et al. (2010) and Smith (2008), is that Exercise Science educators need to focus on teaching evidence-based practice to students. Without this focus, the academic discipline of Exercise & Sport Science is said to have been infiltrated by the bias and misinformation found in the products and services coming out of the Exercise and Sport community today (Ammonette, English, & Ottenbacher, 2010; Smith, 2008). As a solution, Ammonette et al. (2010) cite the concept of Evidence-Based Programming (EBP), which arose in America in the early 1990's to address the lack of research evidence being used to make clinical decisions in the medical profession. In the context of Exercise Science, their paper advocates that the foundation of undergraduate programmes should be teaching students to: develop a question; find evidence; evaluate the evidence; incorporate evidence into practice; and re-evaluate the evidence. They emphasize that every class should involve evidence-based education so that, by graduation, students would have accumulated years of practice finding and evaluating research (Ammonette et al. 2010).

What is a rigorous science education?

In the European Commission publication entitled 'Europe Needs More Scientists' (Gago, 2004), the authors concur with the views of Ives and Knudson (2007), Ammonette et al. (2010) and Smith (2008) that university curricula should emphasize evidence-based practices. However, the report also highlights the need for evidence to be integrated with the more theoretical aspects of the discipline, thereby reassuring students of, "the 'reality' of their new understanding" (pp 107, Gago 2004). This point is supported by research in to effective teaching and learning in science at secondary school, which advocates that meaningful understandings are constantly developed by emphasizing the links between science knowledge and the real world (Tytler, 2003). In addition, Tytler advocates that students are actively engaged with ideas and evidence; science is linked to students' lives and interests; students' individual learning needs and preferences are catered for; assessment is embedded within the science learning strategy; the classroom is linked with the broader community; and learning technologies are exploited for their learning potentialities (pp 285, Tytler 2003). Tytler's research has been used to shape policy in Australia and, while it is directed at the teaching of science in secondary schools, his messages resonate at a tertiary level.

In the United Kingdom, the Quality Assurance Agency for Higher Education (QAA) publishes benchmark statements for every academic discipline. For example, on graduating with an honors degree in biosciences, students should: (i) be able to access bioscience information from a variety of sources and to communicate the principles in a manner appropriate to the programme of study; (ii) have ability in a range of practical bioscience

techniques, including data collection, analysis and interpretation of those data, and testing of hypotheses; (iii) have an understanding of the explanation of biological phenomena at a variety of levels (from molecular to ecological systems) and be able to explain how evolutionary theory is relevant to their area of study; (iv) be able to plan, execute and present an independent piece of hypothesis-driven work within a supported framework in which qualities such as time management, problem solving, and independence are evident; (v) have some understanding of ethical issues and the impact on society of advances in the biosciences, be able to record data accurately, and to carry out basic manipulation of data (including qualitative data and some statistical analysis, when appropriate); (vi) have developed basic strategies to enable them to update their knowledge of the biosciences (QAA 2007). However, as it happens, the QAA do not include Exercise & Sport Science in the benchmark statement for the biological sciences. Instead the discipline is listed in the Health, Leisure, Hospitality, Sport & Tourism benchmark statement. These graduates are expected to embrace arguably less 'scientific' but more nebulous skills, such as those required to "monitor and evaluate human responses to sport and/or exercise" (QAA 2008).

In New Zealand, undergraduate education is subject to quality assurance by the Committee on University Academic Programmes (CUAP) and the Institutes of Technology and Polytechnics Quality (ITPQ). In both instances, new programmes are required to undergo a peer review process, which means that proposals are circulated to subject area experts at each of the seven other universities; or at polytechnic level, to the nominated selection panel. Whether or not a programme merits the title 'science' is at the discretion of the review panel.

Rationale for current study

This study concluded that available literature goes some way to answering whether undergraduate programmes in Exercise & Sport Science provide a rigorous science education. From the literature, the authors predict that there is a high degree of variability in the standards of scientific rigor between programmes (and papers) pertaining to deliver the science behind sport and exercise. It is clear from the literature that this study is likely to find some significant areas for improvement; but also some great areas of potential.

The rationale for this study was to investigate current teaching practices in Exercise & Sport Science in New Zealand, concluding in a guide for academics of the discipline wishing to enhance the scientific rigor of their teaching. To this end, the present study set out to answer four research questions over the course of three phases:

- What constitutes a rigorous science education at a tertiary level?
- How are undergraduate programmes in Exercise & Sport Science currently being taught?
- Is our definition of a rigorous science education valid in the context of Exercise and Sports Science?
- Can we measure the frequency with which undergraduate programmes in Exercise & Sport Science are currently providing a rigorous science education?

1. Phase 1

Investigation to define what constitutes a rigorous science education at an undergraduate level

1.1. Methods

1.1.1. Ethics

Phase 1 of the project was evaluated by peer review and judged to be low risk. Consequently, it was not reviewed by one of Massey University's Human Ethics Committees. The Project Leader assumed responsibility for the ethical conduct of this research. However, participants were invited to direct any concerns about the conduct of the research to Professor John O'Neill, Director of Research Ethics, Massey University.

1.1.2. Qualitative Research

Phase 1 relied on qualitative research methods. Qualitative research is intended to understand, describe and sometimes explain social phenomena 'from the inside' (Flick, 2007). There are a number of different ways to approach qualitative research and, in Phase 1, the planned approach was to analyze the opinions of individuals relating to their professional practices. The research question driving this qualitative research was: What constitutes a rigorous science education at a tertiary level?

1.1.3. Recruitment of Participants

Potential participants were selected using a maximum variation sampling technique (Miles & Huberman, 1994). The objective was to identify a minimum of 5 international, 5 national and 10 internal science educators from the widest possible range of science disciplines and levels of academic experience.

Potential participants received an email from the Project Leader, accompanied by an Information Sheet for further information. Participation was expressly voluntary and, those who chose to participate would not receive compensation for their time. The deadline for participation was initially flexible and finally set as 30 June 2010, which was six weeks from the date of invitation. The following science educators chose to participate:

International

- Professor Timothy Noakes, Department of Human Biology, University of Cape Town, South Africa
- Professor Mark Hargreaves, Head of Department of Physiology, University of Melbourne, Australia
- Dr Simon Brown, Department of Biochemistry, University of Tasmania, Australia

- Sarah Harris, Director of Earth and Ocean Sciences, Carl Weiman Science Education Initiative, University of British Columbia, Canada

National

- Margaret Goldstone, Associate Dean of Academic Programmes (Science), University of Auckland
- Associate Professor Greg Anson, Head of Exercise & Sport Science, University of Auckland
- Professor Peter Molan, Department of Biological Sciences, University of Waikato
- Dr Paul Teal, School of Engineering and Computer Science, Victoria University of Wellington
- Dr Kirsty Fairbairn, Department of Human Nutrition, University of Otago
- Dr Ben Kennedy, Department of Geological Sciences, University of Canterbury

Massey University

- Distinguished Professor David Parry, Department of Fundamental Sciences, Massey University
- Distinguished Professor Gaven Martin, Pure Mathematics, Massey University
- Professor Frazer Allan, Head of Institute of Veterinary Animal and Biomedical Sciences, Massey University
- Professor Elwyn Firth (Doctor of Science), Institute of Veterinary Animal and Biomedical Sciences, Massey University
- Professor Tim Parkinson, Institute of Veterinary Animal and Biomedical Sciences, Massey University
- Professor Shane Cronin, Institute of Natural Resources, Massey University
- Associate Professor Kathy Kitson, BSc Programme Director, Massey University
- Dr Neville Honey, Institute of Molecular Biosciences, Massey University
- Dr Mark Waterland, Institute of Fundamental Sciences, Massey University
- Dr Chris Scogings, Department of Computer Science & Information Technology, Massey University
- Jenny McKelvie, Institute of Fundamental Sciences, Massey University
- Bill MacIntyre, School of Education, Massey University

1.1.4. Data Collection

Participants were asked to answer the question: “In your opinion, what constitutes a rigorous science education at a tertiary level?”. Intentionally, further guidelines were not provided in the hope that participant responses would be eclectic. In appreciation of participants’ time, they were advised to invest no more than fifteen minutes in their response. In terms of confidentiality, participants were reassured that their name would not be associated with their response unless special permission was granted. Participants were asked to send their response in writing via email to the Project Leader.

1.1.5 Data Analysis

The qualitative analytic method adopted was thematic analysis, which followed a six-step process documented by Braun & Clarke (2006): familiarization; generating initial codes; searching for themes; reviewing themes; defining and naming themes; producing the report.

Thematic analysis is a method for identifying, analyzing and reporting themes within data. A theme captures something important about the data in relation to the research question, and represents some level of patterned response or meaning within the data set (Braun & Clarke, 2006). In this study, thematic analysis followed an inductive approach, which can also be described as a ‘bottom-up’ approach. This means that the themes arose from the data, rather than from the researcher’s interests in the area.

1.2. Results

Our investigation revealed that the term ‘rigorous’ meant different things to different people; some of whom preferred not to place too much emphasis on the term in their response. However, all respondents provided a valuable contribution to the definition of a good science education from their perspective. From the thematic analysis of data emerged the following themes:

1.2.1. Programme & Pedagogy

It was said that, “the word ‘rigorous’ indicates the courses used in a science education programme will be the very best available”. Several respondents alluded to the overall notion of such programmes pushing the learner beyond what they started with while also maintaining a sense of enthusiasm about science that would leave them, “a voice for advocacy of science in society”.

Respondent: The most important thing about a ‘rigorous’ science education is that the student is more curious, more excited, more willing and more able to try to explain reality at the end of the education than they were at the start.

Respondents commonly recognized the important role of the lecturer in a rigorous science education. Lecturers’ demonstration of enthusiasm and passion for their field was noted; and that this was best achieved by lecturers with a true appreciation of science from themselves being actively involved in research. Several respondents commented emphatically on the importance of research-led teaching, for example:

Respondent: To summarise my opinions, the basis for a rigorous science education at tertiary level is that it must be taught by people who understand science and who are actively researching.

Evident “concern for students’ learning” was cited as a desirable attribute among lecturers; and that their student-centered teaching strategies should always be under review for continuous improvement. It was described by one respondent that this would involve lecturers planning for differentiated learning depending on the range of academic

ability among students. Another respondent acknowledged that learning should increasingly move away from, “a didactic style of teaching into a more self-discovery and enquiry-based model”. Or, in more direct terms from another respondent, “we need less talking by teachers and replace with maximal stimulation in inventive and fun ways of student thinking”. One expert summarized these messages:

Respondent: Learning in science education is rigorous when the learner is actively involved with reflecting and evaluating the key elements of the nature of science. Rigorous definitely does not imply 'passive / transmissive-type learning'.

Teaching methods aside, best practice among lecturers would also include careful planning resulting in well articulated goals and accompanied by, “meaningful assessment of learning aligned with articulated goals”. It was said that before, during and after assessment, students should receive constructive feedback to help them move forwards by lecturers who recognize and interact with them as individuals. In other words:

Respondent: Within an excellent science programme students should be supported by the provision of the following: good roadmaps to the programme and its direction and outcomes; excellent course advice and support as each milestone is attempted; students are individually noticed; there is excellent feedback on performance and assignments; staff who are knowledgeable, friendly, approachable and passionate about their field.

1.2.2. Generic Skills

It was noted several times that, “the purpose of an undergraduate science education is no longer simply to train that small fraction of the population who will become the next generation of scientists”. It was therefore deemed important by most respondents that a rigorous science education should include exposure to Generic Skills that would prepare the student for their future:

Respondent: Many science graduates do not use any discipline-specific knowledge in their working lives. If nothing else, this prompts the inference that transferrable skills are more valuable to the average graduate than all the science with which their teachers are so involved. Viewed in this light, a science degree is just the vehicle selected by a student for the delivery of transferrable skills.

One respondent cited Bloom’s Taxonomy, which defines three types of learning domains as (a) Cognitive: mental skills; (b) Affective: growth in feelings or emotional areas; and (c) Psychomotor: manual or physical skills. The respondent preferred to think of Generic Skills as proficiency in the ‘Affective Domain’. In concurrence with other respondents noted, this domain would include a wide range of attributes for students to develop, including: professional communication and presentation skills; the ability to work both independently and as a team; awareness of themselves and others; the confidence to manage their own learning; analytical thinking skills that can be applied to problem solving; and good organizational skills including time management.

1.2.3. Acquiring Knowledge

A paradox lay in discussion about the acquisition of knowledge. On one hand, it was noted that, “there is a huge mass of facts that have to be understood and assimilated” as part of a rigorous science education. But, on the other hand, “rigor is not an endless list of facts that covers every bit of knowledge”. What most respondents agreed is that a rigorous science education required a foundation of knowledge from across the fundamental sciences and mathematics, alongside the opportunity for ‘deep preparation’ in one discipline. One respondent reflected specifically on the first-year of undergraduate programmes:

Respondent: It may be unfashionable in this age of proliferating sub-disciplines, but I believe that students are ill-served by premature specialization. Inevitably, then, I favour a common first year of mathematics, physics, chemistry and a fourth (broad) subject, and that this should be the clear basis of the work in subsequent years.

However, a couple of respondents noted that students often objected to being taught foundation knowledge from across the fundamental sciences, preferring to focus exclusively on their chosen discipline. For example, one respondent recalled the “tragedy” of an exceptional physics student whose knowledge of simple chemistry was, “appallingly low”. The following respondent advocated that a rigorous science education would take a hard-line approach to ensuring students acquire foundation knowledge from across the fundamental sciences:

Respondent: Students have been known to try to avoid the ‘hard’ sciences such as mathematics, physics, statistics and chemistry... Even though the ‘hard sciences’ provide them with the skills that they will ultimately require if they are to perform satisfactorily in the career they will often prefer to do something easier. However, I believe that the student will ultimately be grateful that they were made to take what an experienced science education leader deemed ‘best’ for them irrespective of the anguish that such papers might have inflicted upon them at the time.

Particular emphasis was placed on mathematics and statistics by some respondents. One alluded to a perception that student competency in mathematics is waning. Overall, there was a consensus that a rigorous science education would place a high importance on achieving, “a level of mathematical and statistical capability to permit manipulation and assessment of scientific data”. One respondent illustrated his point with a poignant quote:

Respondent: I remember this from my childhood, attributed to Lord Kelvin: “I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be”... A rigorous scientific education is one which equips students with mathematics.

1.2.4. Applying Knowledge

Several respondents commented that a rigorous science education would, “presumably mean that one has enough understanding of principles to... be able to apply those principals in practice”. It was suggested that this could begin with the use of “real world” examples to ensure that, “the relevance of fundamental knowledge is understood early in a curriculum”. Another respondent went on to note the value of observing academics themselves in, “arenas other than the classroom / lecture / practical so they see other things in us and about what we do... the different environment provides a different perspective on application”. However, respondents concurred that students in a rigorous science programme would eventually gain experience of translating theory in to practice themselves, either in a laboratory or field environment:

Respondent: *A rigorous science education includes giving the students education and experience in practical work in the subjects they are studying so that they develop a basic competence in the commonly used techniques in these subjects and in using instruments commonly used in these subjects.*

As part of an education in how to apply knowledge, the importance of Generic skills related to science was raised; notably, the ethical, cultural and social issues surrounding science, especially implications of the Treaty of Waitangi. Equally, the ability to communicate science to potential clients using an appropriate degree of scientific language combined with empathy for their concerns:

Respondent: *Another aspect of science education I find also very important is to be able to articulate as many concepts as possible in plain English. Communication of scientific concepts is often important to explain findings to people who might not otherwise believe them because the science involved is a mysterious ‘black-box’.*

1.2.5. Challenging Knowledge

Having talked about the acquisition of knowledge, it was described by one respondent that, “to some extent there is no knowledge in science, just a working hypothesis which is currently the best explanation of a series of phenomena”. For this reason, another respondent indicated that a rigorous science education should nurture students who “do not accept anything as a final truth” and “continually question the basis for their beliefs”. The same respondent went on to use a poignant quote to illustrate the point:

Respondent: *To borrow the famous phrase, at least 50% of what we teach is wrong but the problem is we don't know which 50% it is. Thus the first step to a proper scientific education at tertiary level is that students must learn that there is no absolute truth and that our perception of truth changes all the time.*

However, the personal experience of one respondent who trained to become a medical doctor highlighted that some science education programmes, “do not include any emphasis on the scientific analysis of published work”. Instead, he observed a trend among medical doctors to, “follow it [information] blindly on the assumption that it must be true

because they were told it by some important professor”. Several other respondents commented on the importance of students being willing and able to challenge information, “ however eminent their teacher may be”.

Many respondents agreed that an understanding of ‘the scientific method’ is required before a student can effectively challenge scientific knowledge; and is therefore “at the heart of a rigorous science education”. In summarizing plentiful comments by respondents, ‘the scientific method’ could be defined as the sourcing of scientific information, followed by the evaluation of published hypotheses, methodologies, data analyses and results. The overall objective is the ability to, “recognize and understand research excellence”. In other words:

Respondent: A rigorous science education includes showing students how what is now taken as facts has been deduced from observations and the results of experiments, and how theories have been proved to be correct through testing by experiments: and through this, getting students to be able to judge whether or not claims are adequately supported by evidence.

1.2.6. Investigating Knowledge

This final theme accepts that a student can be trained to apply knowledge (1.2.5) and challenge knowledge (1.2.4) without ever having investigated knowledge themselves. However, this final theme advocates that students should develop their own experimental skills as part of, “a logical progression towards being an independent science researcher”. One respondent concluded that independent research is integral to a rigorous science education:

Respondent: The quickest way to discover the complexity to discover truth is to undertake research. This very quickly shows one that the search for truth is a complex undertaking and which is strewn with errors and potential biases. Thus I would say that a rigorous science education at a tertiary level must include undertaking some research projects, preferably of novel information.

The development of experimental skills can equally be described as the ability to execute the ‘scientific method’ independently, with the objective of students becoming, “confident and capable of discovering”. Several respondents noted the importance of being able to construct a testable hypothesis; design a rigorous methodology to test the hypothesis; gather and analyze data; and “interpret results against the proposed hypothesis to produce a justified conclusion”. In other words:

Respondent: The ability, from a foundation of factual information, to formulate testable hypotheses; to understand the need for rigorous testing of hypotheses and be able to plan and execute such testing; to understand the importance of noting and analyzing unexpected results and the validity of both qualitative and quantitative observations.

Finally, a couple of respondents reflected on the epitome of a rigorous science education. It was said that students should not only prepare themselves to apply knowledge but prepare themselves to, “discover for people and

society”. One respondent asserted that the, “generation of new knowledge is a core societal duty of a graduate”. Another respondent concluded:

Respondent: *We can be quite confident that the discoveries of science in the next 50 years will be even more dramatic than those of the last. Our society will change significantly. Our tertiary education degrees in science must prepare students to contribute to... these advances.*

2. Phase 2

Qualitative analysis of the scientific rigor of undergraduate programmes in Exercise & Sport Science

2.1. Methods

2.1.1. Ethics

Phase 2 was reviewed and approved by the Massey University Human Ethics Committee: Southern B, Application 10/36. Those invited to participate in this study were under no obligation to participate. Those choosing to participate were guaranteed anonymity and that individual data would remain confidential. Participants were instructed to direct any concerns about the conduct of the research to the Chair of Massey University Human Ethics Committee.

2.1.2. Qualitative Research

Phase 2 relied on qualitative research methods. The research question driving this qualitative research was: How are undergraduate programmes in Exercise & Sport Science currently being taught?

2.1.3. Recruitment of Participants

Phase 2 recruited participants from a New Zealand university as a case study of the Exercise & Sport Science community in New Zealand. A case study is a common research method in the social sciences; and this study is not the first to have used students, graduates and lecturers from a New Zealand university as a representative sample of a specific academic community in New Zealand (Martin & Hughes, 2009). Nevertheless, this study recognizes that the Exercise & Sport Science community at one university is a convenience sample, which is guaranteed to be representative of neither the New Zealand nor the global community, but which was the only feasible way to proceed in an attempt to learn about the community with limited funding.

The first participant group recruited in Phase 2 were lecturers. This group was a total population sample meaning that all lecturers of Exercise & Sport Science at a New Zealand university were invited to participate (n = 12). The second participant group were lecturers from within the College of Sciences but outside the Division of Exercise & Sport Science who teach Bachelor of Science (BSc) undergraduates majoring in Exercise & Sport Science. The sample invited to participate were known to teach substantial numbers of Exercise & Sport Science undergraduates each year (n = 8).

Potential participants received an email from the Project Leader, accompanied by an Information Sheet for further information. Participation was expressly voluntary and, those who chose to participate would not receive compensation for their time. Those wishing to participate were invited to schedule a convenient date and time with the Research Assistant via email. Seven academics from the Division of Exercise & Sport Science; and four academics from outside the Division chose to participate.

2.1.4. Collection of Data

Data was collected via interview with the Research Assistant. Participants located in Palmerston North were interviewed during face-to-face meetings, while participants located in Albany and Wellington were interviewed over the telephone. Each participant provided written consent before commencement of their interview. Each participant consented to their interview being digitally recorded. Prior to the interview, each participant had received the following interview questions, which are based on appreciative enquiry:

Lecturers from within the Division were asked to reflect on a rigorous science education at an undergraduate level in the context of Exercise & Sport Science:

1. Thinking of activities that do happen frequently, what would you continue?
2. Thinking of best practice, what would you like to start / see more of?
3. Is there anything that you would like to stop / see less of?
4. Thinking of any changes that you would like to make, what might be the limitations?
5. In summary, to improve the rigor of Exercise & Sport Science discipline, what would you prioritize?

Lecturers from outside the Division were asked to reflect on a rigorous science education at an undergraduate level in the context of the students that major in Exercise & Sport Science who are enrolled on their papers:

1. What attributes / skills would you like to continue seeing?
2. What attributes / skills would you like to start seeing / see more of?
3. Are there any attributes that you would like to stop seeing / see less of?
4. Thinking of any changes that you would like to see, what might be the limitations?
5. In summary, to improve the rigor of Exercise & Sport Science discipline, what would you prioritize?

2.1.5. Data Analysis

Interviews were transcribed by an administrator from the College of Sciences who had signed a confidentiality agreement. As in Phase 1, the qualitative analytic method adopted was thematic analysis, which followed a six-step process documented by Braun & Clarke (2006).

2.2. Results

From the process of thematic analysis in Phase 2, the most apparent themes closely reflected the same six themes that were evident in Phase 1:

2.2.1. Programme & Pedagogy

'Programme and Pedagogy' includes high-level reflections on the Exercise & Sport Science programme, those who teach it; and the overall capacity to deliver a rigorous science education. To summarise, in principle, Exercise & Sport Science can provide a rigorous science education; however, in practice, it often does not. One interviewee said, "*We are training exercise scientists but I don't necessarily see quite enough of the rigorous science*".

Pedagogy

Lecturers of Exercise & Sport Science were praised. One interviewee from outside the Division of Exercise & Sport Science ('The Division') described the team in Albany as, "*probably the most enthusiastic bunch of guys you could ever have for their subject, especially with all their vast knowledge*". The team was also reported to lead their teaching with research that applies, "*very good scientific rigor*". Another interviewee asserted that research-led teaching occurs frequently in the Division, saying:

Interviewee: The paper that I teach, we may look at say the muscular system. Instead of quoting out of a text book, I usually point to Hans Edge who used to teach here and give them an example of some of the muscle biopsy studies that he did and some of the results that he got.

Programme

The perception of New Zealand undergraduate degrees were compared to the perception of those overseas. After three years of undergraduate study, British students earn an honors degree; whereas New Zealand students earn a bachelors degree. Three interviewees agreed that New Zealand graduates require a fourth year of postgraduate study to attain the same level of knowledge and expertise as British graduates. In the context of Exercise & Sport Science, one interviewee said:

Interviewee: If you were to take a graduate from the UK, a graduate from the US and a graduate from New Zealand in Exercise & Sport Science I have a feeling that I wouldn't give it (a job) to the New Zealand graduate.

Another comparison made between New Zealand and the United Kingdom regarded quality assurance. One interviewee reported that a quality assurance audit in the UK requires academics to present five years of paperwork to show: how courses had developed over time; how individual papers had developed; and how student, graduate, industry and employer feedback had been taken in to account. In contrast, it was reported that a teaching audit does not exist in New Zealand and, consequently, one interviewee said:

Interviewee: *I have been here five years, nearly six, and nobody has said, “that is not really what goes into a biomechanics programme”. I could have changed it; I could be teaching the biomechanics of knitting and nobody would have questioned it by now.*

In the absence of oversight, several interviewees commented on the evolution of Exercise & Sport Science programmes. It was said by one interviewee, “*we have borrowed bits from physiology and borrowed bits from nutrition and borrowed bits from chemistry and sort of cobbled together something, then added a few of our own papers*”. Consequently, interviewees highlighted several limitations. Firstly, that the Exercise & Sport Science faculty are unaware of what is taught in papers that have been ‘borrowed’ from outside the Division. Secondly, with Massey having an agricultural background, papers such as Mammalian Biology are more focused on animals than humans. Thirdly, papers are disjointed meaning that certain concepts are taught repeatedly, too early or too late. And, finally, without cohesion between papers, there is no reinforcement of fundamental knowledge across different contexts.

Although the aforementioned relates to Massey, one interviewee commented on the evolution of Exercise & Sport Science internationally. He explained that universities across the world have historically struggled to know where Exercise & Sport Science ‘fits’. Only sometimes is it aligned with the faculty of sciences; and other times with the faculties of education or humanities. Hence, Exercise & Sport Science is often associated, if not confused, with types of sport and recreation studies. In this context, another interviewee said, “*You can’t even get them to call it Exercise Science. They call it ‘sport’*”.

The association of Exercise & Sport Science with other programmes was said to be detrimental because they, “*pull down people’s perception of what the top level is*”. One interviewee from outside the Division perceived that some polytechnic degree programmes in sport and/or exercise science have a reputation within Public Health for, “*slightly shonky science*”. Other interviewees perceived that some polytechnic degrees are valuable qualifications; but do not provide a rigorous science education. In light of the variation between programmes, one interviewee stated:

Interviewee: *We really need to highlight the fact that we are scientists who have an interest in Exercise and Sport topics rather than scientists who have an interest in plant biology, for example. And that is what we need to do to differentiate ourselves from leisure and toys type related studies.*

The public perception of Exercise & Sport Science influences the caliber of student attracted to the discipline, according to several interviewees. In comparison to American students, one interviewee was impressed with the quality of bachelor of science students in New Zealand (although notably less impressed with those on the bachelor of Exercise and Sport programme). Another interviewee used his own experience to highlight that Exercise & Sport Science is worthy of the best students, saying: “*I know I could have gone into medical school in Cambridge, for example, but I did not want to because I wanted to go into the Exercise & Sport Science field*”.

However, interviewees from outside the Division reported that Exercise & Sport Science students are not serious scientists but instead students who are attracted by the prospect of studying something that is similar to their interest in sport. Consequently, they are reported to become quickly disengaged with the fundamental science that they are required to study and, therefore, “*generally these students aren’t the best ones in the class – quite often within they are coming in at the bottom rung*”. It was perceived that the best science students are directed towards “*more prestigious*” science degrees such as medicine or something more fundamental. In a further comparison, Exercise & Sport Science students were described by two interviewees as being even less capable than those majoring in nutrition. It was revealed that double-major students that have been advised to discontinue nutrition papers have been retained by the Exercise & Sport Science programme. One interviewee from outside the Division cautioned that Exercise & Sport Science students need to meet the same standards as other College of Science students:

Interviewee: I hear from other staff members what sport calls a B student we call a C student; what sport calls an A student we call a B student.

2.2.2. Generic Skills

‘Generic Skills’ focuses on the Generic skills and attributes that students develop during their undergraduate studies. Interviews elicited little information regarding Generic skills, although one interviewee did indicate that undergraduates do profit from working in teams during laboratory practicals in physiology papers. However, the same interviewee went on to advocate more opportunities in oral communication because, as he explained:

Interviewee: When students graduate and go into the wider world they obviously have to go and sell pitches (or whatever depending on the domain they work in) and the ability to talk in front of an audience is important.

2.2.3. Acquiring Knowledge

‘Acquiring Knowledge’ focuses on students learning facts about the fundamental sciences along with mathematics and literacy. A leading point made by several interviewees was that Exercise & Sport Science is a discipline that combines all the fundamental sciences: biology and chemistry are applied to the study of human physiology, while physics and mathematics are applied to the study of biomechanics. One interviewee said, “*It is actually one of the few disciplines that really does have the potential to pull in just about everything*”.

Several interviewees provided examples of how the fundamental mechanisms of science (including mathematics and statistics) occur in the human body at rest and during exercise: (1) the physics and mathematics behind biomechanics; (2) the biochemical processes at a cellular level underlying hydration; (3) the neural and endocrine pathways underlying physiological responses; (4) the RNA expressions in muscle cells; (5) the laws of thermodynamics relating to specific heat capacity; (6) Newton’s laws of motion behind ergonomics; and (7) the statistics published in scientific journals. However, at the same time, all of these interviewees indicated that the

fundamental science knowledge they describe is typically not demonstrated among Exercise & Sport Science undergraduates:

Interviewee (1): *We struggle to get lecturers in biomechanics because over the years it's been that people haven't gone that way because they don't want to do the physics or maths.*

Interviewee (2): *When I am trying to teach them (Exercise & Sport Science undergraduates) it is like taking them back to primary school almost, "this is a cell, this is a cell nucleus, this is a chromosome".*

Interviewee (3): *In sports science, I don't think there is enough understanding of basic science prior to going into applying information to sports science. For example, these research projects... the students won't often understand the mechanism of the response that they are testing.*

Interviewee (4): *From my experience in my undergraduate programme... we measured enzyme kinetics... and we did DNA extraction from different cell cultures... As far as I am aware we don't do anything along the lines of what I would consider fundamental biochemistry.*

Interviewee (5): *Students need a better grounding in just physical science. I think students come through from school and they don't understand that underlying all the things we do in exercise science are more basic principles.*

Interviewee (6): *Sometimes I digress when I am doing a (third year) lecture on to say Newton's laws of motion. What I tend to see is that the engineers and technologists will yawn because they tend to say, "oh yes I know that", but the exercise scientists might not appreciate it in quite that way. I am a little bit surprised sometimes about that sort of thing especially when some of the exercise scientists will have done basic biomechanics already. Sometimes I feel it is going in one ear and out the other.*

Interviewee (7): *I find it crazy that students don't do statistics in their three years. They have no idea what a P value is; what confidence in tools are; what significance everything is; what an ANOVA is; what a MANOVA is.*

The reason for a lack of fundamental knowledge among undergraduates of Exercise & Sport Science was attributed to several different factors:

Firstly, many interviewees spoke about the low baseline of science knowledge (including mathematics) among Bachelor of Science students entering university. Especially, it was noted, in comparison to American and British high school leavers, along with Engineering students. It was hypothesised that a higher level of physics and mathematics might be stipulated in the entry requirements for Engineering students, while a degree of surprise was expressed that such requirements were not expected of Exercise & Sport Science students:

Interviewee: *I was shocked to find out that there are actually students here in the Bachelor of Science programme who have never had physics before.*

Secondly, in New Zealand, between approximately one-third and one-half of papers will be Exercise & Sport Science specific papers. Some of the remaining papers are compulsory but from outside the Division. Examples at Massey include, Mammalian Biology and Biostatistics. This system then allows students to select the remainder of their papers from other science disciplines. A couple of interviewees reported that this New Zealand model is in contrast to the UK model where most Exercise & Sport Science undergraduates receive all their teaching from within their Exercise & Sport Science division.

On one hand, the New Zealand model was praised for enabling students to acquire a broad range of science knowledge, thereby allowing them to, *“be a scientist without necessarily being particularly interested in sport”*. On the other hand, it was reported that students will not always select the papers that best compliment Exercise & Sport Science. For example, it was said that students will not select a mathematics paper unless they are required to; only a small number of students select the Chemistry for Living Systems paper; and an even smaller number of students, if any, are perceived to enroll on elective physics papers. One interviewee said that this was because the undergraduates are more interested in sport than in science. Another interviewee concluded:

Interviewee: *if you want to hang a sign up that says ‘I am an exercise scientist’ then a far more prescribed program is required.*

Thirdly, the several interviewees cautioned against a physiology focus. Although one interviewee believed that, *“physiology is the most important factor that should be considered in Exercise & Sport Science”*, he shared the same view as a colleague who said, *“it probably pays to go ahead and try to get everyone to really get the full breadth of exercise science”*. A broad education in Exercise & Sport Science was said to require the inclusion of a motor behavior paper that would include some psychology. Importantly, it was highlighted, that a motor behavior component would be necessary for New Zealand programmes to become recognized in Australia, the United Kingdom and the United States.

Finally, a couple of interviewees from outside the Division reported that the discipline has seemed *“superficial”* since it branched off from mainstream Physiology. One interviewee explained that, since the 1960’s, Exercise Scientists have remained interested in the high-level human animal and therefore distant from the fundamentals of physiology. Meanwhile, pure physiologists have drilled deeper to look at organ systems, individual tissues, the cellular level, and nowadays the sub-cellular level. Another interviewee agreed saying:

Interviewee: *There seems to be a feeling that students don’t need the rigor of those particular sciences (chemistry & cell biology) to be able to do exercise and sport, that they need a more anatomical view of the body rather than necessarily the biochemistry.*

2.2.4. Applying Knowledge

‘Applying Knowledge’ focuses on opportunities for students to witness theory being put in to practice; if not the opportunity to do so themselves. A couple of interviewees who coordinate exercise physiology papers described the synergy between their lectures and laboratory practicals, in which the theory is routinely put in to practice. So, for example:

Interviewee: They learn about the cardiovascular system all the theory and then in the two or three lab practicals they actually put those systems to test so they actually take cardiovascular variables like blood pressure, heart rate, respiratory variables and we stress them.

However, several interviewees commented that more effort could be made to take practical demonstrations outside the laboratory in to applied settings. One interviewee said, “*I don’t think we do a single experiment outside of our lab*” and then went on to assert that students could learn a great deal from simple exercises like: measuring oxygen uptake around a running track; measuring heart rate when you go running; filming somebody doing high jumps; or videoing people in the swimming pool. Another interviewee reported that some third-year project students had previously made use of the hot and cold bath facilities at the Massey University Sport and Rugby Institute but noted that such experiences do not happen easily or frequently enough. The same interviewee believed that Exercise & Sport Science at Massey could do more to leverage its, “*great supportive ancillary network*”, especially considering the success of the partnership between the Millennium Institute of Sport and Health and Auckland University of Technology (AUT). A third interviewee advocated that a placement of six or twelve months would help students, “*put some of what they are learning into practice*”. Finally, making a comparison with overseas Exercise & Sport Science programmes, a fourth interviewee said that, “*graduates from the other countries would have had more exposure, more practice generally speaking than New Zealand*”.

An interviewee from outside the Division reported a recent conversation that added further substance to the argument that more opportunities are necessary for students to put theory in to practice. The conversation was with a double-honors student who had approached the interviewee asking whether she ought to undertake a short applied course to prepare herself for the workforce:

Interviewee: This particular student was feeling that if she had to go and work in a gym to give nutrition advice and combine that with the exercise science of it she felt that, although she had all the technical knowledge, she would be unable to go in and transfer her knowledge into an exercise programme... She felt that she was at a disadvantage from the ones I call gym bunnies with their 6 month course, their personal training course.

However, the same interviewee, along with a couple of others, guarded against Exercise & Sport Science degree programmes competing with more vocational programmes saying, “*I don’t see universities as being an area for job preparation to that extent*”. In other words, some awareness of how to apply knowledge would be desirable; but the

absence of many obvious career paths for Exercise & Sport Science graduates left interviewees pondering the question, “in what applied setting is it best to give students exposure?”

One interviewee described the opportunities for Exercise & Sport Science graduates in clinical settings such as gait laboratories, which design interventions to improve motor performance among people suffering from movement diseases, such as cerebral palsy or Parkinson’s disease. The interviewee went on to say that, “*for the most part, medical professionals know almost nothing about movement and exercise*”, which therefore presents great opportunities for graduates of Exercise & Sport Science. However, another interviewee reported that an extremely limited number of Exercise & Sport Science graduates, especially in New Zealand, actually find employment in sport or exercise related science:

Interviewee: When I look at students and how they use their degree that is where Exercise & Sport Science is no different I think to the vast majority of university subject areas that don’t have a vocational outcome. It is only a few, physiotherapy, law, medicine, vet that have a vocational outcome where you would have a greater than 50% follow on from the subject area to the job. In that sense Exercise & Sport Science is no different to geography or philosophy, or art, only 10 to 25% at best.

Consequently, several interviewees talked about the importance of preparing Exercise & Sport Science graduates for jobs that apply their knowledge to general science environments. One interviewee tells her students that they should think of themselves as science graduates who are able to work in any scientific laboratory. Another interviewee highlighted that companies like Fonterra recruit BSc graduates who are able to apply their scientific theory and laboratory skills to a range of science environments.

2.2.5. Challenging Knowledge

‘Challenging Knowledge’ focuses on the ability to evaluate scientific methods found in primary sources of literature as an integral component of undergraduate education in Exercise & Sport Science. The objective is to prepare undergraduates to become effective critics of science in a world where there is no such thing as absolute truth. One interviewee introduces this point clearly:

Interviewee: Maybe I am old fashioned but I think leaving university with a degree shouldn’t mean that you just know a bit more than somebody else. It should mean that you are very critical about new information, you have the skills to be able to pull it apart and you have the skills to be able to construct new ideas around it and you should get that from a degree, not a PhD. I don’t see much of that.

Another interviewee admitted that student pressure to receive, “*all the information they need in a nice package*” combined with the teaching and research pressures on academics often means that questioning knowledge is postponed until postgraduate level:

Interviewee: *We say oh well if you go into postgraduate we will start doing things differently where you will start questioning the information. I think that is probably too late at postgraduate, we should be encouraging undergraduates to do exactly that.*

Going on to think about critical thinking in the specific context of Exercise & Sport Science, a couple of interviewees commented on the limitations of websites like Wikipedia and bodybuilder.com; along with what one interviewee described as, “*so much junk out there*” relating to things like fad-diets and supplements. In concurrence, another interviewee observed that the world of Exercise and Sport is full of people with commercial interests who can, “*pretty much design an experiment to show just about anything*”. Consequently, it was said by several interviewees that it is particularly important for Exercise & Sport Science students to develop skills in reading scientific journal articles, which one interviewee said are the, “*forefront of academic rigor*”. A colleague went on to say:

Interviewee: *By the time they come to the end of their third year they should have a good understanding about the make-up and design of a research study; how that is linked to the scientific rigor; and understand how that is associated to the findings of that paper”.*

One interviewee reported giving students, “*a good thorough grounding in how to attempt to read a scientific journal*” by asking them to consider ‘scientific principles’ such as empirical data collection, the way of looking at the world, and issues relating to measurement. However, another interviewee described undergraduates’ lack of ability to seek and evaluate primary sources of information as a, “*bugbear*”. He described asking third year students to write a laboratory report including an introduction and discussion that cite appropriate journal articles. Although some of the students are capable, others are suspected of simply copying from articles without understanding the content. The interviewee concluded:

Interviewee: *You really want to challenge those students and the best way to challenge the students is through research articles but by the time they finish their third year they don’t really know the intricacies associated with a research paper.*

Comparison with other students

Academics outside the Division indicated that more could be done to develop the critical minds of undergraduates. In regards to Exercise & Sport Science students in their third year, one interviewee expressed, “*their level of enquiry doesn’t seem to be naturally as strong as I would like it to be for a scientist*”. In contrast, he reported that Engineering students automatically drive discussion:

Interviewee: *What surprises me is that I will ask the class to make a measurement on a person and I will show them how to do that and then I will set them a little exercise which is to go and make measurements on half a dozen people and compare the results. They all do one measurement and they will do what they are told but they tend not to come back and say we are concerned about the reliability of that*

measurement... My feeling is that in a class where there have been some of the engineers and technologists, they would be the ones to say it's obvious that repeatability in measurements is important.

A second interviewee from outside the Division provided an equally poignant example, which relates back to the commercial world of Exercise and Sport:

Interviewee: One of my postgraduate sports science people, he is a sports science graduate who came through the undergraduate course who, in his postgraduate presentation, was still advocating a supplement use for sports people which had absolutely no scientific validation whatsoever so he has obviously not grasped this idea that you have to think critically about what is being presented to him in a scientific context .

2.2.6. Investigating Knowledge

'Investigating Knowledge' focuses on students themselves conducting experiments in a laboratory as an integral component of undergraduate education in Exercise & Sport Science. The objective of laboratory experience is to prepare undergraduates to become independent investigators proficient in the scientific method.

One interviewee reinforced that it is essential for students to graduate with laboratory skills because, "*it gives a good understanding of where the science is actually coming from*". However, several interviewees concluded that opportunities for investigation were too limited and insufficiently rigorous. A comment from one interviewee provides a good introduction to the problem:

Interviewee: If you had a graduate entering the workplace with high performance athletes and let's say they were going to do a maximal exercise test with respiratory gas analysis and with a blood lactate measurement, I would not be confident of most of our third years to independently run a test like that in terms of actually knowing the protocols and knowing the techniques needed for those measurements.

Undergraduates were reported to comment upon more frequent opportunities for laboratory experience in their Exercise & Sport Science papers, than in their other science papers. However, there were plenty of indications that undergraduates, "*at Massey and perhaps in the greater New Zealand don't get as much laboratory experience as they could or should by the end of the 3 year degree*". Interviewees elaborated on this point in a couple of ways:

Firstly, university degree programmes need to prepare undergraduates with laboratory skills that are more sophisticated than those offered by sub-degree programmes. One interviewee explained that you don't need a degree to, "*measure somebody's oxygen uptake when they are riding a bicycle*". However, another interviewee reported that the majority of practical laboratory experiences in Exercise & Sport Science papers are simply about demonstrating a measurement of human performance rather than exploring the variations between possible methods; the consequences of those variations; and differences between populations. In agreement that laboratory practicals have the potential to become more rigorous, a third interviewee said:

Interviewee: *All the more practical papers along the way with lab classes those are the kind of places where the complete circular scientific method kind of rigor should be exposed to them (undergraduates)."*

Secondly, interviewees criticized the tendency to spoon-feed undergraduates in the laboratory, who are typically expected to follow, "recipes", which instruct students to, "press these buttons, come out with these numbers". Interviewees recommended that undergraduates need frequent opportunities to develop and test their own hypotheses; and that as much can be learned from investigations that don't work as from those that do. One interviewee concluded with the following point:

Interviewee: *There is an expectation that every time you do a practical you come out with a meaningful result. Well that's not the way science works. It is about increasing inquisition I guess – sometimes you find something out, sometimes you don't. So there should be more opportunity to do that.*

In the opinion of several interviewees, including those outside the Division, the primary opportunity for undergraduates to 'investigate knowledge' at Massey is via a third year research paper, which is compulsory for Exercise & Sport Science students. One coordinator of this paper described how undergraduates are asked to independently conceive, conduct and report a study; and attempt to do so in a way that would be expected of postgraduate students. Reflecting on this process, one interviewee offered the following commendations:

Interviewee: *They have to do their own research so they learn how to set up a piece of research , how to apply for ethics, how to go into and work with a group of athletes and actually conduct a specific piece of research and then write it up. We (in Nutrition) don't do that until postgraduate or honors. I think that is a real strength (of the Exercise & Sport Science major).*

However, the third-year research paper also received some criticism. For example, when one interviewee was asked to elaborate on what could be improved about the third-year projects, his response was, "I would say almost everything". His opinion was that students had not investigated, "the mechanism behind a lot of the phenomena", but instead delivered a report on simply, "what people do". In addition, an interviewee (a coordinator of the third-year project) revealed some limitations, which surrounded the aptitude that students displayed during their project. Firstly, students were said to be weak at formulating precise and appropriate methodologies. Secondly, that they, "haven't a clue" what to do with their data once it has been collected; or even whether it can be used to answer their research question. Consequently, where the third-year research paper is concerned, the interviewee concluded:

Interviewee: *The idea of a complete rigorous investigation is not there. They (students) just think that you put your numbers in a computer and push a button and that's it... It's just failing to complete the whole circle of rigor from what you want to do, to doing it, to completing it, to reintegrating it in the traditional scientific methods circle. That rigorous approach seems to be missing to me.*

Finally, the view of another interviewee was that a single, third-year research project amounts to very limited practice of the independent research skills that cannot be gained from supervised laboratory practicals.

Consequently, one interviewee believed that aspersions cast on undergraduates' research ability can be attributed to the fact they've, "*only once been given the responsibility and independence of doing it on their own*".

Comparisons with other undergraduates

Although interviewees from outside the Division recognized the value of the third-year project, in comparison to undergraduates from other science majors, third-year Exercise & Sport Science students often gave the impression that they had, "*not done very much*" in the laboratory. One interviewee revealed his perception of Exercise & Sport Science students vis-à-vis Engineering students and it was the investigative skills of Engineering students that impressed him most:

Interviewee: Almost consistently I found the engineering and technology students to be really quite smart and quite rigorous. They are really very, very, very able and their (research project) presentations show that they explore things in quite a lot of rigor.

Another interviewee made the comparison between their knowledge of New Zealand undergraduates vis-à-vis those studying overseas. It was reported that overseas programmes incorporate more discipline specific laboratory components and that, especially in the United Kingdom, the third-year undergraduate dissertation is the equivalent of a fourth-year honors project in New Zealand. The interviewee concluded by reflecting on his personal experience as an undergraduate in the UK:

Interviewee: I know that by the end of three years my laboratory skills were a lot better and, particularly if I wanted to go on to postgraduate study or go into the workforce into this area (of Exercise & Sport Science) my Generic practical laboratory scientific skills were much, much more advanced than our students here.

3. Phase 3

Pilot instrument to analyze the scientific rigor of undergraduate programmes in Exercise & Sport Science

3.1. Methods

3.1.1. Ethics

Phase 3 was reviewed and approved by the Massey University Human Ethics Committee: Southern B, Application 10/36. Those invited to participate in this study were under no obligation to participate. Those choosing to participate were guaranteed anonymity and that individual data would remain confidential. Participants were instructed to direct any concerns about the conduct of the research to the Chair of Massey University Human Ethics Committee.

3.1.2. Quantitative Research

Phase 3 relied on quantitative research methods. Quantitative research focuses on gathering numerical data and generalizing it across groups of people. Phase 3 set out to generalize across the academic community within the Exercise & Sport Science discipline in New Zealand. Numerical data would relate to their perceptions of Exercise & Sport Science as a rigorous science education at an undergraduate level. The research questions driving this quantitative research were:

- (A) Is our definition of a rigorous science education valid in the context of Exercise and Sports Science?; and
- (B) Can we measure the frequency with which undergraduate programmes in Exercise & Sport Science are currently providing a rigorous science education?

3.1.3. Sample Selection

Phase 3 of this study recruited participants from the same New Zealand university as Phase 2. The first participant group recruited in Phase 3 was 'lecturers'. This group was a total population sample meaning that all lecturers of Exercise & Sport Science were invited to participate (n = 12). The second participant group recruited in Phase 3 was 'graduates'. All graduates with a BSc that included Exercise & Sport Science as a major discipline in 2009 or 2010 were invited to participate (n = 36).

3.1.4. Mode of Administration

Participants were asked to respond to a survey. Using multiple modes of survey administration opens up the possibility of introducing a systematic bias in the results associated with the method of data collection (Kuh, 2000).

To avoid this bias, the Project Team decided to distribute the survey via one mode only. In a tertiary environment, higher response rates are associated with paper surveys than online surveys (Hughes, 2010). Therefore, hardcopy surveys were delivered to participants via mail.

3.1.5. Developing the Instrument

Given the absence of validated measures available from the literature, this study embarked on developing a pilot instrument suitable for quantifying the scientific rigor of undergraduate programmes, particularly in Exercise & Sport Science. The survey comprised 50 items derived from the results of Phase 1: Programme & Pedagogy (e.g. Papers are among the very best science papers available); Non-Scientific Skills (e.g. Students learn about teamwork / collaboration); Acquiring Knowledge (e.g. Students learn facts about physics); Applying Knowledge (e.g. Students observe others translate theory into practice in real-life); Challenging Knowledge (e.g. Students evaluate methodologies found in literature); and Investigating Knowledge (e.g. Students undertake experiments, which they designed).

The survey asked participants to reflect on the 50 activities in the context of their experience of Exercise & Sport Science at an undergraduate level. Using a Likert Scale, participants were asked to consider each of the 50 items and indicate whether they strongly disagree = 1, disagree = 2, feel neutral = 3, agree = 4, or strongly agree = 5 with the two statements: (A) This is important and (B) This happens frequently .

3.1.6. Validity

Validity refers to whether an instrument actually measures what it sets out to measure (Field, 2009). In terms of validity, the survey relies on self-reports, which is common practice when assessing the quality of undergraduate education (Kuh, 2000). However, the validity of self-reports can be jeopardized by the inability of respondents to provide accurate information in response to a question and unwillingness on the part of respondents to provide what they know to be truthful information (Kuh, 2000). With this in mind, self-reports are likely to be valid under five general conditions (Bradburn & Sudman, 1988), which the Phase 3 survey were intentionally designed to satisfy. They are: (a) When the information requested is known to the respondents; (b) The questions are phrased clearly and unambiguously; (c) The questions refer to recent activities; (d) The respondents think the questions merit a serious and thoughtful response; (e) Answering the questions does not threaten, embarrass, or violate the privacy of the respondent or encourage the respondent to respond in socially desirable ways. Specifically in relation to point (b), the survey was piloted by a sample lecturer and a sample graduate participant. These pilot participants were subsequently asked to explain the meaning of each item and their responses to ensure that respondents would not interpret items to mean different things. A few items were identified where additional clarity would produce more accurate and consistent interpretations.

3.1.7. Reliability

Reliability is the degree to which a set of items consistently measures the same thing across respondents (Kuh, 2000). Although the sample size was not large enough to have conducted a factor analysis, Tables 1 – 6 present how results from graduates and lecturers were combined to assess the reliability of the instrument in three different ways using Statistics Package for the Social Sciences (SPSS), version 16.0: Firstly, Cronbach's Alpha is the most common measure of scale reliability and indicates that the overall reliability of a questionnaire is good when α values are around .8, although values as low as .7 are acceptable (Field, 2009). It is also possible to calculate *Cronbach's Alpha if Item is Deleted*, which are the values of the overall α if that item isn't included in the calculation. Using responses to the question (B) This happens frequently, the reliability of the six scales were tested. Testing included checking whether the reliability of each scale could be improved if one or more items were deleted. All six scales had high reliabilities ranging between Cronbach's $\alpha = .94$ and $\alpha = .78$. Secondly, skewness is a pertinent indicator of reliability, which represents the extent to which scores are bunched toward the upper or lower end of a distribution. All six scales had skewness values ranging from approximately + 1.0 to - 1.0, which are generally regarded as evidence of normality (Kuh, 2000). Thirdly, inter-item correlations for all six Scales range between .01 and .82 (with two exceptions), which means that all dimensions of each scale are positively related. So, take the Programme & Pedagogy scale for example, lecturers citing recently published research is not antithetical to papers preparing students to become scientists. At the same time, many of the correlations are low to medium in strength, indicating that each dimension makes a distinctive contribution to the Scale.

3.1.8. Statistical Analysis

Having undertaken reliability testing, the six scales were computed using mean scores, as the arithmetic mean of each of the items which made up the scales for data relating to statements (A) This is important and (B) This happens frequently. Descriptive statistics were gathered for each scale. Scale data was then subjected to an independent samples t-test, with respect to participant groups; followed by a paired samples t-test, with respect to statements (A) and (B). In addition, scale data were subjected to a simple linear correlation analysis.

TABLE 1: RELIABILITY COEFFICIENTS & INTER-ITEM CORRELATIONS

PROGRAMME & PEDAGOGY	Alpha Reliability = .84									
	1A	1B	1C	1D	1E	1F	1G	1H	1I	
1A. Papers are scientifically rigorous	1.00									
1B. Papers are among the very best science papers available	.58	1.00								
1C. Papers challenge students intellectually	.71	.64	1.00							
1D. Papers leave students enthused about science	.08	.13	.20	1.00						
1E. Papers prepare students to become scientists	.44	.42	.45	.52	1.00					
1F. Lecturers are enthusiastic about science	.26	.05	.34	.50	.38	1.00				
1G. Lecturers cite recently published research, including their own	.27	.13	.38	.36	.29	.42	1.00			
1H. Lecturers use techniques that help students learn effectively	.45	.26	.24	.40	.62	.38	.46	1.00		
1I. Lecturers provide constructive feedback	.26	.36	.46	.33	.56	.29	.50	.35	1.00	
Mean	3.95	3.21	4.05	3.75	3.65	4.60	4.30	4.00	4.05	
Standard Deviation	.71	.98	.76	.79	.99	.50	.73	.86	.89	

TABLE 2: RELIABILITY COEFFICIENTS & INTER-ITEM CORRELATIONS

GENERIC SKILLS	Alpha Reliability = .84					
	2A	2B	2C	2D	2E	2F
2A. What students learn helps prepare them for their futures	1.00					
2B. Students learn about professional communication skills	.52	1.00				
2C. Students learn about teamwork / collaboration	.45	.45	1.00			
2D. Students learn about self-directed learning	.51	.33	.32	1.00		
2E. Students learn about thinking analytically to solve problems	.63	.55	.35	.42	1.00	
2F. Students learn about good organizational skills	.56	.68	.26	.50	.53	1.00
Mean	3.68	3.70	4.25	4.00	4.05	3.80
Standard Deviation	.89	1.13	.85	.79	.69	1.01

TABLE 3: RELIABILITY COEFFICIENTS & INTER-ITEM CORRELATIONS

ACQUIRING KNOWLEDGE	Alpha Reliability = .83					
	3A	3B	3C	3D	3E	3F
3A. Students learn facts about biology	1.00					
3B. Students learn facts about chemistry	.41	1.00				
3C. Students learn facts about physics	.54	.55	1.00			
3D. Students learn facts about mathematics	.39	.70	.62	1.00		
3E. Students learn facts about statistics	.43	.52	.34	.20	1.00	
3F. Students learn facts about literacy	.43	.45	.42	.34	.64	1.00
Mean	4.10	3.65	3.90	3.60	3.65	3.70
Standard Deviation	.79	.93	.64	.82	1.04	.86

TABLE 4: RELIABILITY COEFFICIENTS & INTER-ITEM CORRELATIONS

APPLYING KNOWLEDGE	Alpha Reliability = .78					
	4A	4B	4C	4D	4E	4F
4A. Students are given examples of how theory applied in practice	1.00					
4B. Students learn about ethical & social issues surrounding science	.36	1.00				
4C. Students learn how to communicate science to potential clients	.38	.60	1.00			
4D. Students observe others translate theory into practice in labs	.45	.33	.53	1.00		
4E. Students observe others translate theory into practice in real-life	.32	.33	.46	.41	1.00	
4F. Students translate theory in to practice in laboratories	.40	.06	.03	.33	.48	1.00
Mean	4.10	3.75	3.55	3.95	3.20	4.15
Standard Deviation	.72	.91	.94	1.00	1.06	.67

TABLE 5: RELIABILITY COEFFICIENTS & INTER-ITEM CORRELATIONS

CHALLENGING KNOWLEDGE	Alpha Reliability = .94						
	5A	5B	5C	5D	5E	5F	5G
5A. Students source reliable scientific information	1.00						
5B. Students read scientific journal articles	.92	1.00					
5C. Students evaluate hypotheses found in literature	.75	.80	1.00				
5D. Students evaluate methodologies found in literature	.78	.82	.73	1.00			
5E. Students evaluate data analysis found in literature	.58	.61	.71	.86	1.00		
5F. Students evaluate results found in literature	.58	.57	.45	.78	.81	1.00	
5G. Students use literature to inform scientific discussions	.72	.67	.55	.63	.54	.78	1.00
Mean	4.00	3.90	3.35	3.40	3.20	3.60	3.80
Standard Deviation	1.08	1.12	1.04	1.19	1.11	1.10	.95

TABLE 6: RELIABILITY COEFFICIENTS & INTER-ITEM CORRELATIONS

INVESTIGATING KNOWLEDGE	Alpha Reliability = .83									
	6A	6B	6C	6D	6E	6F	6G	6H	6I	6J
6A. Students observe someone else undertake experiments	1.00									
6B. Students test hypotheses, which are not their own	.55	1.00								
6C. Students test hypotheses, which they construct themselves	.16	.06	1.00							
6D. Students undertake experiments, which they designed	.02	-.01	.77	1.00						
6E. Students analyze data, which was gathered by someone else	.45	.50	.12	.23	1.00					
6F. Students analyze data, which they had gathered themselves	.10	.40	.22	.24	.28	1.00				
6G. Students analyze data, which reveal novel results	.30	.37	.49	.60	.49	.71	1.00			
6H. Students use their own results to inform scientific discussions	.17	.23	.15	.08	.38	.61	.66	1.00		
6I. Students use their results towards the development of knowledge	.07	.20	.18	.20	.28	.57	.67	.75	1.00	
6J. Students report experiments using scientific writing skills	.28	.30	.38	.14	.13	.74	.41	.48	.30	1.00
Mean	4.15	3.95	3.90	3.90	3.65	4.40	3.50	3.95	3.70	4.55
Standard Deviation	.88	.89	.85	.79	.67	.50	.89	.76	.80	.51

3.2. Results

3.2.1. Response Rate

Responses were received from 9 lecturers and 11 graduates. This represents a response rate of 75% from lecturers and 31% from graduates. However, it is worth noting that, of the surveys distributed to graduates, a number were 'returned to sender', which indicates that the database of alumni addresses was out-of-date.

3.2.2. Descriptive Statistics

Table 7 presents descriptive statistics for responses relating to statement (A) This is important and (B) This happens frequently.

Notably, in the case of both graduates and lecturers, means results for (A) are higher than for (B). With all results for (A) between 4.0 and 4.7, this represents a solid agreement (agree = 4.0) that the six scales are important; whereas, with all results for (B) between 3.0 and 4.1, this represents more of a neutral perception (neutral = 3) that the six scales happen frequently. A paired samples t-test was undertaken to compare the means from statements relating to (A) This is important and (B) This happens frequently. Among graduates, significant differences were found between all six scale-pairs at the $P < 0.05$ level. Among lecturers, significant differences were only found between 'Programme & Pedagogy' and 'Applying Knowledge' at the $P < 0.05$ level.

Also, for each of the six scales for (A) and (B) the means results for graduates are higher than for lecturers. However, an independent samples t-test revealed no significant differences between graduates and lecturers, with the exceptions of: 6(A) 'Investigating Knowledge' $t(18) = 2.64$, $P < 0.05$; and 5(B) 'Challenging Knowledge' $t(18) = 3.35$, $P < 0.01$. The significance of these differences are explored in the Discussion.

Table 7: MEANS, STANDARD DEVIATIONS

Responses relating to statement: (A) This is important and (B) This happens frequently

	Graduates		Lecturers	
	Mean	SD	Mean	SD
1(A) Programme & Pedagogy	4.6	.23	4.4	.52
2(A) Generic Skills	4.6	.50	4.2	.70
3(A) Acquiring Knowledge	4.3	.58	4.1	.67
4(A) Applying Knowledge	4.6	.41	4.2	.38
5(A) Challenging Knowledge	4.7	.46	4.3	.63
6(A) Investigating Knowledge	4.5	.42	4.0	.49
1(B) Programme & Pedagogy	4.1	.36	3.8	.71
2(B) Generic Skills	4.1	.50	3.8	.86
3(B) Acquiring Knowledge	3.8	.37	3.7	.87
4(B) Applying Knowledge	3.9	.45	3.7	.79
5(B) Challenging Knowledge	4.1	.62	3.0	.89
6(B) Investigating Knowledge	4.1	.49	3.8	.41

3.2.3. Correlations

Tables 8 and 9 present linear correlations. Notably low correlations between scales relating to (A) and (B) indicate that importance has little bearing on what actually happens. This is with one exception at the $P < 0.01$ level in the perception of graduates between 2(A) the importance of Generic Skills and 1(B) the frequency of Programme & Pedagogy.

Also in the perception of graduates, there is a notable significant correlation at the $P < 0.01$ level between the frequency of 4(B) Applying Knowledge with 2(B) Generic Skills, 3(B) Acquiring Knowledge and 5(B) Challenging Knowledge. In the perception of lecturers, of the 15 linear relationships between scales relating to importance, 10 relationships are significant at the $P < 0.01$ level. Also in the perception of lecturers, there is a notable significant correlation at the $P < 0.01$ level between the frequency of 6(B) Investigating Knowledge with 2(B) Generic Skills and 5(B) Challenging Knowledge.

Table 8: CORRELATIONS

Responses relating to statement: (A) This is important and (B) This happens frequently in the perception of graduates

	1(A)	2(A)	3(A)	4(A)	5(A)	6(A)	1(B)	2(B)	3(B)	4(B)	5(B)	6(B)
1(A) Programme & Pedagogy	1.000											
2(A) Generic Skills	.429	1.000										
3(A) Acquiring Knowledge	.150	.015	1.000									
4(A) Applying Knowledge	.061	.465	-.368	1.000								
5(A) Challenging Knowledge	.109	-.263	.205	.037	1.000							
6(A) Investigating Knowledge	.204	-.258	.663*	-.458	.631*	1.000						
1(B) Programme & Pedagogy	.333	.909**	.085	.564	-.227	-.395	1.000					
2(B) Generic Skills	.195	.555	-.180	.087	-.315	-.509	.631*	1.000				
3(B) Acquiring Knowledge	-.120	.111	.281	.041	-.123	-.365	.451	.588	1.000			
4(B) Applying Knowledge	-.011	.481	.345	.090	-.120	-.197	.666*	.773**	.781**	1.000		
5(B) Challenging Knowledge	-.018	.148	.180	.322	.036	-.290	.420	.526	.815**	.736**	1.000	
6(B) Investigating Knowledge	.148	.164	.710*	-.456	.139	.386	.228	.385	.505	.715*	.435	1.000

** Correlation is significant at the 0.01 level (2-tailed) | * Correlation is significant at the 0.05 level (2-tailed).

Table 9: CORRELATIONS

Responses relating to statement: (A) This is important and (B) This happens frequently in the perception of lecturers

	1(A)	2(A)	3(A)	4(A)	5(A)	6(A)	1(B)	2(B)	3(B)	4(B)	5(B)	6(B)
1(A) Programme & Pedagogy	1.000											
2(A) Generic Skills	.976**	1.000										
3(A) Acquiring Knowledge	.887**	.852**	1.000									
4(A) Applying Knowledge	.942**	.941**	.809**	1.000								
5(A) Challenging Knowledge	.190	.257	.250	.038	1.000							
6(A) Investigating Knowledge	.898**	.844**	.929**	.850**	.164	1.000						
1(B) Programme & Pedagogy	.401	.315	.440	.376	.015	.599	1.000					
2(B) Generic Skills	.600	.539	.520	.310	.271	.505	.608	1.000				
3(B) Acquiring Knowledge	-.047	-.106	.355	-.181	.424	.300	.385	.476	1.000			
4(B) Applying Knowledge	.171	.169	.244	.234	.057	.299	.589	.585	.411	1.000		
5(B) Challenging Knowledge	.649	.573	.663	.427	.114	.680*	.787*	.901**	.595	.718*	1.000	
6(B) Investigating Knowledge	.335	.203	.346	.161	.122	.418	.771*	.880**	.519	.649	.857**	1.000

4. Discussion

The present study has undertaken three phases, which has attempted to answer four research questions:

- What constitutes a rigorous science education at a tertiary level?
- How are undergraduate programmes in Exercise & Sport Science currently being taught?
- Is our definition of a rigorous science education valid in the context of Exercise & Sport Science?
- Can we measure the frequency with which undergraduate programmes in Exercise & Sport Science are currently providing a rigorous science education?

Triangulation of results have implications for four groups: (a) the Ministry of Education; (b) the Exercise & Sport Science community; (c) Administrators of Exercise & Sport Science; (d) Teachers of Exercise & Sport Science papers:

4.1. For the Ministry of Education

The Ministry of Education in New Zealand might be interested in anecdotal evidence collected in phase 2 suggesting that New Zealand high school leavers are less prepared for a tertiary education in science than their British counterparts; and therefore the three years of undergraduate study in New Zealand and the United Kingdom cannot be compared because many of the components of a rigorous science education have to be postponed until the fourth year of postgraduate study in New Zealand. To elaborate, the first year of undergraduate study in New Zealand is reported to be spent tutoring students in basic concepts, which many academics argue should have been learned at school. In concurrence, Parkinson et al. (unpublished) report both student and lecturer accounts of extremely variable entry-level knowledge among first year students upon transition from high school in to science degrees.

The present study also recommends that the New Zealand Ministry of Education consider formulating benchmark statements for undergraduate science degrees. The objective would be to define teaching and learning outcomes that must be delivered by programmes pertaining to be science. An example of what this study recommends would be the benchmark statement for the Biosciences, which is published by the Quality Assurance Agency for Higher Education (QAA) in the United Kingdom (QAA 2007). This is because a series of assumptions are associated with the New Zealand approach to quality assurance: First, that someone in New Zealand is already upholding teaching standards considered to be best practice among not only the discipline specific community but also the wider science community; second, that this person is among the peers nominated; third, that this person's voice is heard and not overruled by the majority; fourth, that this person (or someone of an equivalent standard) is consistently selected on to associated review panels; and, finally, that the newly established university programme elects to participate in ongoing review as they evolve over the years. In the instance of Exercise & Sport Science, this study strongly recommends that all programmes pertaining to be 'science' or for the preparation of 'scientists' should be

benchmarked against biosciences rather than against non-scientific disciplines such as sport coaching, sport management, leisure or tourism.

4.2. For the Exercise & Sport Science community

This study proposes that administrators across the Exercise & Sport Science community in New Zealand consider evaluating the benefits of retaining 'Sport' in programme titles that meet the criteria of a rigorous science education. This is in light of the fact that, when talking positively about rigor, participants in phase 2 tended to talk about 'Exercise Science'; while aspersions cast on the discipline most frequently referred to 'sport'. This recommendation is based on several issues arising from the present study.

Firstly, there is a 'softness' associated with Exercise & Sport Science due to its association with the popular culture of sport; which leads to the perception of 'Sport Science' being particularly accessible. This is connected to the unscientific approach taken to many of the seemingly scientific products marketed across the commercial world of exercise and sport, which has been documented by Ammonette et al. (2010) and Smith (2008). However, this challenge is not unique to Exercise & Sport Science. For example, the scientific credibility of many television personalities and entrepreneurs in Nutrition regularly come under scrutiny.

Secondly, although not unique to Exercise & Sport Science, the discipline is said to suffer from the lackluster caliber of high school leavers. The present study indicates that undergraduates of Exercise & Sport Science are likely to be more attracted to the concept of 'sport' than of 'science'; and often think of Exercise & Sport Science as a 'soft' science. Consequently, this leads to undergraduates of the discipline tending to lack the spectrum of fundamental scientific knowledge that lecturers expect from their peers in more traditional science disciplines.

Thirdly, contrary to a concern raised by Boone (2010) that Exercise Science is an illusion and a meaningless preparation for the workforce, results of the present study indicate that the exercise science aspects of Exercise & Sport Science have high potential to be rigorously scientific and are actually extremely meaningful for students entering scientific careers, e.g. researchers in gait laboratories. However, results of the present study in combination with those of Hughes (2010) suggest that some undergraduates of Exercise & Sport Science may not aspire to careers that require preparation in science. In those instances, a rigorous science education might not necessarily be the best use of their time.

Based on these three arising issues, the present study proposes that the removal of 'Sport' from rigorously scientific 'Exercise Science' programmes would aid academics of the discipline frustrated at teaching students who are more interested in their knowledge of sport than their expertise in the science of exercise. This is because the removal of 'Sport' would distance the discipline from popular culture and result in attracting students who are committed to an education in science. These are the students that Hipkins et al. (2006) describe as the "serious scientists" who, they found, were most likely to be taking two or three science disciplines in Year 13, along with mathematics.

4.3. For administrators of Exercise & Sport Science

Regardless of whether ‘Sport’ is included or excluded, the present study believes that all related programmes pertaining to be ‘science’ should undergo an audit process to address the impression that the discipline is less rigorous than other scientific disciplines. This is in the context of our phase 3 results, which tell us that the six scales of rigorous science education are important in the context of Exercise & Sport Science. However, in the absence of significant correlations between importance and frequency of the six scales, our results suggest that attributed importance has little bearing on what actually happens. This impression is primarily based on phase 3 survey item ‘Exercise & Sport Science papers are among the best science papers available’, which was the lowest scoring item in the survey. This impression was consistent across phase 3, in which means results for importance were higher than those for frequency. Without having gathered comparable data from other science disciplines, it is difficult to judge Exercise & Sport Science in isolation. However, in phase 2, anecdotal reports from academics outside the Division indicate that there is probably some truth in the perception that Exercise & Sport Science is currently less rigorous than other scientific disciplines.

On a separate issue, in response to reports that students do not necessarily select elective papers that enhance their Exercise & Sport Science studies, it is likely that administrators will need to consider heavier prescription of course requirements. Firstly, in terms of major requirements, Phase 2 results suggest that students of Exercise & Sport Science benefit from the widest possible range of exercise sciences including, not just physiology but also biomechanics and motor behaviors; and that these components are compulsory in each year of study. This point is consistent with Ives and Knudson’s (2007) international perspective that an excessive focus on physiology is detrimental. Secondly, it is suggested that Exercise & Sport Science undergraduates are required to study from a narrow selection of papers from the fundamental sciences, including Biology, Chemistry and Physics. Thirdly, an element of mathematics and statistics should be compulsory to aid undergraduate analysis of scientific results. Administrators will need to consider the pros and cons of hosting fundamental science papers within Exercise & Sport Science departments, versus ‘borrowing’ papers from the wider Faculty of Sciences. In the instance that papers are borrowed, consideration needs to be given to their relevance to students primarily interested in the application of science to the human body. The results of this study and Parkinson et al. (unpublished) caution that, for example, the teaching of physiology in the whole mammalian context can lead to serious disengagement among students of Exercise & Sport Science.

4.4. For teachers of Exercise & Sport Science papers

For teachers of Exercise & Sport Science papers, this study proposes a focus on: Programme & Pedagogy; Generic Skills; Acquiring Knowledge; Applying Knowledge; Challenging Knowledge; and Investigating Knowledge. From the outset, teachers should be mindful that the difference between importance and frequency was significant for all six scales among graduates, while it was only true of two scales among lecturers.

4.4.1. Programme & Pedagogy

Academics should focus on research-led teaching. Evidence from the present study indicates that the Exercise & Sport Science faculty are predominantly rigorous scientists and research-led teachers who cite their own research in lectures and who often find opportunities to involve undergraduates as participants in postgraduate and faculty research projects. However, aspersions are cast that teaching is not consistently research-led across New Zealand institutions in the field of Exercise & Sport Science. As it is explained in phase 1, rigorous science is best taught by academics who understand the scientific method; testament of which would usually be considered as an active record of research and publication in peer-reviewed journals.

While teaching should be research-led by discipline-specific research, it should also be led by teaching-specific research. This is particularly highlighted in phase 1 by participants who advocate student-centered teaching techniques. Associations between pedagogical styles and students' learning have been widely reported in the literature on adult learning and elaborated upon in the context of science and technology by Parkinson et al. (unpublished). Results of the phase 3 survey report that lecturers of Exercise & Sport Science do frequently use techniques that help students learn effectively, and that it is indeed important to do so. However, interview discussion in phase 2 did not focus heavily on this topic knowing that it has been covered extensively by Parkinson et al. (unpublished).

4.4.2. Generic Skills

There are an increasing number of references to 'non-technical skills' in the literature, especially with recent assertions that these are what make graduates most employable, above and beyond their discipline-specific skills (Allan & Hughes 2009). The present study concurs with the importance of generic skills and advocates that every teacher of Exercise & Sport Science plays an integral role in this aspect of education; not least as role models of generic skills themselves. Using the example of veterinary science, Allan & Hughes (2009) recommend the integrated dissemination of the following non-technical skills: Professional Duty of Care; Effective and Empathetic Communication; Understanding of Business; Capacity for Self-Management and Self-Knowledge; Adaptability and Ability to Collaborate; Recognition of and Compliance with Ethical and Professional Standards.

In phase 3 statistical analysis reveals a significant difference between the importance of 'Generic Skills' and their frequency in Exercise & Sport Science papers, in the view of graduates. However, there is no significant difference according to the perception of lecturers. A possible explanation for this might reflect an argument presented by Allan & Hughes (2009) that science academics don't always find themselves confident in non-technical skills and therefore find these challenging to disseminate and role model. However, this study recommends that teachers of the discipline familiarize themselves with studies in education that have strongly indicated the benefit of incorporating non-technical skills in to every paper; and effective models of doing so. Professional development in non-technical skills are almost always available from central university resources.

4.4.3. Acquiring Knowledge

Teachers of Exercise & Sport Science may be unable to influence the programme structure. However, this study proposes that individual academics should endeavor to integrate as much fundamental science and mathematics as possible in to each individual paper. Results from phase 2 suggest there is abundant scope for aspects of fundamental biology, chemistry, physics, mathematics and statistics to be highlighted in all papers relating to physiology, biomechanics and motor behavior. This study advocates that it would be particularly effective for teachers of Exercise & Sport Science papers to plan a coordinated approach to the dissemination of fundamental knowledge so that concepts can be reinforced across papers. In addition, for programmes that ‘borrow’ papers from the wider Faculty of Sciences, teachers of Exercise & Sport Science should be seeking to understand what their students are being taught, with a view to build on fundamental knowledge in the context of the human body in movement.

For students who have the intention to study science at tertiary level, it has been advised that they may find it beneficial to take a combination of sciences at secondary school (Fullarton et al. 2003). Therefore, considering that Exercise & Sport Science incorporates physics, chemistry, biology and mathematics, it is contentious that students are able to enter the programme without NCEA Level 3 credits in all four of these subjects. Although teachers of Exercise & Sport Science may not be able to influence the entry requirements of Bachelor of Science programmes, a possible intervention would be talking to school students about the scientific rigor of Exercise Science; whether that means lecturers visiting schools, school students visiting laboratory classes, or both. This type of collaboration with schools was also recommended by Parkinson et al. (unpublished).

4.4.4. Applying Knowledge

Giving students the opportunity to apply their knowledge in meaningful situations is discussed by Gago (2004) and Tytler (2003); and is reinforced by participants of phase 1. This study advocates that each paper should allow students to gain experience of translating theory in to practice themselves in laboratory and field environments. Given that there are only jobs available in exercise science for a small percentage of its graduates, the benefits of applying knowledge to generic science scenarios is also advocated.

In terms of discipline-specific field environments, results of phase 2 indicate that Exercise & Sport Science programmes are well placed to leverage mundane exercise scenarios and ancillary sport and/or exercise related networks for the purpose of applying knowledge. However, according to phase 3 results, in the perception of both lecturers and graduates, there is a significant difference between the importance and the frequency of ‘Applying Knowledge’. Anecdotal evidence from phase 2 suggests that this might be associated with a perception that ancillary networks are not leveraged to their full potential for the purpose of applying knowledge.

4.4.5. Challenging Knowledge

In phase 1, participants assert that understanding how the scientific method is used to construct and critique knowledge is at the heart of a rigorous scientific education. However, phase 2 revealed that undergraduates of Exercise & Sport Science do not typically demonstrate the natural levels of enquiry expected from scientists; and do not have sufficient knowledge of statistics to read peer-reviewed journal articles. In phase 3, a significant difference was revealed between graduates and lecturers, with graduates perceiving that ‘Challenging Knowledge’ happens more frequently than lecturers perceive. This connects with results from phase 2, in which lecturers admit to postponing the tutoring of students in critical thinking until postgraduate years. The result may also be explained by the failure of graduates to realize their shortcomings.

This study recommends that each paper should nurture students to continually question the basis for their beliefs, which would require students to understand how the ‘scientific method’ is used to construct and critique knowledge. In agreement with Ammonette et al. (2010), this study advocates that a system such as Evidence-Based Programming (EBP) should become the foundation of every paper in Exercise Science. This would mean that teachers of every paper would require students to examine a research question; examine evidence; evaluate the evidence; apply evidence into practice; and re-evaluate the evidence.

4.4.6. Investigating Knowledge

The United Kingdoms’ Quality Assurance Agency for Higher Education benchmark statement for biosciences requires students to independently plan and execute a hypothesis-driven experiment. In phase 1, participants agreed that independent mastery of the scientific method is integral to a rigorous science education. However, results from phase 2 of this study indicate that undergraduates of Exercise & Sport Science in New Zealand need more opportunities to practice becoming independent investigators. Results of phase 3 reveal a significant difference between graduates and lecturers, with graduates attributing more importance to ‘Investigating Knowledge’ than lecturers. This is likely to be related to lecturers’ perception that it’s acceptable for a focus on investigation to be delayed until postgraduate years; while graduate results are a likely reflection on students’ preference for ‘hands-on’ learning (Parkinson et al. unpublished).

Rather than postpone rigorous science until postgraduate years, this study advocates that each undergraduate paper of Exercise & Sport Science should progress students towards becoming independent investigators by providing opportunities to execute the ‘scientific method’ and, where possible, the prospect of generating new knowledge through research projects. As it was highlighted in phase 1, the best way to grasp complexity and discover truth is to undertake research.

Limitations

This study did not identify any limitations with phase 1. There were no limitations with phase 2, although it would have been interesting to also interview graduates. Phase 3 of the study followed a standard methodology but was limited by its sample:

Firstly, using one university as a convenience sample means that results are not guaranteed to be representative of undergraduate programmes in Exercise & Sport Science in New Zealand. Secondly, in order to have confidence that survey results are representative, it is important to have a large number of randomly-selected participants. For a 95% confidence level a good estimate of the confidence interval is given by $\frac{1}{\sqrt{N}}$, where N is the number of participants or sample size. In phase 3, a sample size of 20 participants meant that the confidence interval was 22.4%. Thirdly, the sample was not large enough to undertake a factor analysis, which would have been a better way of reliability checking. Finally, a small sample size meant that linear correlations between the six scales showed a high potential of shared variance.

Further Study

The present study has presented six criteria that define a rigorous science education at an undergraduate level: Programme & Pedagogy; Generic Skills; Acquiring Knowledge; Applying Knowledge; Challenging Knowledge; and Investigating Knowledge. The validation of these scales is worthy of further study with a larger sample size that would allow factor analysis to be undertaken. In the context of Exercise & Sport Science, this would ideally involve the participation of all undergraduate programmes in New Zealand; if not Australia and beyond if the opportunity arose.

The potential also exists for the study to be expanded to include a much wider range of undergraduate science education. Such a study would require significant funding and extensive collaboration; as well as recommended expertise from experts in the pedagogy of science education. However, as far as it has been possible to ascertain from the literature, such a study would be the first to produce a reliable instrument for the measurement of the scientific rigor of undergraduate programmes pertaining to be science.

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Appendix

BASED ON YOUR PERCEPTION OF UNDERGRADUATE SPORT & EXERCISE SCIENCE PAPERS

1 = strongly disagree | 2 = disagree | 3 = neutral | 4 = agree | 5 = strongly agree

Part 1		This happens frequently					This is important				
		1	2	3	4	5	1	2	3	4	5
	Papers are scientifically rigorous	1	2	3	4	5	1	2	3	4	5
	Papers are among the very best science papers available	1	2	3	4	5	1	2	3	4	5
	Papers challenge students intellectually	1	2	3	4	5	1	2	3	4	5
	Papers leave students enthused about science	1	2	3	4	5	1	2	3	4	5
	Papers prepare students to become scientists	1	2	3	4	5	1	2	3	4	5
	Lecturers are enthusiastic about science	1	2	3	4	5	1	2	3	4	5
	Lecturers cite recently published research, including their own	1	2	3	4	5	1	2	3	4	5
	Lecturers use techniques that help students learn effectively	1	2	3	4	5	1	2	3	4	5
	Lecturers provide clear learning goals	1	2	3	4	5	1	2	3	4	5
	Lecturers provide constructive feedback	1	2	3	4	5	1	2	3	4	5
	Lecturers interact with students as individuals	1	2	3	4	5	1	2	3	4	5
Part 2		This happens frequently					This is important				
		1	2	3	4	5	1	2	3	4	5
	What students learn helps prepare them for their futures	1	2	3	4	5	1	2	3	4	5
	Students learn about professional communication skills	1	2	3	4	5	1	2	3	4	5
	Students learn about teamwork / collaboration	1	2	3	4	5	1	2	3	4	5
	Students learn about awareness of self and others	1	2	3	4	5	1	2	3	4	5
	Students learn about self-directed learning	1	2	3	4	5	1	2	3	4	5
	Students learn about thinking analytically to solve problems	1	2	3	4	5	1	2	3	4	5
	Students learn about good organizational skills	1	2	3	4	5	1	2	3	4	5
Part 3		This happens frequently					This is important				
		1	2	3	4	5	1	2	3	4	5
	Students learn facts about biology	1	2	3	4	5	1	2	3	4	5
	Students learn facts about chemistry	1	2	3	4	5	1	2	3	4	5
	Students learn facts about physics	1	2	3	4	5	1	2	3	4	5
	Students learn facts about mathematics	1	2	3	4	5	1	2	3	4	5
	Students learn facts about statistics	1	2	3	4	5	1	2	3	4	5
	Students learn facts about literacy	1	2	3	4	5	1	2	3	4	5

Part 4		This happens frequently					This is important				
		1	2	3	4	5	1	2	3	4	5
	Students are given examples of how theory is applied in practice	1	2	3	4	5	1	2	3	4	5
	Students learn about ethical and social issues surrounding science	1	2	3	4	5	1	2	3	4	5
	Students learn how to communicate science to potential clients	1	2	3	4	5	1	2	3	4	5
	Students observe others translate theory into practice in laboratories	1	2	3	4	5	1	2	3	4	5
	Students observe others translate theory into practice in real-life situations	1	2	3	4	5	1	2	3	4	5
	Students translate theory in to practice in laboratories	1	2	3	4	5	1	2	3	4	5
	Students translate theory in to practice in real-life situations	1	2	3	4	5	1	2	3	4	5
Part 5		This happens frequently					This is important				
		1	2	3	4	5	1	2	3	4	5
	Students learn how scientific ideas have developed over time	1	2	3	4	5	1	2	3	4	5
	Students source reliable scientific information	1	2	3	4	5	1	2	3	4	5
	Students read scientific journal articles	1	2	3	4	5	1	2	3	4	5
	Students evaluate hypotheses found in literature	1	2	3	4	5	1	2	3	4	5
	Students evaluate methodologies found in literature	1	2	3	4	5	1	2	3	4	5
	Students evaluate data analysis found in literature	1	2	3	4	5	1	2	3	4	5
	Students evaluate results found in literature	1	2	3	4	5	1	2	3	4	5
	Students use literature to inform scientific discussions / solve problems	1	2	3	4	5	1	2	3	4	5
Part 6		This happens frequently					This is important				
		1	2	3	4	5	1	2	3	4	5
	Students observe someone else undertake experiments	1	2	3	4	5	1	2	3	4	5
	Students test hypotheses, which are not their own	1	2	3	4	5	1	2	3	4	5
	Students test hypotheses, which they construct themselves	1	2	3	4	5	1	2	3	4	5
	Students undertake experiments, which they did not design	1	2	3	4	5	1	2	3	4	5
	Students undertake experiments, which they designed themselves	1	2	3	4	5	1	2	3	4	5
	Students analyze data, which had been gathered by someone else	1	2	3	4	5	1	2	3	4	5
	Students analyze data, which they had gathered themselves	1	2	3	4	5	1	2	3	4	5
	Students analyze data, which reveal novel results	1	2	3	4	5	1	2	3	4	5
	Students use their own results to inform scientific discussions / solve problems	1	2	3	4	5	1	2	3	4	5
	Students use their own results towards the development of new knowledge	1	2	3	4	5	1	2	3	4	5
	Students report experiments using scientific writing skills	1	2	3	4	5	1	2	3	4	5