A Path Drawn Out
Understanding Tertiary Science Participation
in Aotearoa New Zealand

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A thesis submitted in partial fulfilment of the requirements for the degree of
Doctor of Philosophy in Education,
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Abstract

Understanding who chooses to progress in science education is an important issue across the world. Not only are governments motivated to boost the number of skilled workers in STEM domains, but efforts are also being made to ensure that science is viewed as a viable pathway for all students, regardless of their gender, ethnicity, or social class. Despite these efforts, inequities continue to persist in Aotearoa New Zealand, and little research has explored what progression through science education looks like. The following work seeks to fill this gap by interrogating a range of data sources regarding students’ experiences in tertiary science education through a theoretical framework based on the work of Pierre Bourdieu. Beginning with quantitative analysis of large-scale administrative student records, I provide a surface-level summary of What science participation looks like in Aotearoa New Zealand. I then introduce the utility of Bourdieu’s sociological theory in explaining Why we see disparities in science education. Through analysis of a questionnaire administered to science students at the University of Auckland, I discuss the influence of social class on science participation, using factors related to Bourdieu's theory that not readily available in administrative data (such as science-related cultural and social capital). Following this, I build a new theoretical model, informed by qualitative analysis of interview data, to delve even deeper into the experiences of university students studying science. Through this final theoretical model, I explore students’ lived experiences in the field of science education, and provide a discussion of How we can make the field of science education more equitable. By adopting a truly mixed-methods approach to understanding participation in science education, my thesis offers a comprehensive, transdisciplinary exploration of tertiary science education in Aotearoa New Zealand. Through this approach, I show how progression in science may be a path drawn out for some students, but not all.
To my family, friends, and teachers who made this possible.
Acknowledgements

I am incredibly fortunate to have been given the opportunity to conduct the following work. My thesis would not have been possible without the University of Auckland Doctoral Scholarship that supported me, and to my study participants who shared their stories with me. I am also thankful for my colleagues at the University of Auckland who have supported this research – especially the following people, without whom my thesis would not have been possible:

To the Starpath Project, and especially Dr Earl Irving, who gave me my first experience of research. I am extremely grateful for their kindness and patience.

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To my friends, who helped keep me sane throughout this journey.

To Loreen Sonji Magariño, who I am eternally grateful to have as my partner. This work would not have been possible without your love and support. Te amo.

To my family. Growing up with you shaped who I am today. To Nan and Jog for taking care of me, to Mum and Dad for supporting me, to my first teacher Carly and to Phil, to James and Clare for always being there for me, and finally to David, my best friend and role model.
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1.1 **Thesis Structure.** The guide to the structure of my thesis. The first conceptual model is introduced in Chapter 2, and focuses solely on understanding what the field of tertiary science participation looks like in Aotearoa New Zealand. Chapter 3 introduces a new conceptual model that incorporates the Bourdieusian concepts of capital and habitus in an attempt to explain what participation looks like, and potential reasons why it looks that way. Chapter 4 seeks to test how science-related capital may impact on students’ self-concept in science. In Chapter 5, I build a new conceptual model that emphasises the importance of the reciprocal relationship between social capital and habitus, summarising its relevance for university science students in Chapters 6 and 7. In Chapter 8, I detail opportunities to provide more equitable outcomes for students in science education.

1.2 **Context by Breadth.** The goal of my thesis is to provide an in-depth exploration of science participation in Aotearoa New Zealand. In order to accomplish this, I aim towards Bourdieu’s goal of a “true social science” ([Bourdieu and Waquant, 1992](#)) by considering both the broad, objective trends in science education, as well as the subjective experiences of students within the field. As we progress through my thesis, I will build a theoretical model that can consider students’ individual experiences as well as offering a lens to explain why we see larger trends in participation.
2.1 **Chapter 2 Signpost.** The oval represented in the figure above symbolises the field of science education. While future chapters will add to this figure, Chapter 2 focuses solely on describing *what* participation in the field of science education looks like in Aotearoa New Zealand. The following chapters will seek to explain *why* we see differences in participation in science, and *how* we may intervene to provide equitable outcomes.

2.2 **Science Participation Rates Across Years by Sex.** These plots show the participation of male and female students in key science subjects in Year 13 from 2004–2018. Biology and Chemistry had a greater share of female students (nearly 70% of biology students in 2018 were female). Physics continues to be male-dominated. “Science” represents core science assessments, which assess topics about more general aspects of science (including applications to everyday life and societal issues). This core science domain had a relatively balanced representation of male and female students across years. Data retrieved from Ministry of Education [2018].

2.3 **Mathematics Participation Rates Across Years by Sex.** These plots show the participation of male and female students in key mathematics subjects in Year 13 from 2004–2018. There have been relatively even levels of participation in mathematics subjects over time, except calculus where male students continue to be enrolled in greater numbers. Data retrieved from Ministry of Education [2018].

2.4 **Science Participation Rates Across Years by School Decile.** School deciles are grouped into quintiles (deciles 1 and 2 together, deciles 3 and 4, and so on). These plots show the rate of participation for each decile group as a function of the total subject enrolments (across all learning domains) for that group. This takes into account that higher decile groups contain a greater number of students than lower deciles. As can be seen in the above plots, students from higher decile schools are more likely to take biology, chemistry, and physics. Low decile schools had a flatter participation rate in physics, but increasing participation over time in biology and chemistry, such that the increase is similar to higher decile schools. The plot of the core “Science” subject appears less ordered and more variable in terms of decile ordering, but also has a lower rate of participation overall. Data retrieved from Ministry of Education [2018].
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2.5 An Example of a Bipartite Network and its Projections. In the case of the current study, white nodes (set $U$) represent standards, and black nodes (set $V$) represent students. A) Nodes of different sets are connected by an edge $E$ (i.e., an edge will exist if a student took a particular standard). B) The projection of set $U$. In the current study, we use this projection to represent a network of standards. Two standards will be connected by edge if a student enrolled in both standards. If two standards are connected through multiple students, multiple edges are produced. In this simple example, two students enrolled in both standards $e$ and $d$, while other connected standards were only taken conjointly by single students. C) The projection of set $V$. In the current study, this refers to a network of students, with edges indicating that students both took the same standards. To help preserve students' confidentiality, we do not report on this projection.

2.6 Network of NCEA Level 3 Standards. The overall standard projection of the NCEA Level 3 standard co-enrolment network. The above network is a composite of all standards offered between 2010 and 2016, and serves to provide an overall guide to the various subject disciplines represented by each community. Nodes represent standards and edges represent a preference for two standards being enrolled in at the same time by students. Colours represent the communities of standards that tend to be taken together. Squared nodes represent externally assessed standards, and circular nodes represent internally assessed standards. Node size reflects the percentage of all students enrolled in a standard.

2.7 Network of NCEA Level 3 Standards Across Years. The standard projection of the NCEA Level 3 co-enrolment network across years. Node size represents the number of students enrolled in each standard as a percentage of the total number of students in each cohort. As years progressed, the number of standards was reduced. Around 2013, a new set of science and mathematics achievement standards were introduced. Post-2013, the network is comprised mainly of one mathematics and science community, which indicates that assessment was more standardised than previous years.
2.8 Entropy by Sex Across Years. Results show that entropy was higher for the male sub-population (purple) than the female sub-population (orange), while the baseline entropy of the population taken as a whole (dotted black) falls in between. This indicates that enrolments for female students were more ordered, and male enrolments were more varied. .................................................. 68

2.9 Entropy by School Decile Across Years. The entropy of each ethnic group sub-population, split by high school decile. The baseline entropy (black dotted line) is lower for the top decile schools (deciles 7–10), and higher for the low decile schools (deciles 1 to 3). There are observable differences in entropy in each decile. Prior to 2013, the overall entropy tended to be higher for Maori and Pacific sub-populations, and lower for Asian and European. After the policy reform, this pattern seemingly changed such that the Pacific sub-population had the lowest entropy. .................................................. 73

2.10 Network of NCEA Level 3 Standards by Ethnicity. The standard projection of the NCEA Level 3 standard co-enrolment network by ethnicity across all years. Node size represents the percentage of students within the sub-population who were enrolled in a standard, colour represents community membership, squared nodes represent externally assessed standards, and circular nodes represent internally assessed standards. For all ethnic group sub-populations, the main science and mathematics communities (orange and blue nodes) tended to have higher probabilities of enrolment. The propensity for science and mathematics standard enrolment was especially true for Asian students, and less true Maori (C) and Pacific Island (D) groups. ....... 77

3.1 Chapter 3 Signpost. Chapter 3 focuses on describing what science participation looks like in Aotearoa New Zealand. It also introduces a theoretical model based on Bourdieu’s 1984 sociological theory which will be used to explore potential reasons for why we may see differences in participation. .................................................. 85
3.2 Simplified Bourdieusian Theoretical Model. The Bourdieusian framework used in the current study is adapted from the original model outlined by Bourdieu (1984) and the work of Archer and colleagues (Archer et al., 2012, 2014, 2015a). A student’s habitus interacts with their acquired level of capital (in particular science-related capital) to generate a student’s practices (behaviours, grades etc.) and their dispositions towards the field. A student’s habitus, a matrix of internal dispositions (Reay, 2004), is formed in relation to the specific socio-cultural and historical context of a field. A student who is positively predisposed to study in a scientific field, whilst also having access to various forms of science-related capital, will likely achieve higher grades in that field and aspire to study in that field in the future. A student who encounters bad experiences in the field will likely be dissuaded from future study via their habitus (‘this discipline is not for me’).

3.3 Student Course Network. A network representing the communities, or fields, of courses formed by students co-enrolling in course at the University of Auckland. Each node represents a course offered by the university, while links between nodes indicate instances where students took those two courses together within their undergraduate degree. Node colour indicates the community that a course belongs to. Communities were revealed in a two step process. Firstly, edges were filtered so only those with an RCP value over 1 were included. Secondly, the Map Equation software package (Edler and Rosvall, 2017) was used to partition the network into communities of courses, which can be interpreted as the underlying academic fields. The revealed fields are labeled in Fig 3.4 and represent the various academic fields that students in our sample were enrolled in.
3.4 **Course Community Network.** The directed network above represents the network seen in Fig 3.3, only the links within communities (i.e. links between courses belonging to the same community) and between communities have been split by gender and aggregated. Odds ratios comparing the likelihood of a female student taking a course in community $m$ and community $n$ were formulated, with the resulting values used as edge weights. The communities were labelled based on the range of courses that it is comprised of. Edges where female students were more likely to take a course in community $m$ and community $n$ are coloured orange, while edges where male students were more likely to take a course in community $m$ and community $n$ are coloured purple. When considering the flow between a pair of nodes connected by two edges, the direction of flow is outward following the link in a clockwise direction. The network shows that transverse movements from fields such as computer science and physics-maths to other domains tend to be female-dominated, whilst movements into these fields are more male-dominated.

3.5 **Student Course Heat Map.** The above heat map represents the same underlying data as that which is used in Fig 3.4. The heat map makes clear the gender differences in the likelihood of students moving from one community to another. Orange areas represent instances where female students were more likely to take a course in community $n$ after taking a course in community $m$. Purple areas indicate male students were more likely to take a course in community $n$ after taking a course in community $m$. Areas that are white or empty indicate no significant relationship. Male students were consistently more likely to take courses in Computer Science and Physics-Maths after taking courses in each other community. Female students tended to be more likely to take courses in life science subjects (e.g., Biological Science and Psychology).
3.6 **Student Progression Alluvial.** An alluvial plot showing the progression of male (purple) and female (orange) students from high school to university physics split by achievement bands. Female students were equally represented among the top-achieving high school group, but less well represented among the middle and low-achieving groups. PLS (Physics for Life Sciences) and AP1 (Advancing Physics 1) represent the two main groups of physics students in our data. As shown in the alluvial plot, PLS was more popular than AP1, especially at the intersection of top-achievers and female students.

3.7 **Distribution of Rank Change by Gender and High School Achievement Group** The above density plots show the distribution of rank change going from high school to Advancing Physics 1 (AP1). Purple represents the distribution of rank changes for male students, while orange represents female students. The dotted vertical line show the median rank change per group. On average, low-achieving female students went down 6 ranks compared to their male counterparts, while middle-achieving female students went down 9 ranks relative to their male counterparts. There was no significant gender difference in rank change for top-achievers.

4.1 **Chapter 4 Signpost.** Chapter 4 focuses on describing one aspect of why we see differences in science participation in Aotearoa New Zealand. After summarising the relevance of self-concept to the interaction of capital and habitus, this chapter will describe how different forms of science-related social and cultural capital relate to students self-concept in science.

4.2 **Conceptual Model.** Latent variables are represented by oval boxes, observed variables are represented by rectangular boxes. Regressions are represented by one-sided arrows, while correlations are represented by double-headed arrows and dashed lines.

4.3 **Model results.** Results of the original conceptual model (Fig 4.2) with standardised coefficients and significance. Single-headed solid lines indicate a regression, while double-headed dotted lines indicate a correlation. Green arrows indicate a positive association, while red indicates a negative association. Faded grey lines indicate no significant relationship. *$p < .05$, **$p < .001$*
Chapter 5 Signpost. Chapter 5 focuses on building a new theoretical model that can offer more answers to the question of why we see differences in participation in science education in Aotearoa New Zealand.

It seeks to emphasise the dynamic relationship shared between capital and habitus.

Sampling Strategy. The above highlights the distribution of participants who were purposefully sampled when arranging interviews. I aimed to interview students with a range of different backgrounds based on different forms of science capital. Axes indicate students’ level of a particular form of capital, including Science Parents, Science Peers, Science Resources, and Science Teachers (with Teachers and Parents highlighted on the right hand side). The locations of 12 of the 19 interviewee participants are highlighted by their pseudonym. The four Science Scholars participants are not included in this visualisation, while three interview participants were chosen to be interviewed, despite being excluded from factor analysis due to having too much missing data in the questionnaire. Individual data points are coloured and shaped according to self-identified gender and ethnicity. In this case, ethnicity is coded according to prioritised ethnicity, where students who identified with multiple ethnicities were first coded as Māori, then Pasifika, then Asian, then European (following guidelines set out by Statistics New Zealand). I only use the prioritised ethnicity for visualisation and not for any analysis.

Complete Theoretical Model. The complete theoretical model. The model, informed by the described experiences of university science students, expands on the interaction between habitus and capital originally illustrated by Bourdieu [1984]. The model provides a step-by-step description of how social capital translates into habitus, and how habitus generates future capital. Theme 1 refers to the initial availability of social capital for an individual. Theme 2 refers to the value gained through leveraging social capital into forms of economic and cultural capital. Theme 3 refers to how capital is internalised by the individual and embodied in their habitus. Theme 4 refers to the impact of doxa (societal discourses) on students, and Theme 5 refers to how habitus and doxa inform the future accumulation of social capital.

Theme 1. The first theme of the theoretical model refers to the initial availability of social capital for an individual.
5.5 **Theme 2.** The second theme of the theoretical model refers to ways in which the value of social capital is leveraged. This theme describes the value of social capital in terms of its utility in mobilising cultural and economic capital. 172

5.6 **Theme 3.** The third theme of the theoretical model refers to the manner in which capital is internalised by individuals and embodied within their habitus. 180

5.7 **Theme 4.** The fourth theme of the theoretical model highlights the impact doxa has on students. In simple terms, doxa refer to pervasive societal discourses that appear to be self-evident. Students, their family, and their educators are often aware of ‘common-sense’ notions of what scientists appear to be like, and which subjects are for different individuals. Theme 4 discusses the impact of these discourses on how students identify with science. 185

5.8 **Theme 5.** The fifth and final theme of the theoretical model. This theme refers to the manner in which students go about generating capital. The manner in which students go about accumulating capital will be guided by their habitus, which is influenced by the prior internalisation of capital and doxa. 188

6.1 **Theoretical Model (Themes 1-3).** The first three Themes of the theoretical model point to the importance of having access to social capital (Theme 1), being able to leverage value from a social relationship (Theme 2), and the manner in which capital is internalised and influences students' sense of belonging in the field (Theme 3). 194

7.1 **Theoretical Model (Themes 4-5).** The final two Themes in the theoretical model point to the significant and pervasive influence of doxa on students' experiences in the field (Theme 4), and the manner in which students seek to accumulate capital in the field (Theme 5). 230

8.1 **Complete Theoretical Model.** The complete theoretical model. The model, informed by the lived experiences of my participants, expands on the interaction between habitus and capital originally illustrated by Bourdieu (1984). The model provides a step by step description of how social capital relates to an individual's internal dispositions (habitus), and how this relates to the future generation of capital. 264
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4.1 Sample Description. The table above shows the counts and percentages of categorical characteristics, and means and standard deviations of ordinal characteristics. Individuals’ self-reported gender was categorised into male, female and gender diverse groups for reporting purposes. Participants were given the option to self-identify with multiple ethnic groups, which means that percentages do not total to 100. *Middle Eastern, Latin American, or African. **Mature students (those with a recorded age over 24) were excluded from analysis (n = 42). $S$ suppressed due to low cell size.

4.2 Questionnaire Items. The table above shows the questionnaire items used in the current study, with loadings onto the relevant latent construct where applicable. Descriptive statistics for each item are also reported. All items were scored on a continuous scale of 0–100, with the exception of Q5 items, which were scored on a Likert scale of 1–5.

4.3 Correlations between constructs for CFA. Variables were standardized to have a mean of 0 and a standard deviation of 1. CFA = confirmatory factor analysis. N=583; M = 0; SD = 1.

4.4 Measurement Model. The measurement model summarises the loading of items onto theoretical constructs outlined in Figure 4.2. The results of the measurement model show that items loadings were significant and acceptable.

4.5 Structural Model. The structural model summarises the inter-relationships between the constructs identified in the measurement model (Table 4.4) and the other variables included in the theoretical model (Figure 4.2). The results of the structural model show that while all of the science capital related constructs (Science Teachers, Science Peers, and Science Resources) are positively and significantly correlated, Science Teachers and Science Peers were the only significant predictors of Science Self-Concept. Of the other variables included in the model, the number of university generations in the family (Uni Generations) and being male (Male) positively and significantly predicted Science Self-Concept. The number of years a student had attended university negatively and significantly predicted Science Self-concept. These results are visualised in Figure 4.3.
5.1 **Qualitative Research Timeline.** Preliminary interviews with four students from the Science Scholars programme informed the design of questionnaire (and contributed to the final qualitative analysis), which was administered to science students at UoA in early 2019. Fifteen students were then purposefully sampled for interviews based on questionnaire responses, resulting in a final overall sample of nineteen participants.

5.2 **Participant Summary.** A table summarising the characteristics of the individuals who participated in interviews following completion of the questionnaire. Aggregated group counts are provided to help preserve anonymity. Participants may have identified with multiple ethnicities or be enrolled in multiple subject disciplines, which means that these counts do not sum to fifteen. Three students who participated in interviews did not provide enough information on construct items to have scores on self-concept and capital scales attributed to them. Information is not presented for the four science scholars students who participated in the first interview phase of the study, prior to administration of the questionnaire.
The following glossary provides a short list of terms that will be used throughout this thesis. While I use many technical terms in my thesis, the aim of this glossary is to provide specific definitions to terms that have broad applications.

- **Field.** Any context where individuals act. An individual's position in the field is determined by the volume of capital they hold that is valued according to the rules of the field. An individual’s disposition towards the field is determined by habitus.

- **Capital.** Any resource that can be used to gain advantage in a field. According to Bourdieu (1986), it manifests in four forms: Economic Capital, Cultural Capital, Social Capital, and Symbolic Capital. Contemporary theorists, such as Archer et al. (2015a), have also expanded on Bourdieu's conceptualisation of capital to include more specific sub-categories (e.g., Science Capital).

- **Economic Capital.** Any financial resource (e.g., money).

- **Cultural Capital.** Any non-financial resource. This includes the items that we own (objectified cultural capital), such as clothes, equipment, furniture etc. It also includes the way that we embody our culture (embodied cultural capital) in our speech, posture, and other physical attributes, and the certificates of cultural competency we obtain from institutions (institutional cultural capital), such as qualifications.

- **Social Capital.** The resources that we obtain through our relationships with others. As summarised by Adler and Kwon (2002), social capital includes benefits associated with obtaining resources through relationships (bridging social capital), and benefits derived from feeling part of a group (bonding social capital).
• Symbolic Capital. The advantage derived from holding capital that is recognised in society as prestigious.

• Habitus. The system of dispositions that is derived from the internalisation of an individual’s external context. It encompasses their “feel for the game”, their perception of chances of success in a field, and their feeling of whether a field is for them or not. It is through habitus that the external structures in society manifest internally, enabling or constraining the range of possible pathways through life. When individuals are exposed to similar contexts, they internalise similar dispositions that take on a collective quality (classed habitus).

• Doxa. Discourses that permeate society and are generally perceived as ‘common’ knowledge and self-evident.
Co-Authorship Forms
This form is to accompany the submission of any PhD that contains published or unpublished co-authored work. Please include one copy of this form for each co-authored work. Completed forms should be included in all copies of your thesis submitted for examination and library deposit (including digital deposit), following your thesis Acknowledgements. Co-authored works may be included in a thesis if the candidate has written all or the majority of the text and had their contribution confirmed by all co-authors as not less than 65%.

Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 2 - Understanding Student Participation in Science Education. Submitted to Frontiers in Big Data on the 26/08/2020

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Certification by Co-Authors

The undersigned hereby certify that:
- the above statement correctly reflects the nature and extent of the PhD candidate’s contribution to this work, and the nature of the contribution of each of the co-authors; and
- that the candidate wrote all or the majority of the text.

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Co-Authorship Form

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**Bourdieu, networks, and movements: Using the concepts of habitus, field and capital to understand a network analysis of gender differences in undergraduate physics.** [https://doi.org/10.1371/journal.pone.0222357](https://doi.org/10.1371/journal.pone.0222357)

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The undersigned hereby certify that:

- the above statement correctly reflects the nature and extent of the PhD candidate’s contribution to this work, and the nature of the contribution of each of the co-authors; and
- that the candidate wrote all or the majority of the text.

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**The Impact of Science Capital on Self-Concept in Science: A Study of University Students in New Zealand.** Frontiers in Education. [https://doi.org/10.3389/feduc.2020.00027](https://doi.org/10.3389/feduc.2020.00027)

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Chapter 1

Introduction

When I was at high school, I did well at science. I was a top achiever and found each of my science lessons interesting. However, I distinctly remember never really seeing science as a path forward through education, or as a future career. While my family shaped me into a person that was capable of being successful in education, university, and science at university especially, was never a ‘thing’ that was expected or even talked about. I always intended to follow the same path as my brothers, who both ended up having careers in the armed forces. As I entered my final years of high school, I was disillusioned with education, my grades had declined, and I had dropped out of science altogether. Following some years outside of education, I entered into university (as the first in my family to do so), motivated to understand why so many students, including myself, become disillusioned with institutional education, and with science in particular. My story provides one example of the complex trajectories that students take through science, but many students are faced with more considerable barriers to progressing in the field. Although my knowledge of university science was limited I re-entered back into institutionalised education as a white man from an upwardly socially-mobile family, *seamlessly*. My privilege enabled me to reach a position where I am now able to conduct research. Many students who have the potential to flourish in science will not be so lucky.

The following research will examine the complex drivers behind students’ participation in science. Using data from a range of sources, including large-scale administrative records, questionnaire responses, and interviews with students studying science at university, I will provide a comprehensive understanding of why participation in tertiary science is a path drawn out for some students, but not for
Introduction

The following section will provide a brief introduction to this topic, outline my key research questions, and summarise how my thesis will answer these questions.

1.1 Understanding Participation in Science Education

Governments and organisation across the world have been increasingly driven to understand who chooses to study science at university and enter into careers in science. There is an increased recognition that many students do not hold interests in science-related careers, with these interests also declining in over the previous decades (Bolstad and Hipkins 2008, Science Education Committee of the Royal Society of New Zealand 2012). Despite commonly being regarded as a subject where bias is unacceptable, a superficial look at the field of science also shows that disparities in participation are common place. Science continues to be a domain where students from different backgrounds participate at different rates. Across the world, there tends to be uneven levels of interests and retention in science and technology subjects across various demographic characteristics, including ethnicity (Wong 2016), gender (Cheryan et al. 2017, Su and Rounds 2015), and Socio-Economic Status (SES) (Archer et al. 2013a). Furthermore, students from less affluent backgrounds tend to have poorer educational outcomes in general (May et al. 2016), and are less likely to realise tertiary education goals (Reynolds and Johnson 2011). These reports point to a concerning issue, where some students may be more able to progress through science education compared to others.

It is important to address these inequities in science education for several reasons. Doing so can increase the number of skilled workers in STEM (Science, Technology, Engineering and Mathematics) domains. This is a priority for governments due to the key function of STEM jobs in contributing to the “knowledge society” (Gilbert 2005) and its associated economic growth (Pricewaterhouse Coopers Australia 2015). This was outlined in a report on the future of science education in Aotearoa New Zealand by the Science Education Committee of the Royal Society of New Zealand (2012 p.14):

School science education programmes designed to support Aotearoa New Zealand’s development as a ‘smart’ country need to produce: (i) a supply of tertiary graduates who have the knowledge, skills and dispositions needed by today’s science workforce (not those needed in the past); and (ii) a wider population that is engaged in science — that is, a population that is interested in science, has some understanding
of the ‘big ideas’ and is ready, willing and able to participate in public
discussions of science-related issues.

As summarised in the second point made above, widening participation in tertiary
science education can also improve the general level of scientific literacy in society.
Not only is this key for improving the life outcomes of individuals, but it also
allows individuals to carry out their roles as informed citizens (Shamos, 1995).
Finally, and most importantly, the need to address inequities should be driven by
the egalitarian ideal that all students should be given a fair chance of success in
science. In Aotearoa New Zealand, the need to address inequities is particularly
salient for government. As outlined in the Child Youth and Wellbeing Strategy
(Child Wellbeing & Poverty Reduction Group, 2019), it is important that all
young people are not only learning and developing, but they are doing so in a way
that ensures that they are happy and healthy. Te Tiriti o Waitangi (The Treaty
of Waitangi) also sets out a requirement for intergenerational inequities to be
addressed regarding Māori (Ministry of Maori Development, 2001), the indigenous
population of Aotearoa New Zealand. Researchers and policy makers are thus
charged with investigating, understanding and addressing disparities related to
participation in science education.

Research into inequities in STEM often focuses on one aspect of an individual’s
identity, without considering the contexts in which students are placed. There is
an increasing wealth of literature detailing gender disparities in STEM interests
and outcomes (Sue et al., 2009; Wang and Degol, 2017), but there are relatively
fewer studies that explore both gender and ethnicity (Fouad and Santana, 2017;
Grossman and Porche, 2014), and even fewer still that investigate the intersections
between gender, ethnicity and social class (Archer et al., 2013b). While it can be
relatively simple to operationalise gender and ethnicity in research (for example
through self-identification or categorisation), social class is a more difficult con-
struct to define and operationalise. Socio-economic status is the most commonly
used indicator of social class, but as argued by Rutkowski and Rutkowski (2013),
a ‘one-size-fits-all’ approach to SES can be criticized for neglecting cross-country
and cross-cultural differences. This argument can be extended further by exploring
how social class relates to a student’s specific field of study or career intention.
While having parents with highly paid jobs has been shown to be beneficial for
students across different contexts, research has also shown that parents’ employ-
ment is linked to domain-specific preferences in education. For example, children
who have parents who work as scientists are more likely to grow up study science
themselves (Moakler Jr and Kim, 2014; Bui and Cain Miller, 2017). We are left with a challenge of understanding participation in science in a way that considers a complex social context. My thesis engages with this challenge by adopting a sociological approach to answering three key research questions.

1.2 Three Key Questions

My work seeks to answer three key research questions to contribute to our understanding of tertiary science participation in Aotearoa New Zealand. Firstly, what does tertiary science participation look like? While there has been much research conducted internationally regarding trends in science participation (National Science Foundation, 2017; Kennedy et al., 2014), there are relatively fewer descriptions of what tertiary science participation looks like in the context of Aotearoa New Zealand. The Learning Curves project, conducted by Hipkins et al. (2005), provides an example of research that has explored the subject choices that students make at high school in Aotearoa New Zealand. Hipkins and Bolstad (2005) discuss the various methods that can be used to explore science participation in Aotearoa New Zealand, and provide a comprehensive summary of what overall participation in science looked like prior to 2005. My thesis will build on this research, by providing a contemporary summary of the patterns of enrolment for students studying science through use of more recently established data sources, and by employing novel methods of analysis that may have applications for all researchers seeking to further explore patterns in students’ subject selection.

My second key question seeks to understand why we see differential patterns in participation in tertiary science education. Previous research in Aotearoa New Zealand points to the important role that identity development plays in influencing the study decisions that students make. In a discussion of how participation in science education is influenced by students’ interests/disinterests in science, Bolstad and Hipkins (2008) highlight the role of society on students’ identity development. They discuss the various factors that motivate students to study science, and the role that gender plays in shaping interest. More recent work in Aotearoa New Zealand by Pomeroy (2016) explores how interests in mathematics is shaped by students’ social location and their experiences in schools and wider society. My research, which adopts a similar research framework to Pomeroy (2016), will seek to answer the question of why students participate in tertiary science education by considering the complex socio-cultural contexts in which students are placed.
Given our understanding of what tertiary science participation looks like, and why it looks that way, my final question considers how we may improve the field of science education to make it more equitable. This final question is motivated by the need to ensure that this thesis can contribute to changing an education system that continues to serve some students at the expense of others. In answering this question, I echo previous work conducted by Bolstad and Hipkins (2008) and the Science Education Committee of the Royal Society of New Zealand (2012), who provide discussions of possible opportunities to increase overall student engagement in science education in Aotearoa New Zealand. My research will contribute to this area by further exploring how we may address disparities in participation in tertiary science education. The following section will describe the methodological approaches I have employed to answer the above key research questions.

1.3 A Bourdieusian Methodology

While it is relatively simple to summarise what participation in tertiary science looks like, understanding why we see differences, and how we can address inequities is more complex. My efforts to answer these questions in a way that considers the socio-cultural and historical contexts in which students are placed requires a comprehensive theoretical framework. To accomplish this goal, I employed the sociological theory of Pierre Bourdieu as a research framework and as an interpretive lens. The following section will describe the relevance of Bourdieu’s work to my research questions in more detail.

Pierre Bourdieu was a French sociologist whose work has garnered much attention in the field of education. At the very heart of Bourdieu’s work was the idea that an individual’s practices are influenced by their structural position within society. Following this premise, Bourdieu’s theory emphasises the significant influence of external structures on an individual’s internal dispositions, and how this leads to inequities in society being perpetuated over time. While much research into inequities in science has neglected the socio-cultural and historical contexts in which students are placed (Cannady et al., 2014), Bourdieu’s work provides a framework that considers the complex contexts in which individuals are placed. Through use of this framework, we can meet the task of uncovering true sources of inequity in society (Bourdieu and Waquant, 1992, p.7):

“The task of sociology, according to Pierre Bourdieu, is ‘to uncover the most profoundly buried structures of the various social worlds which
constitute the social universe, as well as the mechanisms which tend to ensure their reproduction or their transformation’.

Bourdieu’s contributions to sociology are wide-ranging, and his work has had cascading impacts as more contemporary theorists have adopted and adapted his theory to suit their needs. More recent research has applied Pierre Bourdieu’s sociological theory to understand who succeeds in education (Lareau, 2011), and who chooses to study science (Archer et al., 2015a). Following in the footsteps of these theorists, I seek to extend Bourdieu’s application to science education by using his concepts to explore science participation in Aotearoa New Zealand. I will draw upon Bourdieu’s concepts of field, capital, and habitus to explore why students choose to study science. Through use of these concepts (which will be introduced in greater detail in the following chapters) I will explore the contexts in which students are placed, how students internalise the world around them, and how this relates to their sense of belonging in science.

1.3.1 “A Total Science of Society”

My thesis seeks to emulate Bourdieu’s work, not only by employing his theoretical concepts to answer research questions, but also by structuring my research in a manner that is informed by his approach to research. Bourdieu strongly advocated for “a total science of society” (Bourdieu and Waquant, 1992, p.10), where theory and practice are interwoven. As outlined by Bourdieu and Waquant (1992, p.34): “[Bourdieu] advocates for the fusion of theoretical construction and practical research operations. He does not seek to connect theoretical and empirical work in a tighter manner but to cause them to interpenetrate each other entirely.” Within each chapter, the mode of analysis has been carefully considered so that it fits within a theoretical framework based on Bourdieu’s sociology.

Bourdieu also advocated for an approach to research where objective trends in society are considered alongside the subjective experiences of individuals. As outlined by Bourdieu and Waquant (1992, p.7), Bourdieu saw how structures in society live a “double life”, in that they exist both outside of individuals (i.e., in the distribution of resources) and inside individuals (as an internalised system of dispositions). My research seeks to provide a comprehensive understanding of science participation in Aotearoa New Zealand by considering both aspects, by providing a description of the “objective” trends in science, and the subjective experiences of students within the field of science.
1.4 Structuring My Thesis

The goal of my thesis is to provide an in depth understanding of participation in tertiary science education in Aotearoa New Zealand, with the specific aims of answering the three key research questions outlined previously. I seek to understand what participation in science education looks like in Aotearoa New Zealand, why we observe differential trends in tertiary science education, and how we can make the field more equitable. These three questions have driven the research process, and my thesis is structured according to these questions. Figure 1.1 provides a visual guide to my thesis, and shows how my theoretical framework will develop as my thesis progresses. I will refer to this figure at the beginning of each chapter to provide a signpost for where a chapter fits within the overall context of my thesis.
Figure 1.1: Thesis Structure. The guide to the structure of my thesis. The first conceptual model is introduced in Chapter 2, and focuses solely on understanding what the field of tertiary science participation looks like in Aotearoa New Zealand. Chapter 3 introduces a new conceptual model that incorporates the Bourdieusian concepts of capital and habitus in an attempt to explain what participation looks like, and potential reasons why it looks that way. Chapter 4 seeks to test how science-related capital may impact on students’ self-concept in science. In Chapter 5, I build a new conceptual model that emphasises the importance of the reciprocal relationship between social capital and habitus, summarising its relevance for university science students in Chapters 6 and 7. In Chapter 8, I detail opportunities to provide more equitable outcomes for students in science education.
As my thesis transitions through its component parts, the theoretical contributions of chapters will become increasingly complex, while the breadth of the data in question will narrow. As highlighted in Figure 1.2, the opening chapters consider a wider scope of data, but are more limited in their theoretical contributions. Theory will be increasingly centred within the chapters as the thesis progresses, culminating in a more complex theoretical model that will be used to explore the unique life experiences of students studying science.

![Figure 1.2: Context by Breadth](image)

The goal of my thesis is to provide an in-depth exploration of science participation in Aotearoa New Zealand. In order to accomplish this, I aim towards Bourdieu’s goal of a “true social science” ([Bourdieu and Waquant, 1992](#)) by considering both the broad, objective trends in science education, as well as the subjective experiences of students within the field. As we progress through my thesis, I will build a theoretical model that can consider students’ individual experiences as well as offering a lens to explain why we see larger trends in participation.

My thesis is split into three parts, reflecting my key three research questions. To answer my questions, I adopt different methodological approaches, and for this reason, the style may change as it progresses. The initial chapters, which focus on answering the question of what science participation looks like in Aotearoa New Zealand, are comprised solely of quantitative research methods. These quantitative chapters are highly structured, following formal, established guidelines set out by academic journals. With the shift in focus to the questions of why we see disparities
in tertiary science participation and how we can improve things, the writing style is
more personal and less formally structured. While the different parts of the thesis
may contrast in these respects, I will maintain a cohesive narrative throughout the
thesis by introducing each chapter with a ‘preamble’ section. In these sections, I
will situate the chapter within the overall context of the thesis, as well as the
real-life context in which the chapter was written. The following section of this
chapter will now provide an overall summary of the component parts of my thesis.

1.4.1 Part I: What Does Science Participation Look Like in
Aotearoa New Zealand?

The first part of my thesis focuses on answering the question of what science
participation looks like in Aotearoa New Zealand. Chapter 2 will focus on exploring
the assessments that students enrol in during the final year of high school. This
first set of work analysed data obtained from Aotearoa New Zealand’s Integrated
Data Infrastructure (IDI), and represents all students from 2010 to 2016 studying
Level 3 STEM standards in Aotearoa New Zealand. The goal of this chapter is to
provide a broad description of trends in science participation by sex, ethnicity, and
school decile\(^1\) through a novel method of network analysis that can help identify
patterns in complex enrolment data. While this chapter discusses high school
level data, the trends that are uncovered provide a wider picture of pathways that
students take through science, and provide an important backdrop for exploring
who chooses to progress through tertiary science education. As shown in Figure
1.2, the discussion of context within this chapter is limited, with the main purpose
being an objective description of what science participation looks like.

Chapter 3 focuses on the patterns of enrolment for undergraduate science stu-
dents, employing a method of network analysis similar to that outlined in Chap-
ter 2. Unlike Chapter 2, Chapter 3 seeks to provide an increased discussion of
the context in which students are placed as they make enrolment decisions. More
specifically, I employ a simple theoretical model based on Bourdieu’s theory as a
lens to interpret gender differences in undergraduate pathways for students who
took physics. This chapter provides a more detailed exploration of the movements
students make in a field. I also begin to offer more description of the socio-cultural
contexts in which students are placed by providing an introduction to Bourdieu’s

\(^1\) School decile refers to the socio-economic status of the school, and is derived from the area
in which the school is located. A high decile (highest being scored as 10) means a school is located
in an affluent area, while a low decile (lowest being scored as 1) means a school is located in a
less affluent area.
concepts of capital and habitus. In doing so, I begin shift my research focus to the question of why we see disparities in tertiary science education.

1.4.2 Part II: Why Do We See Disparities in Tertiary Science Education?

The chapters that make up Part I provide an idea of what trends and disparities are common in tertiary science education, but to understand science participation more fully, the focus now shifts to question why we see differences in participation across science domains. Chapter 4 begins to answer this question by discussing the results of a questionnaire designed to assess aspects of students’ experience that are not readily available in administrative data. More specifically, the questionnaire was designed to record students’ level of science-related capital, and how this relates to students’ internalised disposition towards science. The transition to a new data source means that, while the breadth of data is reduced, the consideration of theory is facilitated further (as highlighted in Figure 1.2). While my work is heavily influenced by Bourdieu’s approach to social science research, in Chapter 4 I also seek to follow other theorists (Lizardo 2004; Reay 2015) by considering the perspectives of research grounded in the field of psychology.

Following the administration and analysis of the questionnaire, respondents were purposefully sampled and invited to be interviewed about their experiences in science. The transition to qualitative data allows for an increased consideration of Bourdieu’s theory, and this is reflected in my development of a new theoretical model summarised in Chapter 5. The change in approach reflects the aim of understanding “not ‘reality’, but agents’ representations of it” (Bourdieu 1986). Chapter 5 discusses the procedures that I used to sample participants for interviews, the process that I used to interview participants, and the approach I took to develop a theoretical model that considers the recollections of participants in tandem with Bourdieu’s sociological theory.

Chapters 6 and 7 then activate the new theoretical model in the lived experiences of interview participants. Chapter 6 specifically focuses on the first half of the theoretical model, discussing themes that consider the experiences that students have accessing forms of social capital, leveraging value from social capital, and internalising their socio-cultural contexts. The experiences detailed in Chapter 6 compliment the analysis of the questionnaire in Chapter 4 by offering an additional lens to understanding students’ experiences of science-related capital. Chapter 7 then discusses the experiences of participants relating to the second
half of the theoretical model, which considers the relationship shared between individual students and the field of science as a whole. This chapter includes themes relating to general discourses that permeate society that influence students in science (doxa), and how the contexts in which students are placed influence their future generation of capital. Chapter 7 compliments Chapters 2 and 3, as it allows us to see how broad trends in science education are manifested in the individual experiences of students and become self-fulfilling.

1.4.3 Part III: How Can we Make the Field of Tertiary Science Education More Equitable?

The closing part of my thesis seeks to build on my understanding of what tertiary science participation looks like and why it looks that way, to offer a discussion of how we can improve things to make the field of tertiary science education more equitable. In Chapter 8, I scrutinise my final theoretical model to offer potential opportunities where interventions may widen participation in science education. I target each of the themes that comprise the theoretical model to establish a wide range of directions that can address sources of inequity. My final chapter will then provide summary of the thesis’ overall findings and contributions.

I will close my thesis with a discussion of its limitations, and specific areas that are worth being the focus of further research. I do not claim to provide a thesis that sufficiently discusses all aspects of an individual’s experience in science with the detail that they deserve. I write about areas such as ethnicity, gender, and sexuality knowing that I have more to learn, and knowing that each one of these aspects of identity is thesis topic in itself. The strength of my thesis lies in its contribution of viewing the complex overlapping layers of various aspects of students’ experiences in science education, through a unique interpretive lens, employing multiple methodological approaches. My thesis now begins with a summary of what science participation looks like in Aotearoa New Zealand.
Part I: What Does Science Participation Look Like?
Chapter 2

Understanding Student Participation in Science Education

Preamble

This chapter provides the first step (see Figure 2.1) towards answering my three main research questions, specifically: what does the field of science education look like in terms of participation? As we progress through the thesis, later chapters will also seek to answer the question of why the field appears to be structured in certain ways, and how we may enact changes to make it science education more equitable for students.

The following chapter was originally submitted as a journal article to Frontiers in Big Data on the 26th of August, 2020. The goal of this article is to provide a detailed summary of student participation in Science, Technology, Engineering and Mathematics (STEM) education in Aotearoa New Zealand. While this article discusses STEM education rather than science specifically, it provides a rich description of what science participation looks like. I focus on exploring the enrolment patterns that can be seen broadly for students in the final year of high school, and then also more specifically in Level 3 STEM standards in the National Certificate of Educational Achievement (NCEA), using micro-data from Statistics New Zealand’s Integrated Data Infrastructure (IDI). These standards are primarily taken by students in their final year of high school, and provide a good signal to what academic pathways students are following. Given that this article was
written for an international audience, I provide a summary of the NCEA that provides an important context for exploring what science participation looks like in Aotearoa New Zealand. The article also provides an introduction to network analysis, a quantitative technique that I employ as a method of exploring patterns in education courses and assessments in the current chapter, and also in Chapter 3.

2.1 Introduction

There is an increasing demand to understand the choices that students make when it comes to selecting courses in secondary school and further education. Obtaining a clear picture of the skills that students leave school with is an important goal for governments across the world, and this is especially true regarding Science, Technology, Engineering and Mathematics (STEM). For example, the New Zealand Qualifications Authority (NZQA) (New Zealand Qualifications Authority, 2016, p.8) specifically stated that:

To meet the demand for essential skills for the twenty first century, New Zealand needs to grow the number and diversity of skilled workers in Science, Technology, Engineering and Maths.
Governments are pushing to not only increase the number of students participating in STEM education, but also to increase the representation of students who have been historically underrepresented in STEM. While trends may differ across countries, disparities in STEM participation tend to be found at the intersection of gender, ethnicity and social class (Archer et al., 2015b; Comparative Education Research Unit, 2017). Globally, women are typically underrepresented in subjects such as physics and computer science, while there tends to be gender parity in subjects such as biology and medicine. In the case of Aotearoa New Zealand, similar disparities in STEM participation are found (New Zealand Qualifications Authority, 2016; Education Counts, 2016a,b). In addition, students from Maori and Pacific Island backgrounds have also been underrepresented in post-compulsory STEM education (Ministry of Education, 2014; New Zealand Qualifications Authority, 2016).

Student attrition from STEM education is often viewed in terms of a leaky pipeline, with students from groups who are underrepresented in STEM being more likely to drop out of STEM education with each advance from one educational stage to the next. However, participation in STEM education is complex. Not only is it important to consider the socio-cultural context in which students are placed when they make their subject choices, it is also important to consider the structural context of the education system. We are increasingly able to draw upon rich, complex, education-related administrative data to achieve this, but we must consider how we can analyse these data in a manner that preserves complex structures and provides new and useful insights. By meeting this goal, we can increase our understand of what participation in STEM looks like.

As detailed by Hipkins and Bolstad (2005), there are many ways in which STEM participation can be reported on. At a broad level, we can summarise the number of students enrolled in each subject (e.g., how many students of each demographic group study biology?). We can also explore patterns at finer-grained levels by summarising participation per high school (e.g., which high schools have higher proportions of students studying science?), or by reporting participation at the level of assessment (e.g., how many students took a specific biology exam?). While it is relatively easy to summarise and interpret participation at broad levels, untangling and understanding patterns of subject participation at fine-grained levels can be a difficult task. This task is especially difficult in the context of Aotearoa New Zealand, which operates a particularly complex high school assessment system.
The goal of the current study is to develop and employ a novel method of reporting on student participation in STEM by looking specifically at students’ co-enrolments at the level of assessment. We begin by summarising the insights that can be gained by exploring STEM participation at a broad level. We then provide a brief summary of the National Certificate of Educational Achievement (NCEA), Aotearoa New Zealand’s internationally unique high school qualification. We then move on to demonstrate how the quantitative technique of network analysis can be employed to reveal structures in NCEA participation. Finally, we discuss the novel insights provided by network analysis of STEM co-enrolments in NCEA assessments spanning the previous decade.

2.1.1 Broad Understandings of Student Participation in STEM

Student participation in STEM is often reported at a broad level, with information detailing the counts of students who are enrolled in each subject, and how this differs across demographic groups. In Aotearoa New Zealand, data is readily available by sex (male or female) and Socio-economic status (SES) from 2004 to 2018 [Ministry of Education 2018]. Exploring these data can provide a surface level description of what the field of STEM education looks like in Aotearoa New Zealand.

As shown in Figure 2.2, in Year 13 (final year of high school), female students in Aotearoa New Zealand are less likely to take physics, with this under-representation being steady across years. The same figure shows that female students are more likely to take biology, and more recently chemistry, with this over-representation becoming increasingly more pronounced over time.

Figure 2.3 shows that female students continue to be underrepresented in mathematics subjects, such as accounting and calculus. However, female students have higher levels of representation in statistics than male students in recent years [Ministry of Education 2018]. The same data shows that, in technology subjects, the computer and engineering subjects have continually been male-dominated, with this becoming more pronounced over time [Ministry of Education 2018]. Food technology and textiles are the only female dominated technology domains.

Data from [Ministry of Education 2018] also allows us to see trends in STEM participation by school decile, a proxy measure of SES. In Aotearoa New Zealand, school decile refers to the affluence of the neighborhood in which a school is located. High decile schools are located in more affluent areas, whilst low decile schools are
Figure 2.2: **Science Participation Rates Across Years by Sex.** These plots show the participation of male and female students in key science subjects in Year 13 from 2004–2018. Biology and Chemistry had a greater share of female students (nearly 70% of biology students in 2018 were female). Physics continues to be male-dominated. “Science” represents core science assessments, which assess topics about more general aspects of science (including applications to everyday life and societal issues). This core science domain had a relatively balanced representation of male and female students across years. Data retrieved from Ministry of Education (2018).
Figure 2.3: Mathematics Participation Rates Across Years by Sex. These plots show the participation of male and female students in key mathematics subjects in Year 13 from 2004–2018. There have been relatively even levels of participation in mathematics subjects over time, except calculus where male students continue to be enrolled in greater numbers. Data retrieved from Ministry of Education (2018).
located in less affluent areas. As shown in Figure 2.4, students who attended higher decile schools had greater rates of participation in science subjects, and this pattern was also evident for calculus and statistics. The relationship between student enrolment in technology learning domains and decile has no discernible pattern.

Broad level data, such as those discussed above, allow us to interpret trends in subject enrolments over time. However, they provide only a surface level understanding of STEM participation. Beneath the aggregation of counts per subject label hides important information that is useful for policy makers and researchers. Each subject consists of many different assessments, each covering unique content and following different assessment criteria. The following section will provide a brief introduction to Aotearoa New Zealand’s main high school assessment system, the National Certificate of Educational Achievement (NCEA).

2.1.2 A Brief Introduction to the National Certificate of Educational Achievement

The National Certificate of Educational Achievement (NCEA) is the main form of secondary school assessment in Aotearoa New Zealand. First introduced to students in 2002, NCEA was designed to replace norm-referenced assessment. In norm-referenced assessments student achievement is judged against the average achievement of the student population (Mahoney, 2005). Instead, achievement in NCEA is based on the competencies of individual students (Hipkins et al., 2016), meaning that achievement is an indicator of what a student knows, and not just how they rank amongst their peers. Therefore, it is possible for all students to pass if they all meet the assessment criteria. Assessment operates at the level of specific skills, or standards, that comprise a subject discipline. For example, instead of just receiving an overall grade for biology, students take several standards in the subject discipline of biology that demonstrate their competence in particular areas (e.g., “Demonstrate understanding of biological ideas relating to micro-organisms”). By successfully completing standards, students accumulate credits, the value of which is linked to the amount of work needed to fulfil a standard. The three levels of the NCEA typically correspond to the final three years of high school. NCEA Level 1 is typically taken in Year 11 (age ~ 15), NCEA Level 2 in Year 12, and NCEA Level 3 in Year 13.
Figure 2.4: **Science Participation Rates Across Years by School Decile.** School deciles are grouped into quintiles (deciles 1 and 2 together, deciles 3 and 4, and so on). These plots show the rate of participation for each decile group as a function of the total subject enrolments (across all learning domains) for that group. This takes into account that higher decile groups contain a greater number of students than lower deciles. As can be seen in the above plots, students from higher decile schools are more likely to take biology, chemistry, and physics. Low decile schools had a flatter participation rate in physics, but increasing participation over time in biology and chemistry, such that the increase is similar to higher decile schools. The plot of the core “Science” subject appears less ordered and more variable in terms of decile ordering, but also has a lower rate of participation overall. Data retrieved from [Ministry of Education](https://www.education.govt.nz) (2018).
What makes the NCEA a unique assessment system is its flexibility. Compared to the systems it replaced (School Certificate, Sixth Form Certificate, and Bursary), there is more variety in the assessments/standards that students may be enrolled in (Mahoney, 2005). In providing increased choice to students and their educators, and more flexible pathways through high school, it was hoped that the NCEA would benefit students from a range of backgrounds. As stated in the New Zealand curriculum (Ministry of Education, 2007, p.41):

Schools recognise and provide for the diverse abilities and aspirations of their senior students in ways that enable them to appreciate and keep open a range of options for future study and work. Students can specialise within learning areas or take courses across or outside learning areas, depending on the choices that their schools are able to offer.

The NCEA meets these goals by providing students with more learning pathways through high school, which aims to serve both students who wish to progress to tertiary study, and those who want to enter into vocational careers. These two pathways are reflected in the two main types of assessment offered: unit and achievement standards.

### 2.1.2.1 Unit and Achievement Standards

Unit standards tend to assess more vocational subjects (e.g., plumbing, hairdressing, agriculture). Unit standards have strict criteria that need to be achieved in order to pass (Hipkins et al., 2016), and are thus suited to assessing skills that follow a procedure. If a student meets the criteria they pass; if they fail a step, they fail the standard. All unit standards are assessed internally by the institution where the student is placed, offering the opportunity to teach and learn in a manner that caters more to students’ contexts. Internal assessments are moderated by the NZQA, according to the New Zealand Qualification Framework (NZQA, 2016), to ensure the assessment is consistent and rigorous. That being said, schools often provide the opportunity for students to retake failed internal assessments at a later time.

Achievement standards assess more traditional subjects that are tied to the New Zealand curriculum, such as science, mathematics, and English. While many achievement standards are assessed internally, a number of them are taken under
standardised conditions and assessed by an external body (i.e., the NZQA). Unlike unit standards, where students can only be judged to have passed or failed, achievement standards often have assessment criteria that can be interpreted more subjectively and require a different grading structure (Hipkins et al., 2016). Instead of pass or fail, achievement standards have four outcomes: not achieved, achieved, merit, and excellence. This grading structure seeks to reward students who demonstrate knowledge at a higher level than simply showing competence. The introduction of different grading levels in achievement standards provides increased opportunity to rank students by performance (Shulruf et al., 2010), a process that NCEA was not initially designed to accommodate (Hipkins et al., 2016).

The relevance of achievement and unit standards can be tied to students’ future aspirations in the context of STEM. Wong (2016, p.20) differentiates these aspirations as being tied to either careers in science, or careers from science. Careers in science may be defined as: “...occupations that are involved with the research or discovery of science as their primary purpose” (Wong, 2016, p.20). Achievement standards may be more closely linked to these types of careers as they provide the means to assess theoretical work, and provide the pathway to university. Careers from science may be defined as “careers that are related to science” but prioritise other aspects of STEM (Wong, 2016, p.20). This includes careers in technology, and also careers in horticulture and farming that are even more applied. The vocational slant of unit standards may prepare students better for these types of careers from science. With that being said, students can take a combination of unit and achievement standards (which can be assessed either internally or externally).

While there are many potential pathways through the NCEA, the eventual goal for students is to accumulate enough credits to achieve NCEA Level 3. Students who wish to attend university must meet a separate goal over and above the requirements for NCEA Level 3. To be eligible to enrol at a university, students must attain University Entrance (UE), which is the equivalent of achieving NCEA Level 3 with a specified number of credits coming from three subjects on an approved subjects list (these include subjects such as biology, physics, mathematics, and English) with specific achievement standards (NZQA, 2020), and a higher standard of literacy than regular NCEA Level 3 (Hipkins et al., 2016). Specific university programs may also have their own requirements for enrolment. For example, to transition from NCEA to engineering at the University of Auckland,
students must attain specific externally assessed achievement standards in Level 3 calculus and physics \cite{University of Auckland 2020}. Alternate pathways to university STEM study are possible, such as completion of university foundation courses, but these take additional time. The decisions that students make regarding the selection of STEM standards in NCEA Level 3 can thus have long-lasting implications. It is therefore especially important to understand how NCEA Level 3 is structured, and how this relates to student outcomes.

Given the complexity of the NCEA, exploring participation in STEM at the level of individual assessments can provide additional insights that complement our broad level understandings of STEM participation discussed previously. Doing so allows us to explore factors related to individual standards (such as the type of standard assessment and whether it was assessed internally or externally) as well as co-enrolment patterns and pathways through assessments. To build on the broad level understandings outlined above, we now adopt the following research questions:

- Can we identify patterns in the NCEA Level 3 standards taken by students in STEM?
- If so, how do the patterns of NCEA Level 3 standard enrolments differ across demographic characteristics, SES, and time?

Given that the NCEA can be considered “one of the most complicated education system in the world” \cite{Hipkins et al. 2016}, unpacking details at a more fine-grained level can be a daunting task. To explore this complicated system and answer our research questions, we employ quantitative techniques based in the field of network analysis. We explain how network analysis can be used as a tool to understand patterns of assessment, especially in contexts where the system is complex (as with the NCEA). The following sections will discuss how network analysis can help us explore what participation looks like for students studying STEM.

2.2 A Network Methodology

2.2.1 Data

We make use of Statistics NZ’s Integrated Data Infrastructure (IDI) to access administrative data pertaining to students’ high school and census information
The IDI is a collection of government data sets, containing micro-data on student enrolment and demographics, linked at the level of individuals for the population of Aotearoa New Zealand. We focus on students taking NCEA Level 3 from 2010 to 2016, as this is the most up to date data available at the time of writing. We focus on NCEA Level 3 as this level is the most highly specialised, and precedes entrance to university and employment. Years prior to 2010 are available, but were omitted due to processing constraints. The years spanning 2010 to 2016 were also of specific interest, due to education policy reforms introduced around 2012 and 2013 (Hipkins et al., 2016).

We apply several rules when selecting student cohorts to be included, in order to minimise the risk of adding statistical noise to our analysis. In order to focus our analysis on students who have had the majority of their education in Aotearoa New Zealand, we only select individuals who are identified as having tax, birth or visa records present in the IDI. We also only include students who had NCEA records when they were 15 or 16 and during NCEA Level 1. These filters help focus our sample on the resident population of Aotearoa New Zealand, and minimise the chances of including visitors or foreign exchange students. We also limit our sample to students who attended state schools in Aotearoa New Zealand. This is because private schools in Aotearoa New Zealand are more likely to offer a combination of the NCEA and other formal qualifications (such as Cambridge or International Baccalaureate), introducing additional layers of complexity. For the purposes of our analysis we also assign each student a single cohort year based on the most frequent year in which they took standards. This is because students are able to take NCEA Level 3 standards over multiple years. For example, if a student took two NCEA Level 3 standards during 2015, and ten NCEA Level 3 standards during 2016, we would assign the student to the 2016 cohort. We choose not to exclude Level 3 standards taken in a different year from the overall cohort year, as these standards would still contribute to the student’s qualification.

We include the following variables in our analysis:

- Students’ sex (male or female). Due to limitations in the administrative data used, we are not able to include gender (and non-binary classifications of gender) in our analysis.

- Students’ ethnicity. Each student is able to identify with multiple ethnic groups, following the classification set out by Stats NZ (Stats NZ, 2005). The main ethnic groups include European; Māori; Pacific Island; Asian; Middle
A Network Methodology

Eastern, Latin American, or African (MELAA); and Other. For the purposes of this study, we do not report results for MELAA and Other populations as they include a broad cross section of individuals, but typically involve relatively small numbers.

- High school decile. This is a rating out of 10 for the affluence of the area where the school is located. For the purposes of the following analysis, we categorise high school decile into 3 groups. Deciles 1–3 are low decile, deciles 4–7 are medium decile, and deciles 8–10 are high decile.

- NCEA Level 3 standards taken. For each student, we have records of all of the standards taken at NCEA Level 3. We only include standards from the New Zealand curriculum learning areas of Science, Technology and Mathematics (Ministry of Education, 2007). For each standard, we have information on its subject area (e.g., physics, biology, mathematics etc.), whether it was a unit or achievement standard, and whether it was assessed internally or externally.

2.2.2 Network Analysis

We employ network analysis to understand STEM enrolment at NCEA Level 3 at a fine-grained level. At its fundamental level, a network is a collection of nodes and edges. Nodes can represent an agent (e.g., a student) or an object (e.g., a standard); edges link two nodes together to indicate some form of relationship. Networks can be used to represent anything from human relationships and transport networks, to biological and computer systems (Barabási, 2003). In education research, network analysis has tended to focus on the relationships shared between students in the classroom (Tranmer et al., 2014), or communication between staff at educational institutions (Daly, 2010). There are few examples of education research that use network analysis to investigate non-social relationships. We seek to expand this area of research by applying network analysis to high school assessment enrolment data. As we will outline in the following section, network analysis can help us identify patterns in NCEA standard co-enrolments.

In our analysis, nodes take the form of students and standards. Edges in our network represent any recorded instance where a student was enrolled in a NCEA Level 3 STEM standard during high school. This creates a bipartite network (also commonly referred to as a two-mode network). A bipartite network is any network...
where there are two types of node, and nodes can only connect to a node of a different type. In our case, a standard cannot be connected directly to another standard, and a student cannot be connected to another student. For example, in A in Figure 2.5 standards may be represented by nodes in set $U$, and students may be represented by nodes in set $V$.

We create a network of students and the standards they were enrolled in for the whole of our student population. We structure this network so that it is multi-dimensional. Each student node belongs to a specific year, region, and decile, while standards can exist across multiple years, regions, and school deciles. In order to analyse the properties of our network, we are required to ‘project’ onto one set of nodes. This means that we take the node set belonging to a single node type, and generate edges between these nodes when they are linked to a common node of the other node set. For example, B and C in Figure 2.5 shows the projection of the network in Figure 2.5. In the projections, standards represented in set $U$ are now connected to one another (B), and students in set $V$ are also now connected (C).

As we are interested in the patterns of standards that students took, we project onto the standard nodes (Figure 2.5:B). This results in a network of standards that are connected by edges indicating that students took those two standards together within their NCEA Level qualification. The edges of the projected standard network can also take on a weighting that corresponds to the frequency that two standards were taken together by students.

### 2.2.3 Normalization and Community Detection

Our goal is to use the co-enrolment network to understand the standards that tend to be taken together, and by which students. To do this, we employ community detection. Community detection is a process in which we identify sets of nodes that are clustered together by the edges in the network. Previous research by Ferral (2005) has employed similar clustering techniques to investigate communities of subjects that tend to be taken together in the NCEA, but this was limited by the number of high schools sampled, the response rate of schools, and the availability of demographic and standard information. Usually, community detection methods identify communities by maximising the modularity score within communities. Modularity refers to the tendency of nodes to connect to other nodes within the same community relative to nodes that are outside the community. While there
Figure 2.5: An Example of a Bipartite Network and its Projections. In the case of the current study, white nodes (set $U$) represent standards, and black nodes (set $V$) represent students. A) Nodes of different sets are connected by an edge $E$ (i.e., an edge will exist if a student took a particular standard). B) The projection of set $U$. In the current study, we use this projection to represent a network of standards. Two standards will be connected by edge if a student enrolled in both standards. If two standards are connected through multiple students, multiple edges are produced. In this simple example, two students enrolled in both standards $e$ and $d$, while other connected standards were only take conjointly by single students. C) The projection of set $V$. In the current study, this refers to a network of students, with edges indicating that students both took the same standards. To help preserve students’ confidentiality, we do not report on this projection.
are many different community detection algorithms, the current study makes use of the infomap algorithm (Rosvall et al., 2009).

In order for our communities to more truly represent the standards that tend to be taken together, we need to normalize our edges so that weights do not refer to the raw counts of students’ co-enrolments. The raw weighting does not consider the fact that standards have different populations of students. As a result, community detection may group two standards together simply because one standard has a large number of students. To explain more clearly, we can use the hypothetical case of English Standard A, Physics Standard A and Physics Standard B. If English Standard A has a population of 1000 students, and 10% of those students take Physics Standard B, the raw weight is 100 students. If 100 students took Physics Standard A, and 90% of those students took Physics Standard B, the raw weight is 90 students. While we would expect the two physics standards to be grouped together, using raw counts of students as edge weights may not result in grouping that meet these expectations. Instead, we make use of a normalization technique called Revealed Comparative Preference (RCP) to provide more consistent communities. RCP is a ratio of ratios that measures the fraction of students from standard $j$ who also took a second standard $i$, relative to the overall fraction of students taking standard $i$, across all other standards. More specifically:

$$RCP(i, j) = \frac{x_{ij} / \sum_j x_{ij}}{\sum_i x_{ij} / \sum_{ij} x_{ij} / \sum_i x_{ij}} = \frac{x_{ij} / x_i}{x_j / x_i} = \frac{x_{ij} \cdot x_i}{x_i \cdot x_j}$$

where $x_{i,j}$ is the number of students taking both standard $i$ and $j$, $x_j$ (or $x_i$) is the total number of students taking standard $j$ (respectively, standard $i$), and $x$ is the total number of unique students enrolled in any standard. This RCP metric is based on the measure Revealed Comparative Advantage, used in economics (Balassa, 1965), and was calculated using the EconGeog package (Balland, 2017) in R (R Core Team, 2017). The RCP calculation returns a value where anything greater than 1 indicates a ‘preference’ for two standards being taken together. Conversely, a value below 1 indicates that, given the number of students in either standard, there was a dispreference for the two standards being taken together.

We remove any edge in the network where the RCP value is below 1, and subsequently any node that no longer has any edges (isolated nodes with a degree of 0). This results in removal of around 31% of edges. Following this pruning stage, the network now consists of standards connected by edges with a weighting relative to the preference for each standard being taken together with its neighbors.
in NCEA Level 3. We then identify communities of standards that are grouped together in our network using the infomap community detection algorithm \cite{Rosvall2009}. In simple terms, the infomap algorithm partitions the network in a way that maximizes the number of edges within a community, relative to the edges between communities.

### 2.2.4 Exploring Participation

To compare student participation across the educational fields detected, we can consider the relative proportion of students from particular years, and across school deciles and social groups. One of our goals is to establish an idea of how each network is structured. Are the enrolments for a specified demographic group spread more evenly across a network, or are they focused in particular areas? To answer this question, we employ the metric of entropy. Entropy is a concept originating from the field of thermodynamics, and provides an indication of how organised or disorganised a system is. In the case of the current study, we use entropy to assess how participation is spread across the network. Using the measures of entropy as signals of disparities, we then explore the rates of participation across communities and standards in finer detail. The following section will outline our measure of entropy.

#### 2.2.4.1 Entropy

Entropy provides an aggregated metric of how ordered a system is. Systems that are highly ordered have a lower level of entropy, while disordered systems have higher entropy. To use an analogy, a crystalline solid with atoms focused together on a regular grid has low entropy, while a gas with atoms randomly spread across a grid has higher entropy. Following this analogy, we may explain low entropy as an indication that a pattern of standard enrolments is more focused or specialised in specific areas. In contrast, high entropy in the network of standards indicates that a pattern of enrolment is more diverse. By partitioning our network into different social groups (e.g., across sex, ethnicity, and school decile) we can explore similarities and differences in network structures.

We calculate entropy in two steps. Firstly, we work out the probability of a sub-population enrolling in a specific standard given the total number of enrolments
in the network for that sub-population. This probability is given by:

\[
p_i^q = \frac{\sum_j x_{ij}^q}{\sum_{ij} x_{ij}^q}
\]

where \(x_{ij}^q\) is the number of students in a sub-population \(q\) enrolled in standard \(i\), and \(x^q\) is the total number of enrolments for that sub-population. Using this measure of probability, we calculate entropy using the following formula (Shannon, 1948):

\[
S^q = -\sum_i N p_i^q \log p_i^q
\]

Where \(p_i^q\) is the probability of a student from sub-population \(q\) enrolling in standard \(i\). The resulting score \(S^q\) provides an single positive value that indicates the entropy in the network, where a lower value indicates lower entropy (i.e., ordered patterns of enrolments), and a higher value indicates higher entropy (i.e., more disordered enrolments).

We ascertain a level of confidence by using a bootstrapping method, where we vary the count of students in each standard \(i\) by a uniform random amount of up to \(\pm 20\%\), and recalculate entropy. We repeat this process 1000 times for each entropy measure.

### 2.2.4.2 Trends

Following the entropy measure, we investigate how participation differs across demographic groups per standard by comparing raw counts, proportions, and probabilities. The communities identified provide a good indication of the standards that tend to be taken together, which allows us to explore rates of participation across groups of standards as well as individual standards. We are able to explore a range of attributes, such as such as the probabilities of sub-populations enrolling in a standard, with respect to sex, ethnicity, school decile, and type of standard (achievement/unit standards, internally/externally assessed).

Following the identification of different communities of standards, our goal is to explore the student enrolment patterns in these communities. Based on trends outlined previously by Hipkins et al. (2016) and based on data from Ministry of Education (2018), we make the following hypotheses:

- Female students will be more likely to have enrolled in standards in communities related to biology.
• Male students will be more likely to have enrolled in standards in communities related to physics, calculus and computer science.

• Students who attended high decile schools will be more likely to have enrolled in externally assessed standards.

Less research has investigated the relationship between assessment type (achievement or unit) and STEM enrolment, but we may expect that students groups who historically succeed in traditional forms of education (high SES, European and Asian students) to be more likely to have enrolled in externally assessed achievement standards. Student groups who have historically been under-served by traditional assessment may be more likely to have enrolled in unit standards.

### 2.3 Results and Discussion

The complete co-enrolment network across all years, regions, and deciles is shown in Figure 2.6. Across all years the infomap algorithm identified 42 communities of Level 3 STEM standards. As NCEA Level 3 is the most specialised stage of high school education, we would expect our network to be strongly partitioned into different community structures. This is reflected in a high modularity score of 0.83. The modularity score indicates that the nodes tend to share more edges with nodes within the same community than with nodes in different communities. The structure of the network changed over the period of time considered in the analysis, with a significant change taking place between 2012 and 2013. During this time, a change in education policy resulted in a reform in assessment. Science and mathematics linked unit standards were phased out, and a new set of achievement standards were introduced. Post the education reform in 2013, the overall number of standards diminished, and the network is mainly dominated by one community of mathematics and science standards (see Figure 2.7). This policy change is also reflected in changing levels of entropy in the network over time. As shown in Figure 2.8, the overall entropy of the network of assessments (taking all students into account) decreased over time. This gives an indication that, following the reforms to standards in 2013, student enrolments were more standardised and focused, and less flexible.
Figure 2.6: **Network of NCEA Level 3 Standards.** The overall standard projection of the NCEA Level 3 standard co-enrolment network. The above network is a composite of all standards offered between 2010 and 2016, and serves to provide an overall guide to the various subject disciplines represented by each community. Nodes represent standards and edges represent a preference for two standards being enrolled in at the same time by students. Colours represent the communities of standards that tend to be taken together. Squared nodes represent externally assessed standards, and circular nodes represent internally assessed standards. Node size reflects the percentage of all students enrolled in a standard.
Figure 2.7: **Network of NCEA Level 3 Standards Across Years.** The standard projection of the NCEA Level 3 co-enrolment network across years. Node size represents the number of students enrolled in each standard as a percentage of the total number of students in each cohort. As years progressed, the number of standards was reduced. Around 2013, a new set of science and mathematics achievement standards were introduced. Post-2013, the network is comprised mainly of one mathematics and science community, which indicates that assessment was more standardised than previous years.
Understanding Student Participation in Science Education

Figure 2.8: **Entropy by Sex Across Years.** Results show that entropy was higher for the male sub-population (purple) than the female sub-population (orange), while the baseline entropy of the population taken as a whole (dotted black) falls in between. This indicates that enrolments for female students were more ordered, and male enrolments were more varied.

Through the use of network analysis we are able to delineate the main fields of study that comprise NCEA Level 3 STEM. Our method of using RCP and community detection separates out standards according to their propensity for being taken together, rather than simply classifying by subject label. The resulting network is partitioned according to two main pathways, communities of standards reflecting progression to university study (i.e., mainly achievement standards), and communities of standards orientated towards vocations (unit standards, and internally assessed standards). The detected communities thus provide a clearer picture of NCEA enrolment than broader subject labels. To provide an example, the chemistry standard “Evaluate the interaction of a chemical process with society and/or the environment” may not assess the same content knowledge as another chemistry standard “Demonstrate understanding of the properties of organic compounds”. Despite both standards belonging to the chemistry domain,
the community detection algorithm assigned them to different communities in the network. While standards assessing applications of science to other vocations or to societal issues may help in the pathway to careers from science, standards assessing scientific theory are more representative of the pathway to university and careers in science.

On the whole, the communities in the network tended to be comprised of standards from the same domain of study. For example, biology standards tend to be taken in conjunction with other biology standards, physics with physics, and so on. However, the community detection algorithm mainly grouped science and mathematics subjects in the two large communities. These two communities, which occurred at different time periods (one before 2013, and one after) can be viewed as the pathway to university study. They consist mainly of achievement standards (many of them externally assessed, especially after 2013), and include physics, biology, chemistry, and calculus.

The following sections will outline some patterns that can be observed from 2010 to 2016 by sex, ethnicity and school decile. While there are a vast number of patterns to be explored and discussed further, we focus our discussion on the main patterns. We provide the reader with full access to an interactive web application that can be used to explore the network in depth (https://stur600.shinyapps.io/ExploreNCEA_L3_STEM/). This application allows the user to filter the network by subject disciplines, types of standard, as well as school decile and demographic criteria. Through the patterns that we highlight, we seek to demonstrate the additional insights that can be gained through investigating the NCEA at a finer-grained level, and how they can further inform our understanding of what STEM participation looks like in Aotearoa New Zealand. We begin our discussion by focusing on the patterns that were seen based on students’ sex, and then move on to discuss patterns by students’ ethnicity and school decile.

Patterns by Sex

Overall, there were small differences in the entropy in the network by sex, with entropy being slightly higher for the male sub-population (see Figure 2.8). This finding suggests that the male sub-population of the network had more enrolments spread across the network, while the female sub-population were more focused in specific areas. Further investigation of communities in the network showed clear
examples of disparities in subject enrolments by sex which may explain the difference in entropy. Male students tended to dominate communities defined by standards in the agriculture, engineering, and practical technology (welding, furniture making etc.) domains, while female students had greater rates of enrolments in standards related to life sciences and textiles.

Corroborating the broad level trends outlined previously in the current study, and the trends detailed across other international contexts (Else-Quest et al., 2013; Sheldrake et al., 2015; National Science Foundation, 2017; Institute of Physics, 2013), female students were more likely to enrol in biology standards, and less likely to enrol in physics and calculus standards. The majority of biology standards had around 60–70% female students across years, while female students were also more likely to have enrolled in standards in the Core Science domain. This domain includes standards such as Research a current scientific controversy (61.5% female) and Describe genetic processes (67.3% female). Female students were less likely to be represented in calculus and physics standards than male students. Investigating these disparities at the standard-level provides additional insights (see Table 2.1).

The rates of enrolment for female students in the physics standards were low, with the proportion of female students in externally assessed physics standards being around 35% overall. The participation of female students in the standards related to calculus were also low compared to male students, with the proportion of female students being around 35–38% in the main externally assessed standards. Interestingly, the internally assessed unit standard equivalents of the calculus standards, which were available to students prior to 2013, had an increased proportion of female students (around 42–46%). Much research has been dedicated to understanding why disparities persist in physics and calculus by sex, with research often suggesting that female students tend to be less confident in mathematics and calculus compared to male students (Hofer and Stern, 2016; Heilbronner, 2012; Simon et al., 2015). It may be that the calculus unit standards, which are assessed internally, in a familiar space with the opportunity to resit, offers a safer assessment environment where female students are more comfortable (see Cheryan et al., 2017 for a comprehensive review of the issues impacting on gender differences in STEM choice).

Patterns by Ethnicity and School Decile

We report the results for ethnicity and school decile together, given that they are inextricably linked; Māori and Pacific students are over-represented in low
Table 2.1: **Calculus and Physics Standard Enrolments by Sex.** Female students were underrepresented in calculus and physics standards in general, but especially in the external achievement standards that were part of the pathway to university science. The representation of female students in calculus unit standards, which were in operation at the same time as externally assessed standards, was closer to even. Exploratory chi-square tests showed that the higher level of enrolments in the internally assessed calculus standards compared to the externally assessed calculus standards was significant ($p < .001$).

<table>
<thead>
<tr>
<th>Standard</th>
<th>Assessment Type</th>
<th>Domain</th>
<th>Female (%)</th>
<th>N (Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differentiate functions and use derivatives to solve problems</td>
<td>EX</td>
<td>Calculus</td>
<td>38.2</td>
<td>22236</td>
</tr>
<tr>
<td>Integrate functions and use integrals to solve problems</td>
<td>EX</td>
<td>Calculus</td>
<td>38.3</td>
<td>22107</td>
</tr>
<tr>
<td>Differentiate functions and use differentiation to solve problems</td>
<td>IN (Unit)</td>
<td>Calculus</td>
<td>42.3</td>
<td>10178</td>
</tr>
<tr>
<td>Integrate functions and use integration to solve problems</td>
<td>IN (Unit)</td>
<td>Calculus</td>
<td>46.3</td>
<td>8352</td>
</tr>
<tr>
<td>Demonstrate understanding of wave systems</td>
<td>EX</td>
<td>Physics</td>
<td>35.2</td>
<td>48432</td>
</tr>
<tr>
<td>Demonstrate understanding of electrical systems</td>
<td>EX</td>
<td>Physics</td>
<td>34.7</td>
<td>46359</td>
</tr>
<tr>
<td>Demonstrate understanding of mechanical systems</td>
<td>EX</td>
<td>Physics</td>
<td>35.2</td>
<td>49584</td>
</tr>
</tbody>
</table>

decile schools. As can be seen in Figure 2.9, entropy differed across groups, across deciles, and changed significantly over time. With that being said, the Asian sub-population tended to have lower entropy overall. The Māori and Pacific sub-populations had higher entropy prior to 2013, but this pattern changed in later years with the entropy of Pacific sub-population decreasing to the same level as Asian. Overall, we observed how ethnic group differences in entropy were greater prior to 2013, and more similar in more recent years. The reduced difference between the entropy of each ethnic group sub-population can be explained in terms of the pivotal reform in the NCEA that took place around 2013 [Hipkins et al. 2016]. These reforms saw curriculum-linked unit standards phased out of operation, and the system was made to be more standardised and less flexible. Māori
and Pacific Island students, who were over-represented in these curriculum-linked unit standards, saw the greatest drops in entropy following the removal of these standards.
Figure 2.9: **Entropy by School Decile Across Years.** The entropy of each ethnic group sub-population, split by high school decile. The baseline entropy (black dotted line) is lower for the top decile schools (deciles 7–10), and higher for the low decile schools (deciles 1 to 3). There are observable differences in entropy in each decile. Prior to 2013, the overall entropy tended to be higher for Māori and Pacific sub-populations, and lower for Asian and European. After the policy reform, this pattern seemingly changed such that the Pacific sub-population had the lowest entropy.
Looking across deciles, Figure 2.9 shows that the top decile school sub-population tended to have lower entropy compared to the other deciles across years. The observed drop in entropy following the policy reform around 2013 is also much smaller than (approximately half) the drop seen for middle and low decile schools. In the years following 2013, the differences in entropy between each ethnic group sub-population at the top decile schools appears to be more compressed, with the entropy for Māori, Europeans and Pacific sub-populations more closely representing the level of Asian. In contrast, lower decile schools had higher entropy, and a greater drop following the policy reform.

The higher entropy for lower decile schools may be a consequence of increased enrolments in internally assessed standards, and fewer enrolments in standardised, externally assessed standards which have historically been a stronger focus for top decile schools (Hipkins et al., 2016). Previous research has commented on this pattern, with Wilson et al. (2017) observing that lower decile schools were less likely to have students enrolled in Subject Literacy Achievement Standards, which are achievement standards that can be used as indicators of subject-specific literacy. After exploring the rates of enrolment, we also confirm that lower decile schools are less likely to have students enrolled in key externally assessed science and mathematics standards.

The lower entropy for top decile and Asian students is likely related to a focused participation in science and mathematics achievement standards required for university entrance. In contrast, enrolment for Māori and Pacific sub-populations has been less focused in these standards and more balanced across other domains (including communities of unit standards). We explore this further by comparing the rates of participation in key externally assessed science and calculus standards. Table 2.2 shows how enrolment differed for each ethnic group sub-population, split by school decile and comparing 2010 to 2016.
Table 2.2: **Key Standard Enrolments by Ethnicity and Decile**. The percentages of students enrolled in key externally assessed achievement standards in STEM by ethnic group and school decile, focusing on a comparison between low (deciles 1–3) and high (deciles 7–10) decile schools, and between 2010 and 2016. The percentage indicates the number of students from that ethnic group in a particular year who enrolled in the standard, as a fraction of the total number of students from that ethnic group in a particular year who took a STEM standard. For example, of the Asian students attending a low decile school in 2010 who took a STEM standard, 36.2% took the calculus standard *Differentiate functions and use derivatives to solve problems*. These percentages show that rates of enrolment differed across ethnic groups, with varied differences within these groups by school decile, and also comparing standards offered in 2010 and 2016.
While Table 2.2 shows that Asian and European had higher rates of participation in key externally assessed science and calculus standards, the differences between low and high school deciles appears to be considerable for the Asian sub-population compared to other groups. For example, the difference in participation for Asian students by decile in the calculus standard on differentiation offered in 2016 is 22%, compared to 6.7% for European, 6.4% for Māori, and 4.7% for Pacific Islands. This may be a consequence of the categorical grouping of “Asian”, which contains an extremely diverse population of students. This categorisation ranges from Pakistan and Bangladesh to China, and also some Pacific Island nations (e.g., Fijian Indians). The diversity of the population, including the cultures and social backgrounds, may have been reflected in an increased diversity of enrolments. The different trends we observe in these key standard enrolments may explain why the Asian sub-population in low decile schools had the higher entropy than other groups in 2015 and 2016 (see Figure 2.9).

The fact that low decile and Māori and Pacific sub-populations had fewer enrolments in key science and mathematics standards (as can be seen in Figure 2.10) provides evidence that the pathway to university science is dominated by higher decile schools, and especially Asian and European students at these schools. In contrast, students from lower decile schools, and also Māori and Pacific students in higher decile schools, had relatively more enrolments in a larger and more disparate pool of internally assessed unit standards. Unit standards provide a valuable type of assessment that prepares students for vocational careers, and it may be that a higher proportion of students from less affluent areas seek vocational careers after high school. However, this does not necessarily explain why Māori and Pacific sub-populations attending higher decile schools are less likely to participate in science and mathematics standards.

The differing patterns of enrolment for Māori and Pacific Island sub-populations and Asian and Pakēha is complex, but may be explained in several ways. Firstly, higher decile schools primarily serving Māori and Pacific students may choose to offer more internal assessments that provide increased opportunity to assess in culturally appropriate way (e.g., less competition, more formative feedback). Secondly, and less optimistically, it may be that teachers hold lower expectations for Māori and Pacific students (Turner et al. 2015), and are less likely to place them in the pathway towards university science. This idea was reflected by a participant in a study by Graham et al. (2010, p.142): “The teachers decide where the class is at in terms of choosing which standards [Unit versus Achieve-
Results and Discussion

Figure 2.10: **Network of NCEA Level 3 Standards by Ethnicity.** The standard projection of the NCEA Level 3 standard co-enrolment network by ethnicity across all years. Node size represents the percentage of students within the sub-population who were enrolled in a standard, colour represents community membership, squared nodes represent externally assessed standards, and circular nodes represent internally assessed standards. For all ethnic group sub-populations, the main science and mathematics communities (orange and blue nodes) tended to have higher probabilities of enrolment. The propensity for science and mathematics standard enrolment was especially true for Asian students, and less true Māori (C) and Pacific Island (D) groups.
ment. It’s a disadvantage on you because it depends on what the teacher thinks you can do and what the kids in your class can do.”

Our results suggest that policy reforms introduced around 2013 did not result in a decrease in participation in science and mathematics for Māori and Pacific Island sub-populations, who were originally over-represented in the curriculum-linked unit standard in earlier years. Instead, as can be seen in Table 2.2 enrolment often increased at a greater rate than other ethnic groups, especially in higher decile schools. For example, in high decile schools the Pacific Island sub-population saw an larger increase of around 10.6% in external biology standards relating to evolution, compared to 0.9% for Asian, 2.8% for European, and 4% for Māori. Although we cannot comment on how this educational reform impacted on students’ outcomes in science and mathematics, the reduced flexibility may actually help students by making NCEA less complex. Previous research has found that the complexity of NCEA can be confusing for students and parents to navigate (Graham et al., 2010; Jensen et al., 2010).

2.3.1 Implications and Future Directions

The current study fills a gap in the previous literature by investigating patterns of co-enrolments in NCEA Level 3 STEM standards by students’ sex, ethnicity, and a proxy measure of SES. We believe that this study is the first of its kind to use bipartite networks to represent high school assessment data. Through our methodological approach, we are able to take into account a wealth of information related to students and the standards that they enrolled in. This includes demographic information (such as sex and ethnicity) and specific NCEA Level 3 standard information, such as the manner in which standards were assessed (externally or internally), and whether the standard was an achievement standard (traditional curriculum based subjects, such as English or science) or a unit standard (more vocational subjects, such as farming or practical technology).

The NCEA is very complex, but our method of analysis allows us to consider the different pathways that students follow based on the assessments they enrolled in. The communities of standards highlighted through our analysis reflect two main pathways, either towards vocations and careers from science, or the pathway towards university and careers in science. Despite growing discussion regarding the outcomes of different types of standards in the Aotearoa New Zealand context.

1Chapters 5 and 7 of this thesis discuss the inequities facing Māori and Pacific Islands students in more detail.
there has been a lack of research into how this information relates to student background. The methodology and results outlined in the current study enables us to represent the NCEA as a complex education system, and this can provide detailed insights into what science participation looks like.

A limitation of our analysis is the fact that we do not have access to students’ level of achievement in the standards they enrolled in Level 3, or in previous years. As detailed by Jensen et al. (2010), achievement outcomes in standards would be highly influential in shaping the pathways that open up or close off for students as they go through NCEA. Furthermore, the disparities seen in participation in key science standards may be tied to the development of academic identity (Bolstad and Hipkins, 2008) which we are also unable to quantify. Archer et al. (2014, p.216) argue that “‘cleverness’ [can be viewed] as a racialized, gendered, and classed discourse, such that the identity of the ‘ideal’ or ‘clever’ student is not equally open to all students as a viable and authentic identity.” This notion of ‘cleverness’ may explain the disparities found in the current study. More specifically, it may be that the ‘clever’ pathway through NCEA is not open to all students. As described by Hipkins et al. (2016), NCEA informally developed into a two-tiered system, with curriculum-linked unit standards commonly being viewed an easy pathway, and achievement standards, and especially externally assessed achievement standards, being viewed as a tougher pathway. Students who identify as less academic may purposefully seek easy pathways through NCEA, without fully understanding that doing so can reduce educational opportunities later on.

Students with a family background of success in education may be more likely to view the academic pathway as normal or even expected. This idea is described in a related study of high school science pathways in the United Kingdom, where Archer et al. (2017) found that students from more affluent backgrounds were more likely to see the science-orientated pathway as an ‘obvious’ choice. Students from less affluent backgrounds may also be more motivated to seek full time employment, rather than pursue a pathway towards university study and the debt it may entail. However, the question remains as to the extent to which students from less affluent backgrounds knowingly choose vocational pathways and are not channeled down this pathway by simply attending a school in a low SES area.
2.4 Conclusion

The current study uses network science methods to explore disparities in science participation in Aotearoa New Zealand. It summarises the broad rates of participation by sex, ethnicity, and school decile, and also explores participation at a finer-grained level through a network analysis of STEM standard co-enrolments for the final year of high school. The initial summary of science participation showed that male students have been more likely to take ‘physical’ subjects (e.g., physics, calculus, practical technology), while female students have been more likely to take life science subjects (e.g., biology, health). A network analysis of NCEA enrolment data corroborated these findings, and added additional insights that showed that participation by sex were more equal in calculus unit standards. Our use of network analysis also allowed us to characterise the structure of co-enrolments for different sub-populations. Through the combination of Revealed Comparative Preference (RCP) and community detection, we were able to explore the specific pathways that students participate in during high school STEM education, while a metric of entropy provided a description of how ordered or disordered co-enrolments were. This use of entropy to characterise co-enrolment provides a novel approach to understanding student pathways through education, and revealed valuable insights. We found that the Asian sub-population in particular had the most standardised pattern of enrolment, and this was corroborated by a closer exploration which shows that these students tended to have enrolments focused in science and mathematics standards reflecting the pathway to university study. In contrast, the Māori and Pacific Island sub-populations, and lower decile school sub-population in general, had enrolment patterns of wider spread, with fewer enrolments focused in externally assessed science and mathematics standards. This appeared to be a consequence of increased enrolments in a proliferation of curriculum-linked unit standards, and after these standards were removed from operation around 2013, differences in entropy between groups decreased. Our findings suggest that while policy changes have impacted on the structure of NCEA enrolments over time, disparities by sex, ethnicity, and school decile continued to be evident. While it is difficult to explain how much of standard enrolment is due to student choice, and how much of it is due to structural inequities present in the school system, our findings reveal disparities in STEM at a fine-grained level. Our findings suggest that the pathway to university science has been dominated by higher decile schools, and especially Asian students at these schools. These results provide a detailed picture of what STEM participation looks like in Aotearoa New Zealand.
2.5 Disclaimer

The results in this paper are not official statistics. They have been created for research purposes from the Integrated Data Infrastructure (IDI), managed by Statistics New Zealand. The opinions, findings, recommendations, and conclusions expressed in this paper are those of the author(s), not Statistics NZ. Access to the anonymised data used in this study was provided by Statistics NZ under the security and confidentiality provisions of the Statistics Act 1975. Only people authorised by the Statistics Act 1975 are allowed to see data about a particular person, household, business, or organisation, and the results in this paper have been confidentialised to protect these groups from identification and to keep their data safe. Careful consideration has been given to the privacy, security, and confidentiality issues associated with using administrative and survey data in the IDI. Further detail can be found in the Privacy impact assessment for the Integrated Data Infrastructure available from www.stats.govt.nz.
Chapter 3

Bourdieu, networks, and movements: Using the concepts of habitus, field and capital to understand a network analysis of gender differences in undergraduate physics

Preamble

The following chapter aims to provide a bridge between understanding what science education looks like in terms of broad patterns of enrolments, and understanding why these patterns exist. Building on the work of Chapter 2, Chapter 3 now looks at exploring the properties of the field of science at university. In order to do this, I introduce concepts from Pierre Bourdieu’s sociological theory (see Figure 3.1). More specifically, I adapt a formula of practice that Bourdieu outlined in his seminal work *Distinction: A Critical Judgement of Taste* (Bourdieu, 1984, p.108), where an individual’s movements in the field is viewed in terms of an interaction between capital and habitus.

I employ a similar form of network analysis to that from Chapter 2. Chapter 3, however, focuses solely on exploring gender differences in the movements that students make within and between different academic fields. Doing so allows a more
comprehensive discussion of the gender inequities in STEM, and provides a more detailed exploration of what tertiary science participation looks like. This chapter will conclude with some discussion that moves beyond answering what tertiary science participation looks like, to possibilities for future research and interventions to address gender disparities in science participation. These discussion points will be expanded on in future chapters, while factors such as ethnicity and social class, which are more difficult to operationalise quantitatively, are also discussed further in later chapters.

The following work was previously published in PLoS ONE (Turnbull et al., 2019) on the 2nd of September 2019, and for that reason there may be some overlap with the content of prior chapters. Coauthors included Dr Kirsten Locke \(^1\), Dr Frédérique Vanholsbeeck \(^2\), and Dr Dion R. J. O’Neale \(^3\).

### 3.1 An Introduction to Gender Inequities in STEM

Historically, women have been underrepresented in Science, Technology, Engineering and Mathematics (STEM) disciplines. This is a concerning issue today internationally, and at all stages of higher education (Abraham and Barker, 2014; Stevanovic, 2013; Smith, 2011). More recent studies indicate specific gender disparities exist within the sub-fields that comprise STEM (Mullis et al., 2016). Female students tend to be underrepresented in physics in higher education, and this is evidenced by research from the United States (National Science Foundation, 2017; Cunningham et al., 2015; Kost-Smith et al., 2010; Heilbronner, 2012), Europe (Huyer, 2007; Stevanovic, 2013; Institute of Physics, 2012, 2013; Smith, 2011), Asia-Pacific regions (Education Counts, 2016a; Kennedy et al., 2014) and Africa (Semela, 2010). In contrast, the same research shows that the life science subjects (biology and medicine) tend to have more of a gender balance. Further studies have shown that gender disparities exist not only in subject participation, but in the levels of confidence that students have across subjects. Female students tend to be less confident than their male peers in physics (Kelly, 2016; Hofer and Stern, 2016) and calculus (Ellis et al., 2016), even after controlling for actual academic achievement (Marshman et al., 2018). Why do we see gender differences

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in the physical and mathematical science subjects, but not the life science subjects? Much research has been dedicated to understanding the extent, causes, and possible solutions to this issue (Cheryan et al., 2017; Brewe and Sawtelle, 2016; Blickenstaff, 2005).

The current study investigates the outcomes for male and female physics students at the University of Auckland (UoA) — the largest university in Aotearoa New Zealand. We adopt a unique approach, by combining quantitative network analysis with a research framework based on Pierre Bourdieu’s sociological theory (Bourdieu, 1984). Whilst we argue that these two approaches can provide a detailed understanding of gender disparities in student enrolment patterns, there is a lack of research in this area (for examples of how network analysis and Bourdieu have been previously used together, see the work of De Nooy (2003), and Bottero and Crossley (2011)). We combine these approaches by using network analysis to provide a representation of Bourdieu’s concept of field, with an emphasis on his ideas of transverse and vertical movements (students moving from one field to an-
other, and moving upwards and downwards in achievement rankings in a field). In order to avoid misinterpretation of Bourdieu’s theory, which is easily done when "bits and pieces" of it are used (Bourdieu and Waquant, 1992), we combine our representation of field with Bourdieu’s concepts of habitus and capital. We argue that network analysis can bring to light the complex patterns of students’ subject enrolment, whilst Bourdieu’s theory offers a rich theoretical framework to explain these patterns. We place the findings of our network analysis in a broad socio-cultural context that brings to light the complex interactions between society, gender and subject discipline. To avoid confusion, the following sections will use ‘field’ as a technical term referring to the Bourdieu’s definition (which will be explained in more detail in the next section), and ‘discipline’ as a non-technical term that describes the different STEM domains.

We begin by introducing a simple model of Bourdieu’s theory, using the field of science education to illustrate its concepts. We then add to this outline of theory by building our method of network analysis into Bourdieu’s theory. More specifically, we describe how network analysis of student enrolment data can provide a representation of field. Exploring the properties of this network structure allows us to understand gender differences in the movements students make within and across fields. According to Bourdieu:

The social space, being structured in two dimensions (overall capital volume and dominant/dominated capital) allows two types of movement... vertical movements, upwards or downwards in the same vertical sector, that is in the same field... and transverse movements, from one field to another, which may occur either horizontally or between different levels. (Bourdieu 1984 p.131)

In science education, individuals may move from one field to another (i.e., from physics to life science), but also upwards and downwards in achievement rankings in the field. We use these concepts of movements to guide our investigation. We seek to understand whether there are gender differences in the number of students moving from physics to other fields, and also in the changes in achievement rankings of students in physics. We close this article with a discussion of our results in the broader context of previous research and Bourdieu’s concepts of capital and habitus.
3.2 Framing Gendered Pathways Using Bourdieu

The metaphor of the leaky pipeline is often used to describe the attrition of women from physics (Huyer, 2007; Schiebinger, 2001), in that women are more likely to drop out with each transition between key stages of education (particularly secondary school to university). This metaphor can be criticized for not only stigmatizing individuals that drop out of the pipeline, but for also being too simplistic (Cannady et al., 2014). It is important to emphasize contextual factors, such as the presence of gender-stereotypes (Nosek et al., 2009) (e.g., men study science, women study humanities) that impact on the decisions that students make. It is also important to consider the complex nature of students’ enrolment patterns; in reality a student’s journey through university study follows a complex network of unique pipes, rather than a singular pipeline. The current study employs a research framework that builds on the limitations of the leaky pipeline. We seek to place our results in a wider socio-cultural context, by harnessing a research framework adapted from the work of Pierre Bourdieu (1984) (see Fig 3.2). We employ Bourdieu’s concepts of capital, habitus and field to interpret our findings, and place them in the context of previous studies that have investigated gender differences in STEM subject selection.

The following sections will outline Bourdieu’s concepts of field, capital and habitus. We apply these concepts to a host of previous research regarding gender disparities in science to outline the socio-cultural context in which students are placed. More specifically, we outline research that describes the state of the field of physics and the distribution of capital within the field of physics. We then discuss the interaction of capital with habitus — the system of dispositions that is formed in relation to the field. We describe how the “smog of bias” (Kost-Smith et al., 2010) that targets women in physics may impact on habitus, and thus practices within the field, such as choosing to discontinue physics study.

3.2.1 Field

For Bourdieu (1984), the world is separated into a collection of different fields. A field can be considered as a system of social locations, where each individual is objectively ranked by the resources (capital) they have relative to others. For example, in the field of tertiary science education, a lecturer ranks higher than a student, whilst a high-achieving student ranks higher than a low-achieving student. To begin to understand the hierarchical nature of a field, we must first understand
Bourdieu, Networks, and Movements

Figure 3.2: **Simplified Bourdieusian Theoretical Model.** The Bourdieusian framework used in the current study is adapted from the original model outlined by Bourdieu (1984) and the work of Archer and colleagues (Archer et al., 2012, 2014, 2015a). A student’s habitus interacts with their acquired level of capital (in particular science-related capital) to generate a student’s practices (behaviours, grades etc.) and their dispositions towards the field. A student’s habitus, a matrix of internal dispositions (Reay, 2004), is formed in relation to the specific socio-cultural and historical context of a field. A student who is positively predisposed to study in a scientific field, whilst also having access to various forms of science-related capital, will likely achieve higher grades in that field and aspire to study in that field in the future. A student who encounters bad experiences in the field will likely be dissuaded from future study via their habitus (‘this discipline is not for me’).

The concept of *capital*. Originally conceived within economics, capital was defined by Adam Smith (in 1887) as “That part [of a person’s wealth] that he expects to provide [them] with . . . income…” (Smith, 1887). Bourdieu interpreted capital as a legitimate, valuable and exchangeable resource that individuals can use to gain advantage in society (Bourdieu, 1986).

Therefore, the rankings are determined by how we define what is valuable and legitimate in the field. The practices of an individual within the field, which are guided by the individual’s internal dispositions (habitus), are judged by criteria
internal to the domain of activity (Hilgers and Mangez 2014). Individuals with a high volume of valued capital will hold power within the field. For example, high-achieving students have high volumes of capital in the field due to their course grades (a signal of success), whilst lecturers and researchers have a greater volume of capital in the form of qualifications and research experience. In the field of tertiary science education, lecturers and researchers sit at the top of the hierarchy, and decide what kinds of capital are valued or devalued (e.g., professors often decide the course content and manner of teaching for undergraduate students at university). We will discuss Bourdieu’s conceptualization of capital and the way it can inform gender equity research in the following section. Before then, we will outline a brief description of how the field of physics is structured from an objective point of view in relation to gender.

The numbers of male and female students holding qualifications in the different science disciplines can provide an objective, surface level understanding of the structure of the field. In the United States, only around 20% of students studying physics at bachelors, masters or doctorate level in 2014 were female (National Science Foundation 2017). This contrasts with biology, where around 50-60% of students studying at bachelors, masters or doctorate level were female (National Science Foundation 2017). Similar gender disparities in physics enrolments have been found in the European (Institute of Physics 2012 2013; Stevanovic 2013) and Asia-Pacific regions (Abraham and Barker 2014; Kennedy et al. 2014). Data from UNESCO shows that, in Europe in 2007, around 71% of tertiary health and welfare students were female, whilst this figure was 39% for natural and physical science (biology, physics, chemistry) (Huyer 2007).

Reports from Aotearoa New Zealand in 2016 show that, overall, secondary school science had a balanced gender-ratio of year 13 (i.e. final year of high-school) students (Education Counts 2016b). However, male students dominated physics and mathematics from year 11 to year 13 at secondary school, with this trend being reflected at university level (Education Counts 2016a). Across the same school years, biology and human anatomy tended to have more female students than male students. Looking at tertiary science education (i.e. university undergraduate and post-graduate levels), these gender disparities were maintained (Education Counts 2016a). Other data from Aotearoa New Zealand in 2016 show that female students were slightly less well represented among bachelor students studying physics and mathematics (43% and 46% respectively) (Education Counts 2016a). At the same level, female students tended to be over-represented in biology and health (67%
Bourdieu, Networks, and Movements

and 74% respectively) [Education Counts (2016a)]. Approximately 25% of doctoral students in physics and astronomy and 44% of students in mathematics were female, while female students comprised 53% of students studying biology and 69% of those studying health. Beyond post-graduate level study, the representation of women in Aotearoa New Zealand professorial roles and leadership positions in physics is particularly poor. For example a report by the New Zealand Association for Women in the Sciences, published in 2011, noted that women were only 29% of workers employed in physics related roles (Aotearoa New Zealand census data); approximately 10% of research active employees in physics at Aotearoa New Zealand universities; and had no representation on the main grant review panel for physics related fundamental research in Aotearoa New Zealand (the Marsden fund) [Bray and Timewell (2011)].

The above outlines clear evidence of gender disparities in the field of science, internationally and in Aotearoa New Zealand specifically. Whilst useful, these figures only provide a static, surface-level understanding of what is happening in the field of science education. As shown in Fig 3.2, the practices and behaviours represented in the field (such as enrolment patterns) are generated through the interaction of capital (resources) and habitus (internal dispositions). We will now visit these two concepts, applying them to previous research, to understand why gender disparities in science education are common.

3.2.2 Capital

The objective rankings within a field are defined by the distribution of capital, and this can be used to inform gender equity research in science (Kelly 1985). Different fields have different forms of logic as to what forms of capital are of value. Using a basic example, a science qualification is worth more in the field of science than in other academic fields. Capital is complex and may take many forms, each of which may be valued differently depending on the dominant logic of the field. According to Bourdieu (1986), capital has four forms: economic (e.g., financial resources), cultural (non-financial assets, such as physical appearance, spoken language, academic achievement), social (e.g., an individual’s social network), and symbolic (prestige and recognition, such as awards). Individuals who begin their life with more capital, be that through inheritance or immediate exposure to the dominant culture, will be more able to gain personal and social advantages. For example, a student who is born into a family that speaks the dominant language of an educational institution may find it easier to learn, and a student with greater
economic wealth may be more able to afford the costs associated with tertiary study (e.g., tuition fees, relocation, travel). The value of capital is not solely determined by form, but also by factors such as the manner of acquisition, and the personal characteristics of the owner. Issues emerge when an individual’s capital is devalued unjustly by the ‘rules’ operating in the field. For example, international research has shown that female physicists tend to receive fewer opportunities and career enhancing resources compared to objectively equal male physicists (Ivie et al., 2013). Previous research of tertiary students suggests that female students may be more likely to discontinue physics education, regardless of performance (Ellis et al., 2016; Ost, 2010). Since disparities in enrolment still exist even after controlling for academic achievement, it is likely that capital is not the dominant factor in driving gender differences in physics education outcomes. Research does suggest, however, that the gender disparities in physics enrolments can be understood in terms of students’ identity (Brown and Leaper, 2010; Hazari et al., 2010, 2013; Brewe and Sawtelle, 2016; Hazari et al., 2017) and self-confidence (Litzler et al., 2014; Concannon and Barrow, 2009; Sharma and Bewes, 2011; Kurtz-Costes et al., 2008; Sawtelle et al., 2012) – factors that can be tied to Bourdieu’s concept of habitus.

### 3.2.3 Habitus

Capital, in its various forms, interacts with habitus (Fig 3.2); a construct defined by Bourdieu (1984) as a system of dispositions formed in relation to a field. Whilst capital is what determines one’s position within the field, habitus is what determines one’s disposition towards it (Bourdieu and Waquant, 1992). An individual’s habitus is the internalization of the socio-cultural and historical context of a field, and it operates “below the level of consciousness and language” (Bourdieu, 1984). Nash (1999, p.177) understood habitus as “a system of schemes of perception and discrimination embodied as dispositions reflecting the entire history of the group and acquired through the formative experiences of childhood”. In simple terms, habitus is what we use to determine whether the field is something we are interested in, based on evidence present in the environment. Whilst habitus is generally formed during childhood within the family (Dimaggio, 1982), it is continually reconstructed and transformed as an individual operates in society. For example, a student who grows up in a family that places high value on science may share the same disposition (Archer et al., 2013b). However, an individual may not choose to pursue science when faced with evidence that the field is not for them (for
example, receiving poor grades, being treated poorly, lack of role models). Based on this internal matrix of dispositions, an individual’s lifestyle practices are generated. According to Bourdieu (1984), the collection of each individual lifestyle produced by habitus then constitutes the represented social world — the way that things appear to be. As the representation of the social world also influences the formation of habitus, the world and habitus share a reciprocal relationship. This relationship facilitates the cultural reproduction of inequity over time.

Habitus can be used as a concept to explain the gender disparities in science enrolments. Based on what they see in their represented social world, students will “refuse what they are refused (‘that’s not for the likes of us’), [adjust] their expectations to their chances, [and define] themselves as the established order defines them.” (Bourdieu 1984). Based on what students see in their environment, they will make decisions on what they feel is a realistic study choice. Archer et al. explain this idea further: “social axes of ‘race’/ethnicity, social class, and gender all contribute to shaping what an individual perceives to be possible and desirable” (Archer et al. 2012, p.885). The manner by which students perceive the different scientific disciplines, as they are represented in society, likely plays an important role in influencing their desire to study those disciplines.

A wealth of research has outlined the various ways that women are subjugated in certain STEM disciplines, especially physics, with the culmination of these factors being referred to as “the smog of bias” (Kost-Smith et al. 2010) or the “gender filter” (Blickenstaff 2005). No single factor can sufficiently explain why women are less likely to pursue physics (Kost-Smith et al. 2010), but a host of factors are likely to interact and impact on the dispositions students hold (habitus). Due to the pervasiveness of these various factors across society, habitus can take on a collective quality where individuals tend to hold stereotypical views on what is expected for members of different groups. To provide a simple example, research across 34 countries has shown that science tends to be implicitly associated with men more than with women, and that this level of gender bias predicts gender differences in science performance (Nosek et al. 2009). As outlined by Bourdieu (1984, p.101), an objective class of individuals can be considered the “the set of agents who are placed in homogenous conditions of existence imposing homogenous conditionings and producing homogenous systems of dispositions capable of generating similar practices”. In more basic terms, individuals who share similar backgrounds and characteristics will have a similar habitus, and this may predispose them to behave in similar ways (Reay 2004).
Every student holds beliefs about their possible educational paths. However, these beliefs are informed, implicitly and explicitly, by evidence in the environment. When deciding on whether to pursue physics, a student may ask: how are people like me treated in physics? Do people see me as a physicist? How many people like me study physics? Whilst we acknowledge that this is not an exhaustive list of reasons why students study physics, the answers to these questions are likely skewed to favour male students over female students. A study by Ong (2005) highlighted the incongruence felt by minority female physics students as they studied physics, where their competence was unfairly questioned because their ‘bodies did not fit’ with the stereotypical depiction of the white male scientist. Similarly, studies have found that women are more likely to be viewed as incompetent, controlling for confounding variables other than gender, by scientists (including physicists) looking to hire a laboratory manager (Moss-Racusin et al., 2012), or by students evaluating their physics teacher (Potvin and Hazari, 2016). Similarly, women rated as more feminine are less likely to be judged as a scientist (Banchefsky et al., 2016). The pervasive nature of the “smog of bias” (Kost-Smith et al., 2010) in physics offers the ‘homogenous conditions of existence’ that may result in a gendered habitus in physics: one that sees physics as unwelcoming for female students. This is likely to explain why studies tend to find that female students are more interested in life science subjects (Buccheri et al., 2011) and male students are more likely to be interested in physics, engineering and mathematics (Su et al., 2009; Bøe and Henriksen, 2013; Cunningham et al., 2015). It is important to note here that the opposite is not true — there is a lack of evidence to suggest that male students are unfairly judged as incompetent or feel unwelcome in the life sciences and therefore choose physical science subjects.

Evidence suggests that the gender differences in subject interest may not be present in early childhood, but emerge by the end of secondary school (Baram-Tsabari and Yarden, 2010). This lends credence to the idea that habitus is formulated over time; as individuals become increasingly aware of societal norms, their interests align with what (through their habitus) seems like a realistic study choice. These stereotypical gender preferences may persist when it comes to the types of science-related career that secondary school students aim for (Kjernsli and Lie, 2011), and students’ choice of STEM major at university (Bottia et al., 2015; Sadler et al., 2012). At university level, gender disparities may even widen further; a study of physics students at a university in the United States found that female students are more likely to see their interest in physics diminish during introductory physics (Kost-Smith et al., 2010).
3.2.4 The Current Study

The current study was motivated by the need to understand any potential gender differences in the movements and course selections that students make during their undergraduate physics study in general, and at the University of Auckland (UoA) in particular. Our study seeks to not only understand the movements of physics students across and within academic fields at the UoA, but to employ a unique approach that highlights the complexity of student enrolments and places them in a wider socio-cultural context. To do so, we employ network analysis on student enrolment records to provide a detailed representation of the field of physics at the UoA. The network analysis approach builds on the work of De Nooy (2003) and Bottero and Crossley (2011) who described the utility of combining network analysis with Bourdieu. Bottero and Crossley (2011) provide an example of how networks of social relations can provide a representation of a field. The current study expands on this area of research by conceptualizing academic fields as communities detected in networks of course selection. Furthermore, we draw attention to under-utilised concepts of Bourdieusian theory: the concepts of transverse movement between fields, and vertical movements within fields. We focus on providing a basic description of the movements that physics students make within and between academic fields at the UoA. Our study echoes previous studies that analyse the pathways that students take through education. However, by combining the network analysis approach with the sociological theory outlined by Bourdieu (1984), we move beyond simple models to a more nuanced description of the way habitus can be demonstrated through network analysis as both a cause and a symptom of gender stratification.

3.2.4.1 Transverse and Vertical Movements

Bourdieu’s theory encourages us to view student movements across STEM domains in relation to the structures of the field, the volume of capital a student holds, and the manner by which habitus guides practices in the field. In addition to our objective representation of the field of physics, we also consider what may motivate these movements, based on evidence from previous research.

According to Bourdieu (1984, p.131), society is structured in a manner that allows individuals to engage in two types of movement: vertical and transverse: “vertical movements, upwards or downwards in the same vertical sector, that is in the same field... and transverse movements, from one field to another, which may occur either horizontally or between different levels”. Vertical movements upwards
require an increase in the prized capital in the field. In tertiary science education, this may be represented by grades in science courses over time. Transverse movements entail a shift to a new field, and the conversion of accumulated capital into the capital accepted in the new field. For example, a student making a transverse movement from physics to life sciences will have to assimilate to a different skill set, and even a different culture. Transverse movements can be used as a strategy to protect a relative vertical position:

“transverse movements entail a shift into another field and the reconversion of one type of capital into another or of one subtype into another subtype... and therefore a transformation of the asset structure which protects overall capital volume and maintains position in the vertical dimension” (Bourdieu, 1984)

When an individual feels that they are slipping in the ranks of the field, they may choose to make a transverse movement to a new field, where their accumulated capital holds more translatable value.

In the current study, we conceptualize cultural capital in its institutionalized form as measured by course grades. The current study, therefore, seeks to understand:

- Whether there are gender differences in UoA physics students moving from one academic field to another.
- Whether there are gender differences in the persistence of UoA students in physics.
- Whether there are gender differences in UoA physics students moving upwards or downwards in academic achievement (as signalled by course grades).

Whilst our data do not allow us to conceptualize forms of capital other than institutionalised cultural capital (i.e., course grades), our methodology leaves the opportunity for future research to incorporate other measures of students’ capital. More specifically, future research should investigate how other forms of capital are distributed across fields and how they relate to the movements that students make.
3.3 Exploring Gendered Pathways Using Networks

3.3.1 Data

The current study uses administrative student data from the UoA from 2009 to 2014 (N = 8905), including demographic and academic information. For the purposes of this study, the only demographic variable considered in the analysis was gender. Academic variables include course codes that students were enrolled in, and the year and semester in which they were enrolled. We did not have information regarding students’ degree plans or majors. Records of non-physics courses were included, as long as a student had enrolled in at least one physics course during the study period. At the UoA, students are required to take two courses outside of their major, with the options being titled as general education courses. We excluded all students who studied a general education course in physics from our analysis. We know that these students are not physics students, and they do not offer a representative sample of students from outside of physics.

A typical Bachelor of Science physics degree at the UoA takes place over the course of three years. In their first year, physics students are required to take Advancing Physics 1 (AP1) and then Advancing Physics 2 (AP2) before moving on to second year physics. Life science students (those majoring in biomedical sciences or medicine) are required to take Physics for Life Sciences (PLS) in their first year. PLS is taught by the physics department. This means that, despite our study population including only students who took a physics course, many of the students present in our data set were likely majoring in life sciences. Our population therefore allows us to compare the outcomes for students in the physics and life sciences disciplines. AP1 and PLS cover the same content, but are presented in a different manner. One significant difference between AP1 and PLS is that AP1 assumes a knowledge of calculus, while PLS does not. This is an important point to consider, as a mathematics background may be an important form of science-related capital [Black and Hernandez-Martinez 2016], and female students may be more likely to drop out of physics education after taking calculus [Ellis et al. 2016]. The current study was able to compare the AP1 and PLS subsets of the general physics population to account for a student’s first year disciplinary intentions. PLS is still considered an acceptable prerequisite for AP2 in lieu of AP1, although it is rare for students to take this route.
3.3.2 Measures

The following variables were used in the analysis:

- Grade Point Equivalence (GPE): GPE is an entry level score that provides a standard measure of a student’s prior academic performance at the time of admission to university, regardless of the qualification they previously took. It is measured on a 0-9 scale, with 9 being the highest performing. It provides an aggregate measure of how well a student did in all of their high school courses (University of Auckland 2016b).

- Grade Point Unit (GPU): GPU is a measure of a student’s university performance in a single course. It is measured on a 0-9 scale, with 0 being equivalent to a fail (D+ or lower), and 9 being equivalent to an A+ grade. GPU was used as a measure of performance for AP1, AP2 and PLS.

- Gender: Due to limitations in the administrative data that were used, gender was only recorded as male or female.

3.3.3 Procedure

Although Bourdieu offers a rich theory to interpret movements within and between fields, we are left with the challenge of defining what constitutes a field. Whilst it could be argued that every student who takes a physics course at university is a physics student, we believe that this is not sufficient. Students may be enrolled in a subject discipline on paper, but actually be fully engaged in a separate field of study. A good example of this is PLS. PLS students may be considered physics students on paper, but their main field of study is likely biomedical sciences or medicine. Through network analysis, we are able to define academic fields in terms of the patterns of course selection. We represent course selection patterns as a network, where nodes represent university courses and edges represent the enrolments of students within courses. We then explore the structure of the network by investigating the communities of courses that tend to be taken together by students. Our approach, similar to blockmodelling approaches (Bottero and Crossley 2011; White et al. 1976), allows us to take a complex network and reduce it to its core structure. It does this by identifying communities of nodes that tend to share more edges. We can then explore patterns at the level of communities instead of at the level of nodes. In the current study, we interpret these communities as academic fields. Following this, we are able to investigate gender differences in the transverse
that students make across the fields represented in our network. We supplement
our network with course achievement data to compare vertical movements within
and across fields.

The following section outlines the series of steps that were used to generate
the course network and use it to answer our research questions regarding gender
differences in students’ transverse and vertical movements. Through the analysis
of course relationships, we can take a non-biased approach to defining the fields
in which students are located.

3.3.4 Forming the Network

To begin the network analysis, we structured the data as an adjacency matrix,
where rows and columns represent the courses taken by students in our sample,
and a cell value is the number of students who took both course $i$ and course
$j$ within their undergraduate degree. Whilst we could define edges in relation to
the frequency of students who took a pair of courses, this does not accurately
reveal the underlying community structure of students’ preferences. For example,
if a pair of courses includes one course with a large number of enrolments, the
edge linking these courses will have a large associated weight as a consequence of
the large population of one course. However, this may not be a true indication of
students’ preference for co-enrolment in these courses. We therefore account for
the course populations by normalizing the matrix using a Revealed Comparative
Preference (RCP) score. RCP measures the fraction of students from a course
who also took a second course, relative to the overall fraction of students taking
course, across all other courses. More specifically:

$$RCP(i,j) = \frac{x_{ij}}{x_j} \frac{x_j}{x_i}$$

where $x_{ij}$ is the number of students taking both course $i$ and $j$, $x_j$ (or $x_i$) is the
total number of students taking course $j$ (respectively, course $i$), and $x$ is the
total number of unique students enrolled in any course. The RCP metric is based
on the measure Revealed Comparative Advantage, used in economics (Balassa
1965), and was calculated using the EconGeog package in R (Balland 2017). The
RCP approach to normalizing gives the “revealed” course preferences, controlling
for the enrolment numbers of each course (that is, the courses that tend to be
taken together by students in the network more often than would be predicted
by the course populations alone). RCP values greater than one indicate that a
pair of courses had a ‘preference’ for being taken together, given the relative populations of both courses, whilst RCP values below one indicate no evidence of any preference. Thus, we exclude any network edge with an RCP weighting lower than one, leaving only the course pairs that had a preference for taking together.

We identify communities of courses that tended to be taken together by students. We employ the community detection algorithm Infomap (Edler and Rosvall, 2017) on the network. In basic terms, this method of community detection reveals communities of nodes based on maximizing a modularity score. In network analysis, modularity is the extent to which a network is partitioned so that the number of edges within communities is greater than the number of edges between communities. Using the igraph package in R (Csardi and Nepusz, 2006), the Infomap algorithm identified 23 communities of courses in our network (see Table 3.1). Each community can be interpreted as a unique academic field consisting of different combinations of courses and requiring different sets of knowledge. The resulting network is shown in Fig 3.3. Nodes in the network represent courses taken by students, whilst edges show a preference for a pair of courses being taken together. Node colours represent the communities of courses, which we interpret as individual fields. Using Bourdieu’s concepts of transverse and vertical movements, we explore the relationships between and within the 23 communities (or fields) in the network.

3.3.4.1 Transverse Movements

To investigate whether there are gender differences in UoA physics students moving from one academic field to another during their undergraduate degree (transverse movements), we build on the network outlined in the previous section. We take the same set of nodes, with the same community structures, but weight edges by the number of students who took course \(i\) before course \(j\). From this new directed network, we are able to assess the movements that students make between communities. To answer our questions regarding the transverse movements that students make from one field to another, we aggregate the number of movements from courses within community \(m\) to courses within community \(n\) (see Fig 3.4). For example, the courses in the Physics-Maths community in Fig 3.3 become a single Physics-Maths node in Fig 3.4. Outgoing edges between communities are aggregated into a single outgoing edge, with a weighting equivalent to the sum of all outgoing edges weights from nodes in the community. Edges between courses within a community are similarly aggregated, and are represented as self-loops (a
link from a node to itself) in Fig 3.4. To investigate how transverse movements differ by gender, we calculate the Odds Ratio (OR) with 99% Confidence Intervals (CI) of a female student moving from community $m$ to community $n$ over a male student. OR are generated using the following formula (Field et al., 2012):

\[
\frac{A/C}{B/D}
\]

where $A$ is the number of female students who did move from community $m$ to community $n$, $B$ is the number of male students who moved, $C$ is the number of
Table 3.1: **Compositions of the Communities Detected in the Co-enrolment Network.** This table shows the number of students and course enrolments for each detected community, with proportion of female students.

<table>
<thead>
<tr>
<th>Community</th>
<th>Count students(^{a})</th>
<th>Proportion female(^{b})</th>
<th>Total enrolments(^{a})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ancient History</td>
<td>150</td>
<td>0.48</td>
<td>205</td>
</tr>
<tr>
<td>Biological Science</td>
<td>5630</td>
<td>0.52</td>
<td>18600</td>
</tr>
<tr>
<td>Chemical Materials</td>
<td>20</td>
<td>0.35</td>
<td>60</td>
</tr>
<tr>
<td>Chemistry</td>
<td>1660</td>
<td>0.49</td>
<td>4180</td>
</tr>
<tr>
<td>Chinese</td>
<td>60</td>
<td>0.27</td>
<td>85</td>
</tr>
<tr>
<td>Computer Science</td>
<td>4405</td>
<td>0.28</td>
<td>22195</td>
</tr>
<tr>
<td>Engineering</td>
<td>980</td>
<td>0.36</td>
<td>9315</td>
</tr>
<tr>
<td>Finance-Marketing</td>
<td>1430</td>
<td>0.29</td>
<td>6735</td>
</tr>
<tr>
<td>Food Science</td>
<td>640</td>
<td>0.53</td>
<td>1505</td>
</tr>
<tr>
<td>Geography-Geology</td>
<td>1470</td>
<td>0.38</td>
<td>6095</td>
</tr>
<tr>
<td>Japanese</td>
<td>85</td>
<td>0.38</td>
<td>180</td>
</tr>
<tr>
<td>Law</td>
<td>170</td>
<td>0.46</td>
<td>240</td>
</tr>
<tr>
<td>Liberal Arts</td>
<td>6410</td>
<td>0.38</td>
<td>12750</td>
</tr>
<tr>
<td>Medical Science</td>
<td>4715</td>
<td>0.53</td>
<td>26790</td>
</tr>
<tr>
<td>Nursing</td>
<td>70</td>
<td>0.81</td>
<td>300</td>
</tr>
<tr>
<td>Optometry</td>
<td>550</td>
<td>0.61</td>
<td>1310</td>
</tr>
<tr>
<td>Pharmacy</td>
<td>645</td>
<td>0.58</td>
<td>2100</td>
</tr>
<tr>
<td>Physics-Maths</td>
<td>3060</td>
<td>0.25</td>
<td>12125</td>
</tr>
<tr>
<td>Population Health</td>
<td>200</td>
<td>0.57</td>
<td>510</td>
</tr>
<tr>
<td>Psychology</td>
<td>1440</td>
<td>0.52</td>
<td>4410</td>
</tr>
<tr>
<td>Sports Science</td>
<td>245</td>
<td>0.47</td>
<td>575</td>
</tr>
<tr>
<td>Statistics</td>
<td>1470</td>
<td>0.36</td>
<td>3985</td>
</tr>
<tr>
<td>Surgery</td>
<td>350</td>
<td>0.43</td>
<td>2800</td>
</tr>
</tbody>
</table>

\(^{a}\)Counts have been rounded to the nearest 5 to preserve confidentiality.

\(^{b}\)Proportions were formulated using original, unrounded values.

female students who did not move, and D is the number of male students who did not move. The null hypothesis in this case is that female and male students were equally likely to make a movement from one field to another. We visualize these results in two different ways: Fig 3.4 shows the co-enrolment network with nodes representing communities and edges representing likelihoods, while Fig 3.5 is a heat map in showing the gender differences in transverse movements. In Fig 3.4 orange edges indicate a higher likelihood of female students going from community \(m\) to community \(n\), and purple edges indicate a higher likelihood of male students going from community \(m\) to community \(n\) (the direction of the movement follows the links in a clockwise direction). In Fig 3.5 communities are indicated on the
horizontal and vertical axes, with movements from community $m$ (horizontal axis) to community $n$ (vertical axis). Once again, orange indicates that a female student was more likely to make a move from community $m$ to community $n$, with colour intensity representing a higher likelihood.
Figure 3.4: **Course Community Network.** The directed network above represents the network seen in Fig 3.3 only the links within communities (i.e. links between courses belonging to the same community) and between communities have been split by gender and aggregated. Odds ratios comparing the likelihood of a female student taking a course in community $m$ and community $n$ were formulated, with the resulting values used as edge weights. The communities were labelled based on the range of courses that it is comprised of. Edges where female students were more likely to take a course in community $m$ and community $n$ are coloured orange, while edges where male students were more likely to take a course in community $m$ and community $n$ are coloured purple. When considering the flow between a pair of nodes connected by two edges, the direction of flow is outward following the link in a clockwise direction. The network shows that transverse movements from fields such as computer science and physics-maths to other domains tend to be female-dominated, whilst movements into these fields are more male-dominated.
From Biological Science
Chemical Materials
Chemistry
Computer Science
Engineering
Finance−Marketing
Food Science
Geography−Geology
Medical Science
Optometry
Pharmacy
Physics−Maths
Population Health
Psychology
Sports Science
Statistics
Surgery

Figure 3.5: **Student Course Heat Map.** The above heat map represents the same underlying data as that which is used in Fig 3.4. The heat map makes clear the gender differences in the likelihood of students moving from one community to another. Orange areas represent instances where female students were more likely to take a course in community $n$ after taking a course in community $m$. Purple areas indicate male students were more likely to take a course in community $n$ after taking a course in community $m$. Areas that are white or empty indicate no significant relationship. Male students were consistently more likely to take courses in Computer Science and Physics-Maths after taking courses in each other community. Female students tended to be more likely to take courses in life science subjects (e.g., Biological Science and Psychology).

### 3.3.4.2 Vertical Movements

We also seek to investigate how male and female students with differing levels of prior achievement choose to invest their capital. Are there gender differences in the vertical movements (moving upwards or downwards in the objective rankings in a field) that students make from one stage to the next? Do male and female students with different levels of prior achievement choose to invest their capital
Exploring Gendered Pathways Using Networks

differently? To understand the nature of students’ vertical movements within and between fields, we incorporate student achievement data into our previously established network. For each course, we have the student grade point unit score (i.e., their level of achievement). Our data set also includes an average high school achievement measure Grade Point Equivalent (GPE), for the majority of students in our network. This allows us to look at the transitions that male and female students make from high school to university study.

We are particularly interested in the movements that students make going from high school to three specific stage one courses: AP1, AP2, and PLS. We also investigate the gender differences in vertical movements that students make from these physics courses to our detected fields, and between our detected fields. For our detected fields we calculate a Grade Point Average (GPA) score for each student (scored on a continuous scale of 0-9), in which we take the mean of the student’s grade point unit scores for each course they took within the community. For example, the Physics-Maths GPA score will be a student’s mean average grade point unit score for all of the courses they took within the Physics-Maths community.

As outlined by Bourdieu, an individual’s power in a field is determined by the composition and volume of capital they hold relative to other individuals. As our goal is to compare the relative vertical position of students within and between fields, we convert the achievement scores (GPE for high school, GPU for the key stage one courses, and GPA for the communities) into percentile ranks. Standardizing achievement in this manner facilitates comparisons across fields. Top-achievers in a field will have a percentile rank score of 100, whilst low-achievers will have a percentile rank score closer to 0. We can then compare the change in percentile rank scores for male and female students across our network. To describe the gender differences in vertical movements, we use independent 2-group Mann-Whitney U Tests (a non-parametric t-test) to test the median difference in percentile rank change between male and female students. Non-parametric tests were chosen as they are robust to outliers and skewed distributions [Erceg-Hurn and Mirosevich 2008], and we do not assume the distribution of rank changes to be normal. We were then able to determine whether there were any significant differences between male and female students gaining in relative performance across fields, with the null hypothesis being that there are no gender differences in percentile rank change. We report effect sizes in terms of the Common Language (CL) effect size [McGraw and Wong 1992], which is robust, widely used and easy to interpret.
As described by Lakens (2013, p.4), the CL effect size indicates: “the probability that a randomly sampled person from one group will have a higher observed measurement than a randomly sampled person from the other group.” In our case, the CL effect size indicates the probability that a female student will have a higher change in rank after moving to a new field over a male student who made the same move. We also report the OR (with 99% CI) of top, middle, and low-achieving female students enrolling in different fields compared to their male counterparts. These achievement groups are based on percentile ranks of all students split into three equally sized bins. We explore the movements from high school to key stage one university courses specifically, and from key stage one physics courses to detected fields.

3.4 Results and Discussion

Networks showing the revealed communities of courses that students take can be seen in Fig 3.3 and Fig 3.4. Fig 3.3 shows the network of courses offered by the University of Auckland (UoA) between the years 2009 and 2014, with communities indicating courses that tended to be taken together within students’ undergraduate degrees (represented by the different colours). The communities included (in ascending order of aggregated course enrolments): Medical Science, Computer Science, Biological Science, Liberal Arts, Physics-Maths, Engineering, Finance-Marketing, Geography-Geology, Psychology, Chemistry, Statistics, Surgery, Pharmacy, Food Science, Optometry, Sports Science, Population Health, Nursing, Law, Ancient History, Japanese, Chinese, and Chemical Materials.

The use of Revealed Comparative Preference (RCP) in conjunction with the community detection revealed underlying academic fields in which physics students participated, as indicated by the combinations of courses that students enrolled in. Physics courses (including AP1 and AP2, the first prerequisites for a physics major at the UoA) and mathematics courses were located in the same field, which we label Physics-Maths. PLS, a physics course required for students wanting to study medicine, was located in the field of Medical Sciences. We report the counts of students per community, with the percentage of female students, in Table 3.1. Liberal Arts, Biological Science, and Medical Science were the three largest communities based on the number of unique students enrolled in each field. Medical Science, Computer Science, and Biological Science were the largest communities in terms of total enrolments (an individual student may be enrolled in more than
one course per field). In terms of the proportion of female students per community, Physics-Maths (0.25), Computer Science (0.28), and Chinese (0.27) were the most male-dominated. Nursing (0.81), Optometry (0.61), and Pharmacy (0.58) were the most female-dominated.

The network and RCP approach provides a non-biased method of classifying the fields in which students are participating. The use of RCP shows that disciplinary labels (i.e., ‘Physics’) are imperfect in classifying the patterns of courses that students enrol in. Although PLS is a physics course, it has a higher affinity with the life sciences, and our community detection approach reflects this by locating PLS within the field of Medical Science. For example, the percentage of female students enrolled in all physics courses (including PLS) was 40%. Our community detection shows that female students only made up around 25% of the main Physics-Maths community. The difference between these percentages is substantial, and raises important implications for the way in which universities report the number of students studying in different disciplines.

### 3.4.1 Transverse Movements

We first wanted to understand whether there were gender differences in UoA physics students moving from one academic field to another. Our results regarding these transverse movements (more detail is given in Turnbull et al. (2019, Table S2)) show that female students were around 1.8 (OR = 1.82, CI: 1.63-2.02) times more likely to take a course in Biological Science after taking a course in Physics-Maths, and 1.4 (OR = 1.44, CI: 1.40-1.47) times more likely to take a further course in Biological Science after taking a previous Biological Science course. On the other hand, male students were around 2 (OR = 0.51, CI: 0.48-0.56) times more likely to take a course in Physics-Maths after taking a course in Biological Science. There were no significant gender differences in students taking a course in Physics-Maths after taking a previous course in that community. Male students were consistently more likely to take a course in Computer Science after taking a previous course in another community, for example going from Biological Science (OR = 0.44, CI: 0.42-0.46), Physics-Maths (OR = 0.52, CI: 0.50-0.54), and Computer Science (OR = 0.44, CI: 0.43-0.45).

The above results show differences in the transverse movements that students make between fields. Female students were nearly twice as likely to switch into Biological Sciences after Physics-Maths, with male students nearly twice as likely to go the opposite direction. Thus, the results of the current study show that
gender disparities are evident, not only in the fields in which students choose to study (see Table 3.1), but also in the transverse movements made between fields. Consequently, students can expect gender disparities in fields to increase over the course of their enrolment. These findings are in line with previous research that shows that the life science disciplines (biology, medicine etc.) tend to be more popular for female students, while physics, maths, computer science and engineering tend to be more popular for male students (National Science Foundation 2017; Cunningham et al. 2015; Kost-Smith et al. 2010; Heilbronner 2012; Stevanovic 2013; Institute of Physics 2012; Smith 2011; Education Counts 2016a; Kennedy et al. 2014; Semela 2010). Male students were consistently more likely to switch into computer science regardless of prior field. This highlights the field of computer science as a key area of future investigation, especially in the context of Aotearoa New Zealand STEM education.

Whilst the above findings indicate gender disparities in student enrolments, it is important to consider the achievement levels of students who enter in to different fields, and whether achievement impacts on the movements that students make. We wanted to know whether there were gender differences in the persistence of UoA students in physics, accounting for student achievement. The question we now ask is where did male and female students with differing levels of prior achievement choose to invest their capital? We look specifically at students coming from high school, to the key stage one physics courses (AP1, AP2, and PLS) and to the disciplinary fields revealed in our network.

3.4.2 Vertical Movements

We investigated the impact of student achievement on student enrolment in two ways. We firstly report the number of top, middle, and low-achievers who made movements from high school to the key stage one physics courses (AP1, AP2 and PLS), and to the fields revealed in our network. We then assessed the vertical movements that students made by analyzing gender differences in the change in objective rankings within and between fields. We begin by reporting the progression of students from high school to university physics. High school students were split into three equally sized bands based on achievement rankings. As highlighted in Fig 3.6, the top-achieving group is gender balanced (50% female students), while the middle-achieving (40% female students), and low-achieving groups (33% female students), have fewer female students.
Figure 3.6: **Student Progression Alluvial.** An alluvial plot showing the progression of male (purple) and female (orange) students from high school to university physics split by achievement bands. Female students were equally represented among the top-achieving high school group, but less well represented among the middle and low-achieving groups. PLS (Physics for Life Sciences) and AP1 (Advancing Physics 1) represent the two main groups of physics students in our data. As shown in the alluvial plot, PLS was more popular than AP1, especially at the intersection of top-achievers and female students.

For students ranking in the bottom third of high school students (“low-achievers”), 17.94% of female students and 35.53% of male students went on to study AP1. In comparing the odds of progression to AP1, we found that low-achieving male students were 2.52 (OR = 0.40, CI :0.30-0.52) times more likely to enter the main physics pathway at the UoA compared to their female counterparts. For students ranking in the middle third of high school students (“middle-achievers”), 10.69% of female students and 30.58% of male students went on to study AP1. Middle-achieving male students were 3.68 (OR = 0.27, CI: 0.20-0.37) times more likely to enter physics at the UoA compared to their female counterparts.

Our findings show that of the students who were ranking in the top third of students coming from high school (“top-achievers”), very few chose to invest their capital in physics. Only 8.72% of male students and 5.06% of female students who
were top-achievers from high school chose to enrol in AP1. These percentages also indicate that from this top-achieving group, male students were 1.79 times more likely to go to AP1 (OR = 0.56, CI: 0.36-0.87). Thus, not only does it appear that physics is an unattractive option of top-achieving high school students, but this is particularly true for top-achieving female students. In contrast, 72.66% of male students, and 88.35% of female students from this top-achieving group enrolled in PLS. Top-achieving female students were around 2.8 (OR = 2.84, CI: 2.10-3.83) times more likely than their male counterparts to follow this pathway.

Our results provide a good indication that the life science fields tend to be viewed as high in symbolic capital (prestige), as they attracted a higher proportion of high-achieving students. This echoes arguments that medicine is perceived as a high status career that is highly sought after (Wong, 2012). The fact that we did find differences in the choices to study PLS over AP1 suggests that physics is viewed as a less rewarding study path than the life sciences. Questions need to be asked about the way in which physics is presented to students in secondary school. Claussen and Osborne (2013) argue that science education needs to highlight the utility value of science in culture, scientific literacy, and employment. Students will choose to invest their capital in a field where they feel that they can get the largest return (be it in educational qualification, future employment opportunities, or enjoyment). Our findings suggest that within science education, physics needs to make a stronger case for its utility in order to attract high-achieving students, in general, and female students in particular. This could be achieved by boosting science capital (Archer et al., 2015a), increasing the knowledge about the future value of physics courses in the employment market (Archer et al., 2014), and providing information on the utility of physics in everyday life.

Increasing the value of physics and boosting the related capital of students within physics, although necessary, is likely an insufficient strategy to address gender disparities. In the context of previous research, it may be that our findings can be explained by the unwelcoming climate presented in the field of physics (Blickenstaff, 2005; Kost-Smith et al., 2010). Following Bourdieu’s theoretical framework (Fig 3.2), we must also consider students’ habitus. The affinities that students feel towards each scientific discipline is influenced from an early age by their experiences in, and perceptions of the field of science education. Using evidence from their life experiences, students enter into university with an idea of what discipline is ‘for me’. For fields such as physics and computer science, where we found the most consistent gender disparities in enrolments, previous research suggests
that students are influenced from an early age by the “smog of bias” (Kost-Smith et al., 2010) that targets women. Through the combination of a myriad of factors, from the negative gender stereotypes (Nosek et al., 2009), to the ways in which women’s competence is unfairly questioned (Moss-Racusin et al., 2012; Potvin and Hazari 2016; Ong 2005), students will internalise (via habitus) the perception that physics is something men do, and where women are unwelcome (Archer et al., 2013a). Until the smog of bias is addressed, female students will continue to have constrained choice in science.

Whilst we could interpret the lower likelihood of a male student studying in the life sciences as resulting from possible obstacles also, we find this an unrealistic interpretation. The sizable representation of male students and researchers in the life sciences presently and historically, and the lack of negative factors that impact male students in this domain, mean that the life sciences are likely still a realistic study choice for male students. To put more simply, male students have more choice on where to invest their capital, whilst female students are more likely to face obstacles. The rules operating in the field of physics may require female students to make extra effort to appear competent and persevere in the field. As outlined by Ong (2005, p.595) in a study of minority female physics students: “the ways in which women of colour organize themselves to appear competent in the context of physics specify invisible rules about the strict boundaries around local scientific communities.” The idea that women in physics may have to “relegate social and cultural identities to the margins” (Ong 2005, p.598) in order to succeed in physics corresponds to Bourdieu’s idea that individuals lacking in the ‘valued’ cultural capital in a field may need to make sacrifices to get ahead (Bourdieu, 1984).

Of the students from AP1 who ranked in the bottom third of achievers (low-achievers), we found that 40.38% of male students, and 28.29% of female students progressed to AP2. Female students from this low-achieving group were around 1.72 (OR =0.58, CI: 0.35-0.98) times less likely to progress from AP1 to AP2. There were no significant gender differences in the middle (OR = 0.84, CI: 0.56-1.24) and top-achieving (OR = 0.77, CI: 0.49-1.21) AP1 students who went to AP2.

The above findings point to previous research that suggests that female students may be less confident in physics (Bøe and Henriksen, 2013; Sharma and Be-wes, 2011; Hofer and Stern 2016) and maths (Else-Quest et al., 2013; Sheldrake et al. 2015), or, rather, low-achieving male students may be over-confident. It
may be that in our sample, gender differences in progression from AP1 to AP2 for middle and top-achieving students were not present as the grades received offered evidence that they belong in physics. For the low-achieving students, belonging is not evidenced by their grades. Low-achieving male students may be buffered by a habitus that, after years of socialization, predisposes them to physics. Female students, on the other hand, may be less likely to have this protective disposition. Whilst further research is needed to substantiate this claim, past research does suggest that students are more likely to make internal attributions of failure for female students in science (i.e., they fail because they are not good at it), and external attributions of failure for male students (i.e., unfavourable circumstances) (LaCosse et al., 2016). Furthermore research by Ellis et al. (2016) found that female students are more likely to discontinue physics after taking an introductory calculus course, with female students also being more likely to cite lack of understanding as a reason for dropping out. This may also apply to students in our sample, as AP1 includes content that requires knowledge of calculus.

We also investigated the rank change for students moving from high school to the key stage one physics courses, and from those physics courses on to the fields detected in our network. We found no statistically or practically significant gender differences in the vertical movements in these pathways, with the exception of students going from high school to AP1. As indicated by Figs 3.6 and 3.7 we found that low and middle-achieving female high school students were more likely to decrease their rank in the field (i.e., make a vertical movement downwards) in AP1 with this being statistically significant. Comparing the ranking on a scale of 0-100 in high school and AP1, on average, low-achieving high school female students went down around 6 ranks compared to their male counterparts (Difference in Position=−5.71, CI: −8.57 - −2.86), with the Common Language (CL) effect size being 0.40. This effect size means that if we were to pick a random male and female student and compare their change in rank, there would be a 40% chance that the female student had a higher change in rank compared to the male student, or, conversely, there would be a 60% chance that the male student had a higher change in rank compared to the female student. Middle-achieving female students went down around 9 ranks relative to their male counterparts (Difference in Position=−8.57, CI: −12.86 - −2.86), with a CL effect size of 0.41. There was no significant gender difference in rank change for top-achievers.
Figure 3.7: Distribution of Rank Change by Gender and High School Achievement Group

The above density plots show the distribution of rank change going from high school to Advancing Physics 1 (AP1). Purple represents the distribution of rank changes for male students, while orange represents female students. The dotted vertical line show the median rank change per group. On average, low-achieving female students went down 6 ranks compared to their male counterparts, while middle-achieving female students went down 9 ranks relative to their male counterparts. There was no significant gender difference in rank change for top-achievers.

These results somewhat echo the findings of Kost-Smith et al. (2010) who found that male students tended to outperform female students on post-test physics concept inventory scores, despite there being no gender differences in pre-test scores. Based on this, we would expect male students in our sample to also increase
their relative position in the field of physics after first year study. With that being said, the gender differences in the vertical movements we did find for middle and low-achieving students were relatively small, and non-existent for top-achieving students. The top-achieving female students in our sample who chose to progress in physics likely have a habitus that is just as congruent with physics as the male students (i.e., they feel that physics is ‘for them’). However, taken in the context with our other findings that female students were less likely to progress from high school to AP1, or from AP1 to AP2, questions must be asked about the distribution of physics-related capital and the development of physics habitus before university education, particularly for middle and low-achieving students.

Many studies point to the late childhood and early teenage years as a key formative stages (Archer et al., 2013b; DeWitt et al., 2014; Baram-Tsabari and Yarden, 2010) for identity within science. Future studies of tertiary education in Aotearoa New Zealand should investigate the role of science identity in subject selection decisions further.

3.4.3 Implications

The current study offers a detailed account of the movements that students make through university physics. Our results show that female students were less likely to progress from high school to AP1, regardless of prior achievement, while low-achieving female AP1 students were less likely to progress to AP2. The findings of the current study suggest that more needs to be done to ensure that physics is perceived as a viable option for female students and high-achieving students (and particularly high-achieving female students). This can be done by using interventions to boost the value that science capital holds in all areas of society. Echoing the arguments of Claussen and Osborne (2013) and Archer et al. (2012), science education in Aotearoa New Zealand, and internationally, needs to highlight the utility value of physics in culture, in boosting scientific literacy, and employment.

However, we argue that boosting the value and access to capital, despite being a necessary goal for boosting the numbers of students in physics, is insufficient to tackle gender disparities. Following our research framework, we should seek to transform the habitus of students to encourage them to invest their capital in physics. We need to continue to change the culture of physics so that it is more likely to be viewed as a viable study option. Whilst we do not want to force students to study in areas where they do not want to be, we echo the sentiments of Cheryan et al. (2017, p.22), who state:
Just because women are excited to go into other fields does not mean that they would not have been equally excited to go into computer science, engineering, and physics if the cultures signaled to them that they belong there.

We need to transform the field of physics so that it signals to female students that they belong there.

Previous research suggests that interventions to boost the number of female students graduating in physics would be most useful at stages of education prior to university (Cheryan et al., 2017), as intentions to study science can be formed by early secondary school (Archer et al., 2013b; Baram-Tsabari and Yarden, 2010). Female students’ self-concept in physics may be improved through exposure to supportive family members (Kelly, 2016) and high school teachers (Hazari et al., 2017; Kelly, 2016).

The results of the current study do also indicate that more needs to be done to support the female students who have already chosen to study physics at university. This may take the form of increased academic support for low-achieving students in particular. Universities can seek to provide group learning experiences in introductory physics (Sawtelle et al., 2012), and more welcoming environments for female students in physics and computer science (Master et al., 2016).

As outlined by Bourdieu, individuals fight to define the criteria of what is of value in the field. Individuals who hold power in the field have the means to change the culture of physics. As stated by Hilgers and Mangez (2014, p.11):

The chances that established actors will succeed in preserving the order [of the field] are, however, greater than the probability of subversion.
The more legitimate an agent, the more her peers consume her products, and the more they consume her products, the more legitimate she becomes.

Following this logic, culture change in the field may require forced institutional changes. Initiatives to help address the inequities faced by women already in the field (Ivie et al., 2013), and to increase the representation of women in research and higher education (Equality Challenge Unit, 2018; European Commission, 2018) are important steps to fostering changes in culture. Through these initiatives, we signal to future students from all backgrounds that physics is somewhere where women belong.
Beyond our research findings, the current study demonstrates the utility of using network analysis and Bourdieu together. Whilst network analysis serves as a good method for representing Bourdieu’s concept of field, Bourdieu’s theory provides a rich interpretive lens. Our approach carries many benefits over other, more simplistic frameworks, such as the leaky pipeline. Employing the concepts of field, capital and habitus allow us to understand the objective structure of physics, whilst respecting the subjective contexts in which students are placed. Doing so removes stigma that can be attached to students who ‘leak’ from the physics education pipeline. Emphasizing the contexts that students are situated in allows us as researchers to place our findings in a broader context and formulate suitable interventions to boost the physics enrolments of underrepresented groups.

3.4.4 Limitations

There are limitations to the current work that future studies should address. Firstly, our data set is limited to UoA physics students, and included only course selection and performance information, and minimal demographic information. We did not have data regarding the course selection information of students prior to university, whilst our measure of high school achievement was a general measure and not subject-specific. More detailed data would have provided more information regarding students’ educational trajectories. With that being said, our results show the utility of working with student record data. Our network analysis, whilst simple, also provides a strong framework for working with more complex data; for example, investigating the distribution of economic, cultural, social capital across the network.

Whilst we argue that our network analysis approach enables us to draw many conclusions from our data, our study would also have benefitted from combining our quantitative analysis with qualitative measures. We have used a quantitative approach to defining the field, and used evidence from other research studies to draw conclusions from our data. Whilst this approach is informative, qualitative approaches can provide even more context specific details. Bourdieu highlighted the need to break the dichotomy between the aim of understanding the ‘objective reality’ (the overall distributions of groups and relationships between them) and the aim of understanding “not ‘reality’, but agents’ representations of it” (Bourdieu, 1986). Surveys and interviews of students would provide contextual and fine-grained detail that would complement our quantitative network analysis.
Qualitative analysis may also be a more appropriate way to investigate gender as a non-binary construct.

Despite having access to information regarding the ethnicity of students, we decided not to present this information in the current analysis. This is due to the fact that preliminary analysis showed low cell sizes for ethnic groups other than Pākehā/New Zealand European and Asian students in physics, in particular Māori and Pacific Island students (these findings are available on request). When possible, future studies should make use of an intersectional research design (one that explores the interaction between gender, ethnicity, social class etc.). This is especially important when using a Bourdieusian framework to interpret results. As suggested by Bourdieu: “The individuals grouped in a class that is constructed in a particular respect... always bring with them secondary properties” (Bourdieu, 1984). Understanding the intersection of student characteristics would allow us to include the secondary properties that Bourdieu speaks of. The authors are currently conducting further analysis to understand why there were low cell sizes for minority groups using data from earlier educational stages (i.e., secondary school).

3.5 Conclusion

The current study investigated gender differences for undergraduate physics students at the University of Auckland (UoA) through the use of network analysis on student data, with an interpretive lens based on the work of Pierre Bourdieu. Our network analysis revealed the different academic fields in which students are situated. We outline the utility of networks in visualizing Bourdieu’s concepts of vertical and transverse movements within and across fields. Analysis showed gender differences in transverse movements (moving from one field to another) consistent with gender stereotypes: female students were more likely to enrol in life science fields (Biological Science, Medical Science), while male students were more likely to enrol in the Physics-Maths and Computer Science fields. Analysis of a UoA student-course network revealed that female high school students are more likely to study life sciences at university compared to physics, and this is particularly true for high-achieving students in this group. Furthermore, of the female students who did enter physics in their first year, low-achieving students in this group were less likely to progress to further physics compared to their male counterparts. We relate these findings to Bourdieu’s concepts of field, capital and
habitus (Fig. 3.2). High-achieving secondary school students (especially female stu-
dents) may see more of a return for their capital in the life sciences compared to
physics. Whilst it may be that physics does a poor job of highlighting its value,
we argue that female students will continue to suffer constraints in their subject
selection until the ‘smog of bias’ (Kost-Smith et al., 2010) in physics is addressed.
As outlined by Kost-Smith et al. (2010), it is unlikely that a single factor can
account for the gender disparities seen in physics enrolment. We suggest that the
various factors that have been linked to the attrition of women from physics (e.g.,
negative gender stereotypes, lack of female role models etc.) culminates into a gen-
dered habitus that increases the likelihood of students viewing physics as a field
that men do and where women are unwelcome. We close by discussing potential
avenues for addressing gender disparities, which focus on not only boosting access
to, and the value of, physics related capital, but also transforming the culture of
the field so that all students (and especially women) view physics as a feasible
study option.
Part II: Why Do We See Disparities in Tertiary Science Education?
Chapter 4

The Impact of Science Capital on Self-Concept in Science: A Study of University Students in Aotearoa New Zealand

Preamble

In the second year of my PhD I was fortunate enough to present the applications of my network analysis to the STEM Transformation Institute at Florida International University. Within a wealth of constructive feedback, I was asked about how much information can be gained through administrative data. Administrative data can be explored to understand overall patterns in participation, but how much can it really tell about *why* patterns appear? In order to answer this question of *why*, I needed to narrow the scope of my data collection and ask students more directly about their experiences in science education. As shown in Figure 4.1, the following chapter considers constructs not readily available in administrative data that may offer additional insights when seeking to understand why we see disparities in science education.

As outlined by [Bourdieu 1984](#), students’ practices within the field can be explained in terms of the interaction between capital and habitus. Thus, to answer the question of *why*, I adopt a new framework that focuses more on exploring the relationship shared between capital and habitus. In order to find out more about the forms of science capital available to students, and how they may relate to
students’ internal dispositions, I administered a questionnaire to science students studying at the UoA. The questionnaire was heavily influenced by the work of DeWitt et al. (2011) and the ASPIRES 2 study in the U.K., who kindly shared their questionnaire and interview protocols with me. The following work describes the questionnaire design, analysis, and results in more detail.

Figure 4.1: **Chapter 4 Signpost.** Chapter 4 focuses on describing one aspect of why we see differences in science participation in Aotearoa New Zealand. After summarising the relevance of self-concept to the interaction of capital and habitus, this chapter will describe how different forms of science-related social and cultural capital relate to students self-concept in science.
This work was published in Frontiers in Education (Turnbull et al., 2020) on the 2nd of April, 2020. Coauthors included Kane Meissel, Kirsten Locke and Dion R.J. O’Neale. Once again, there is overlap between the content in the following chapter and previous chapters, as this content was necessary to ensure each article stood as a self-contained piece of work. The following chapter will once again provide a brief introduction to Bourdieu’s theory, but with an increased focus on the concept of science capital, a concept that can be used to collate the various forms of social and cultural capital related to science.

### 4.1 Introduction

Much research has been dedicated to understanding who chooses to study science at university, and what factors influence retention and completion of university science degrees. One particular factor that is associated with retention is students’ science self-concept. Broadly speaking, self-concept is an individual’s perception of their self (Shavelson et al., 1976), while science self-concept relates to an individual’s belief regarding their general competency in science (Jansen et al., 2015). Understanding students’ science self-concept is important for several reasons. Students who feel that they are good at science are more likely to have better outcomes in science classes (Uçar and Sungur, 2017; Tighezza, 2014; Chang and Cheng, 2008; Peters, 2013), hold aspirations for further study (Mujtaba et al., 2018), and graduate from university (Larson et al., 2015). In turn, graduating from university tends to lead to better life outcomes in general (Oreopoulos, 2007), and greater economic outcomes (Norton and Cherastidtham, 2016; Mahoney et al., 2013). Research on factors affecting student’s self-concept in science also has important implications for governments, as they seek skilled workers in Science, Technology, Engineering and Mathematics (STEM) to help gain economic prosperity and growth (Price-waterhouse Coopers Australia, 2015). In Aotearoa New Zealand, the education system is not only charged with producing an increase in the number of skilled workers in STEM domains, but also with producing confident learners. This message is made clear in the official high school curriculum (Ministry of Education, 2007):

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1. School of Learning, Development, and Professional Practice, Faculty of Education and Social Work, University of Auckland, Auckland, New Zealand
2. School of Critical Studies in Education, Faculty of Education and Social Work, University of Auckland, and Te Pūnaha Matatini, University of Auckland, Auckland, New Zealand
3. The Department of Physics, University of Auckland, and Te Pūnaha Matatini, University of Auckland, Auckland, New Zealand
The New Zealand Curriculum is a clear statement of what we deem important in education. It takes as its starting point a vision of our young people as lifelong learners who are confident and creative, connected, and actively involved.

A wealth of research has shown that disparities in tertiary science participation exist across the intersection of gender, ethnicity and social class (Reynolds and Johnson, 2011; Meehan et al., 2017). Students from high Socio-Economic Status (SES) backgrounds are more likely to realise tertiary education goals (Reynolds and Johnson, 2011), whilst interest in science also tends to differ across SES, gender (Cheryan et al., 2017), and ethnicity (Wong, 2016). Previous theorists have used metaphors, such as the gender filter (Blickenstaff, 2005) and the smog of bias (Kost-Smith et al., 2010) that consider the way contextual factors impact on student outcomes. For example, Kost-Smith et al. (2010) argue that gender disparities cannot be attributed to one specific factor, but instead there are a range of factors and small effect sizes that combine to produce inequity. Differing levels of self-concept may be one such factor that contributes to the disparities observed in STEM participation. For example research shows that female students tend to report lower levels of self-concept in mathematics and science (Else-Quest et al., 2013), and gender differences in confidence may persist even when accounting for actual achievement (Ellis et al., 2016).

A student’s self-concept does not exist in a vacuum. It is important to consider the factors that relate to students’ self-evaluations of their ability in STEM domains. Why do gender, ethnicity, and social class often share a relationship with students’ beliefs regarding their competency in science? The goal of this article is to explore the factors affecting science self-concept further, using a theoretical framework that can answer this question. More specifically, we hope to highlight the way in which students’ self-concept in science is rooted in societal structures. To do this, we employ the sociological theory of Pierre Bourdieu (Bourdieu, 1984). Recent research has made use of Bourdieu’s sociological theory as a framework for understanding the uneven patterns in student interests and pursuits in science (Archer et al., 2013b, 2015a). Bourdieu’s theory enables us as researchers to place individuals in the context of their environment, and to understand how social, cultural, and historical factors structure the world in which individuals live, and the internal dispositions they hold. The following section outlines Bourdieu’s theory in more detail, with specific reference to science capital (Archer et al., 2015a).
4.2 Bourdieu and Science Capital

While applications of Bourdieu’s sociological theory are wide-ranging, it has been increasingly used as a theoretical framework to understand student experiences in science education (Archer et al., 2015a). Bourdieu’s sociological framework encourages us to explore how resources are distributed across society, and how external structures in society relate to an individual’s internal dispositions. According to Bourdieu (1986), resources, or capital, can take various forms; such as economic, cultural, and social. Economic capital refers to an individual’s financial resources (e.g. money, investments). Cultural capital refers to an individual’s non-financial resources, such as the objects they own (e.g. books, clothing, furniture), or the characteristics they embody (e.g. accent, posture). Bourdieu (1986) defines social capital as that aspect of our relationships with other individuals that enables us to generate economic and cultural capital. With all forms of capital, the value is determined by the field in which it is being used. To give a basic example, owning science books may be of value for someone studying in the field of science, but this is of less value to someone studying opera. Contemporary research has applied Bourdieu’s sociology to explore student outcomes in the field of science specifically by using the concept of science capital (Archer et al., 2015a). Science capital has been described by Archer et al. (2014) as a:

conceptual device for collating various types of economic, social and cultural capital that specifically relate to science — notably those which have the potential to generate, use, or exchange value for individuals or groups to support and enhance their attainment, engagement and/or participation in science.

Science capital provides a framework that is relatively simple to interpret and can facilitate our understanding of students’ access to resources and the value that they derive from them in science. The following section describes the economic, cultural, and social forms of capital that are important to consider when exploring students’ self-concept in science. We begin by describing the importance of financial assets (economic capital) and non-financial assets (cultural capital) in education. We then describe the importance of shared relationships with others (social capital) which can provide access to resources. We summarise these social relationships in terms of teachers, peers, and family. We finish this section with a discussion of how these resources relate to the way in which students may view themselves in
the field of science through Bourdieu’s concept of *habitus* and the psychological construct of self-concept.

### 4.2.1 Economic and Cultural Capital

Simply put, the concept of economic capital refers to an individuals’ financial assets (e.g., money). The benefits of economic capital are well studied and relatively easy to interpret. Previous research has shown that family income and wealth are large predictors of educational success (Shapiro et al., 2013; Blanden and Gregg, 2004). In Aotearoa New Zealand, a 30 year longitudinal study conducted by Gibb et al. (2012) found that childhood family income is a strong predictor of educational achievement in later life. As outlined by Bourdieu (1986), the value of economic capital comes from its exchange value. For example, students from economically wealthy families are likely able to afford books, laptops, and other aids to study. In paying for these objects, students are exchanging economic capital for non-financial assets. Bourdieu categorizes these non-financial assets under the term cultural capital, and it is through cultural capital that educational advantages are accumulated. Recognising the role of non-financial forms of capital, and with it the social relationships that facilitate access to capital, is complex. In doing so, however, we are able to develop a theoretical model of social class that takes into account factors beyond economic wealth.

Cultural capital refers to the non-financial resources an individual has at their disposal (Bourdieu, 1986). Cultural capital is a complex concept as it is manifested in the objects that one owns (e.g., books, furniture, clothing), or embodied (e.g., in our posture, accent, bodily physique). In the context of science, cultural capital may take the form of objects that are used, such as chemistry sets, laptops, or books. Students may also boost their cultural capital in science with access to other science-related resources, such as visiting science museums (Dawson, 2014) or after-school science clubs (Mujtaba et al., 2018). Cultural capital can play an important role in students’ progression to university study (Aschaffenburg and Maas, 1997). This is echoed in the field of science education, where research has found that access to science-related cultural capital is associated with decisions to study science further in high school (Mujtaba et al., 2018), and at university (Lyons, 2006).

The manner in which students embody their cultural capital may also carry different value in science. Scientists are typically viewed as old, white males (Nosek et al., 2009; Barthelemy et al., 2016) and individuals who differ from this stereo-
type may face barriers to acceptance in the field (Ong 2005). Research has shown that women tend to be viewed as less competent in science solely in terms of their gender in many different roles, whether it involves a student’s application for a lab assistant role (Moss-Racusin et al. 2012), or students’ evaluation of their science teachers quality (Potvin and Hazari 2016).

4.2.2 Social Capital

While economic and cultural capital are important factors to consider in relation to self-concept, social capital is especially important. Social capital refers to value that is gained through relationships with others. This value can be viewed in terms of the economic and cultural capital that can be mobilised through relationships, but also through the impact of relationships on students’ internal dispositions (Adler and Kwon 2002). Having social relationships with individuals who hold valuable forms of capital is highly beneficial. For example, for a student studying at university, having parents who also studied at university may lead to better outcomes. These students are not only more likely to have access to educational resources (objectified cultural capital), but they may also be exposed from an early age to an academic way of life (embodied cultural capital). The following section details three valuable sources of social capital for students studying science: teachers, peers, and family.

4.2.2.1 Teachers

One of the most important forms of social capital for students is the student-teacher relationship. The value of this relationship is derived from several factors. Firstly, the content knowledge that teachers hold is an important form of cultural capital for students (Goldhaber and Brewer 2000; Wayne and Youngs 2003; Keller et al. 2017), as it gives students access to knowledge. Students who have access to teachers with more content knowledge are more able to derive value from their relationship. However, it is also important to consider that content knowledge is transmitted as a function of the quality of the student-teacher relationship. The attitudes and behaviours of teachers can significantly impact on the interest students hold in STEM (Keller et al. 2017) and the way in which students see themselves in science. As outlined by theorists such as Bandura (1986) and Siegle and McCoach (2007), teachers can boost a student’s belief that science is somewhere that they belong by encouraging them and recognising their ability. For example, students who feel recognised as being good at physics are more likely
to hold further interest in physics (Hazari et al., 2017). Through a Bourdieusian lens, recognition provides a signal to students that the field is somewhere they belong. Studies of classroom environments have continuously shown that positive teacher-student interactions are a strong source of interest in science (Osborne et al., 2003; Keller et al., 2017). Mujtaba et al. (2018) found that encouragement was an especially important influence in students’ aspirations to study chemistry. The social capital provided by teachers may be particularly important for students choosing to study in fields where they are members of an underrepresented group, or where their capital is undervalued by those with power in the field.

4.2.2.2 Peers

It is also important to consider the impact of students’ social relationships with their peers in science outcomes (Osborne et al., 2003). Adolescence is a time where individuals begin to be increasingly influenced by their peers (Douvan et al., 1966), which can impact on academic engagement and achievement (Ryan, 2000) and students may be subjected to group norms that influence the decisions they make about future study (Brown et al., 1986). Following this, it is no surprise that individuals belonging to friendship groups that value science are more likely to have motivations to pursue science further (Robnett and Leaper, 2013). Other research shows that students’ persistence in STEM domains at university may be influenced by their academic peer groups (Ost, 2010).

4.2.2.3 Family

Finally, students’ social capital is bolstered by their relationships within the family. Parents’ educational expectations for their children are key predictors of educational aspirations (Wu and Bai, 2015). In science, Lyons (2006) found that parents’ attitudes towards educational qualifications and encouragement were important factors relating to students’ decisions to study science. Students with highly educated parents are also much more likely to fulfil goals of attaining tertiary qualifications (Reynolds and Johnson, 2011), while students with parents who are employed in STEM occupations are more likely to choose to major in STEM at university (Moakler Jr and Kim, 2014). These findings point to Bourdieu’s concept of social reproduction, where the social position of families are transferred across generations. Parents who are university-educated may be more likely to engage in the concerted cultivation of children — the process of deliberately building cultural capital that is valued by educational institutions (Lareau, 2011). Parents
from higher SES backgrounds may hold higher educational expectations for their children (Carolan and Wasserman 2015), whilst they may also be more involved in their children’s education (Cheadle and Amato 2011). Beyond the deliberate cultivation of their children, parents who studied science at university are also more able to use science-related discourse which is an important manifestation of cultural capital (Lyons 2006; Bernstein 1971). The role of the family goes beyond typical forms of social capital, as the family provides the context in which individuals develop their identity. For this reason, family-related factors can be strongly tied to Bourdieu’s concept of habitus.

4.2.3 Habitus

As previously discussed, students’ experiences within fields and their interactions with resources may begin to be embodied physically as embodied cultural capital. At the same time, students also embody these experiences mentally. The mental embodiment of capital can be summarised by Bourdieu’s concept of habitus. Bourdieu defines habitus as the internal dispositions that an individual holds that generate practices within the field. While an individual’s volume of capital may determine their position in the field, their habitus determines their disposition towards the field (Bourdieu and Waquant 1992). Habitus represents an individuals’ internalisation of society — the resulting mental structure of the process commonly referred to as socialisation (Nash 1999).

For Bourdieu, habitus is the mechanism which mediates between structure and agency. Students internalise the environment in which they are placed and make judgements on what is possible and realistic “for them”. A student’s family background is likely to have an integral role in shaping habitus. Students from families that are familiar with university, or that have a history of working in science-related fields, may be more likely to have internalised dispositions that see science as something that is for them. A student’s habitus is influenced by their familial context (Dimaggio 1982), with some theorists pointing to the concept of “family habitus” as a tool to understand how family resources, values, and lifestyle choices are internalised by children (Archer et al. 2012; Tomanović 2004). The resources available to students through their family are thus extremely important, not only

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4It is important to note that we do not suggest that the cultural capital espoused by those who are privileged is ‘better’, only that it carries more value in the field of science education. Even though science is commonly perceived as having a ‘culture of no culture’ (Traweek 2009), the ways of teaching, assessing, and valuing students’ capital is predominantly defined by those with power in the field of science — historically western, male, and wealthy.
The Impact of Science Capital on Self-Concept in Science

because they offer objectified forms of cultural capital, but also because they offer exposure to ways of thinking and understanding that have been historically proven to be valued by educational institutions. Students may be more likely to view science as a realistic study choice, and university as a possible destination, if they have parents who have modelled these trajectories previously (Lyons, 2006).

While family provides the context in which habitus is established, habitus is also informed by broader cultural groupings that individuals identify with, and their experiences in other contexts, such as school. Bourdieu (1984, p.101) stated that if individuals are exposed to “homogenous conditions of existence” (i.e., similar life experiences) individuals will have similar habitus. In this sense, habitus can take on a collective quality where members of the same group are socialised in similar ways, predisposing them to hold similar dispositions. For example, Edgerston et al. (2014) use the concept of gendered habitus to explain how gender socialisation relates to gender disparities in educational achievement. Research also suggests that contexts outside of the family, such as school and peer groups, become increasingly important as students progress through education, while the impact of the family may diminish (Holm and Jæger, 2011).

Much research has discussed applications of habitus in education research (Reay, 2004; Nash, 1999), although the concept is often criticised for being too complex (Goldhaber and Brewer, 2000) and difficult to operationalise (Dumais, 2002). Most research on habitus has been qualitative, but, as outlined by Mu (2014), there is an increasing need to consider quantitative applications of habitus. As habitus represents the internalisation of broader social structures, it takes on a collective quality that operates across social groups. While qualitative methods may be more able to describe individual experiences of habitus, quantitative methods are able to explore this collective quality of habitus. The current study operationalises habitus quantitatively through the use of a science self-concept inventory. The construct of science self-concept was chosen as it is can be theoretically tied to arguments outlined by Bourdieu regarding habitus (Mu, 2014; Bodovski, 2014). The following sections will describe self-concept in more detail and explain its relevance to Bourdieu’s theory and the current study.

### 4.2.4 Self-concept

While quantitative applications of habitus in education research are relatively rare, quantitative applications of self-concept have been more widely used, operationalised and validated (e.g. Marsh, 2014; Hattie, 2014). Despite much variety in
definitions of self-concept existing in research (Shavelson et al., 1976), self-concept can be broadly defined as the way in which an individual perceives their self (Rosenberg, 1979; Shavelson et al., 1976). As outlined by Shavelson et al. (1976, p.488) “Self-concept may be described as: organized, multifaceted, hierarchical, stable, developmental, evaluative, and differentiable.” In basic terms, self-concept is an individual’s judgement about their general competence in a domain (Jansen et al., 2015), which can be general (i.e. “I am good at school”) and specific (i.e. “I am good at science at school”). In many ways, self-concept is thus theoretically similar to habitus. Self-concept (Shavelson et al., 1976, p.488) and habitus (Nash, 1999) are both multifaceted in that they operate across general and specific domains. They are also both relatively stable (Shavelson et al., 1976, p.488) and durable (Bourdieu, 1984), although both are subject to change when influenced by environmental sources located outside of the individual, such as the appraisals of others (Bong and Skaalvik, 2003).

Although we identify similarities between self-concept and habitus, it is important to note that we do not consider them to be two different technical terms referring to the same underlying construct (a jangle fallacy). While habitus is the internal, deeper “system of dispositions” (Bourdieu, 1984, p.471) that generates practice, often operating “below the level of consciousness” (Bourdieu, 1984, p.466), self-concept is a perception one has of their self (i.e., “I am good at science”). While habitus includes domain-specific self-perceptions of competence, it also encompasses an “estimation of chances” (Bourdieu, 1977, p.76) that guides future practices and dispositions (i.e., “is science for me?”). Self-concept may be viewed as an aspect of habitus that can be scrutinised through introspection. This point is argued by Bodovski (2014, p.395), who suggests that we may view both general and area-specific self-concepts as “illustrations of different aspects of habitus.”

Despite the conceptual differences between habitus and self-concept, we argue that scores on inventories assessing self-concept can be productively interpreted through a Bourdieusian framework, and this has been evidenced in prior research (Dumais, 2002). As habitus may operate under the surface or unconsciously, it is a difficult concept to measure psychometrically, while self-concept is easier to assess. Importantly, the decision to interpret self-concept in terms of student habitus is necessary as it: “ensures that the research focus is always broader than the specific focus under study” (Reay, 2004). In other words, using the concept of habitus facilitates the understanding of how an individual’s self-concept is generated in relation to the socio-cultural context in which an individual lives. Given
the similarities between self-concept and habitus, self-concept inventories are an appropriate and useful tool to explore an individual’s habitus.

Few Aotearoa New Zealand based studies have explored university students’ self-concept or beliefs regarding their academic competency (Dalgety and Coll, 2006; Murphy, 2018). In one such study, Dalgety and Coll (2006) explored the self-efficacy of first year university chemistry students in Aotearoa New Zealand across three time points in an academic year. They found male students tended to report higher scores in specific items related to self-efficacy (for example in their belief that they could achieve a passing grade in a chemical hazards course). While the work of Dalgety and Coll (2006) offers many insights into student’s internal dispositions at university in the context of Aotearoa New Zealand, the lack of research in this area, especially within the last decade, is a lacuna to be filled.

4.2.5 The Current Study

The current study seeks to address the lack of research into self-concept in science for students of Aotearoa New Zealand by exploring the relationship between science capital and self-concept in science for university students based at the University of Auckland. More specifically, we apply Pierre Bourdieu’s (Bourdieu, 1986, 1984) concepts of capital and habitus to explore the interaction between students’ access to resources and internal dispositions. Whilst the factors affecting outcomes in science are wide-ranging (Osborne et al., 2003), we focus on the impact of science-related resources and social experiences in science on students’ self-concept in science. In doing so, we are able to assess the impact of social class on self-concept, but using a definition of class defined in terms of capital (social, cultural, and economic resources), as opposed to solely economic wealth. Our specific hypotheses are as follows. We expect:

- Higher levels of science-related social and cultural capital to be associated with higher levels of self-concept in science.

- Relationships with high school teachers will be the most important form of social capital. This is based on the idea that teachers are experts in the field and their judgements provide the most domain-specific feedback. In terms of habitus, students will be more likely to internalise the idea that they are good at science if they have an expert (the teacher) encourage them and/or recognise their ability.
• Male students will have higher levels of self-concept than female students. This is based on previous research that points to gender disparities in confidence in science and mathematics (Else-Quest et al., 2013; Ellis et al., 2016).

• The number of university generations within a student’s family, and having parents positively orientated towards science will be positively associated with self-concept. We would expect students who have available academic role models in their family to have a habitus that is predisposed to university science study. Such students will be more likely to hold the belief that university is somewhere where they belong, and somewhere that they can be successful, because that is what their family does.

While acknowledging that differences in science self-concept may exist across ethnic groups, the decision was made to exclude ethnicity from the current study. This decision was made to be consistent with kaupapa Māori values, a research position specific to the context of Aotearoa New Zealand that acknowledges the right of Māori (the indigenous population of Aotearoa New Zealand) to self-determination. This means that research concerning Māori should be done with Māori, and for the benefit of Māori (Walker et al., 2006). We seek to acknowledge our responsibility as researchers by elucidating the patterns found in the current study through a separate qualitative research project. This approach enables students from historically marginalised groups, such as Māori and Pasifika, the opportunity to have their own voices heard. This qualitative piece seeks to minimise the risk of deficit-theorising by allowing for more depth and nuanced understandings of Māori and Pasifika experiences in science. Future work should consider ways of knowing and constructing science and culture that are grounded in Māori ways of knowing, such as Mātauranga (Hikuroa, 2017). We hope that the results of the current study can aid in this endeavour.

4.3 Survey Methodology

During the first semester of 2019, an online questionnaire was administered to science students at the University of Auckland (UoA) via email following approval from the UoA Human Ethics Committee. In order to boost the rate of response, the questionnaire was designed to be quick (10 minutes), consisting of 48 items. Questionnaire responses were anonymous, with the exception of students who left their email to be entered into a prize draw. In total, 693 students consented to
participation and completed the questionnaire, with a mean respondent age of around 19 years (the sample is summarised in Table 4.1).

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<th>N</th>
<th>Count</th>
<th>Percent</th>
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<tr>
<td>Male</td>
<td>685</td>
<td>247</td>
<td>0.36</td>
</tr>
<tr>
<td>Female</td>
<td>685</td>
<td>431</td>
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<tr>
<td>Gender Diverse</td>
<td>685</td>
<td>7</td>
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<tr>
<td>Euro</td>
<td>693</td>
<td>367</td>
<td>0.53</td>
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<tr>
<td>Asian</td>
<td>693</td>
<td>305</td>
<td>0.44</td>
</tr>
<tr>
<td>Pasifika</td>
<td>693</td>
<td>28</td>
<td>0.04</td>
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<tr>
<td>Māori</td>
<td>693</td>
<td>48</td>
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<tr>
<td>MELAA*</td>
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<tr>
<td>Other Ethnicity</td>
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<tr>
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<th>N</th>
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<tbody>
<tr>
<td>Age**</td>
<td>594</td>
<td>19.93</td>
<td>3.65</td>
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<tr>
<td>Parent Job (0-4)</td>
<td>681</td>
<td>2.61</td>
<td>0.71</td>
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<td>Uni generations (0-3)</td>
<td>687</td>
<td>1.67</td>
<td>1.04</td>
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Table 4.1: Sample Description. The table above shows the counts and percentages of categorical characteristics, and means and standard deviations of ordinal characteristics. Individuals’ self-reported gender was categorised into male, female and gender diverse groups for reporting purposes. Participants were given the option to self-identify with multiple ethnic groups, which means that percentages do not total to 100. *Middle Eastern, Latin American, or African. **Mature students (those with a recorded age over 24) were excluded from analysis (n = 42). S suppressed due to low cell size.

The questionnaire asked students for factual information about themselves, and also questions linked to five latent constructs informed by and adapted from the work of DeWitt et al. (2011). The constructs, outlined in our conceptual model (see Figure 4.2), included self-concept in science (Science Self-Concept; 5 items), experience of high school science teacher quality (Science Teachers; 5 items), parental attitudes towards science (Science Parents; 4 items), peer attitudes towards science (Science Peers; 4 items), and access to science-related resources (Science Resources; 5 items). The first four constructs were measured through items asking students to rate their agreement regarding a statement on a Visual Analog Scale (VAS), with scores ranging from 0 (do not agree) to 100 (strongly agree). VASs have been used extensively in past research and have been found to be as valid and as easy to use as likert scales (Hasson and Arnetz 2005). Given that the sample population in the current study can be expected to have
high scores on the constructs measured (i.e., in general, we would expect students who choose to study science to score highly on science self-concept measures) there is the possibility of a ceiling effect that could occur with likert scales (Chyung et al., 2018). A continuous rating scale was thus used to decrease the risk of a ceiling effect and provide sufficient variance needed for analysis (Chyung et al., 2018).

The final construct, access to Science Resources, was measured on a 1–5 scale, where students were asked how often they participated in a science-related activity (1 being never, 5 being once a week). For all constructs, item statements and loadings can be seen in Table 4.2. These loadings refer to the extent to which an item relates to the underlying latent construct, and may be interpreted similarly to a correlation (i.e., loadings close to 1 indicate an item strongly loads onto a construct, while loadings closer to 0 are weaker). Other questions asked for factual information, such as gender, ethnicity, family education, and parents’ job.

The following variables were included in our analyses:5

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5 Items adapted from the work of DeWitt et al. (2011) were selectively chosen to focus on
• **Science Self-Concept:** We included 5 items from the positive and negative self-concept scales of [DeWitt et al. 2011] (“I am good at science”, “If I study hard I will do well in science courses”).

• **Science Teachers:** Experience of high school science teachers refers to the extent to which students recall having positive experiences with their high school science teachers. This scale, which included 5 items, refers to the degree of enthusiasm, care and recognition the student perceived.

• **Science Parents:** Parental attitudes towards science was adapted from the parental attitudes towards science scale of [DeWitt et al. 2011] and included 4 items. The item “My parents would be happy if I became a scientist when I grow up” was replaced with “My parents/carers would like it if I worked in science” to better relate to the target population.

• **Science Peers:** Peer value of science was measured through 4 items adapted from the “Peer orientation towards school” and “Peer attitudes towards science” scales of [DeWitt et al. 2011]. One item, Q4.1 (“My friends see me as a ‘science’ person”), did not load on to the construct. It is likely that this construct represents the participants’ views of their peers, as opposed to the participants’ subjective experience of their peers’ perceptions of them.

• **Science Resources:** Students’ access to resources was adapted from [DeWitt et al. 2011] and included 5 items. To suit our target audience, we replace the original phrase “How often do you do the following things when you are NOT in school...”, with “Growing up, how often did you...”. One item, Q5.5 (“Growing up, did you go to a lunchtime or after-school science club?”) did not load onto the construct. This may be due to the low number of students who responded positively to this question. An important point to consider is that we, as researchers, are defining science-related cultural capital in our own terms. Whilst the items used in the current study are by definition forms of capital, we acknowledge that other forms of capital exist and hold value in different socio-cultural contexts.

• **University Generations:** University Generations is a count score of the reported number of consecutive generations a participant’s family has gone through with the best previously reported loadings, and which made the most sense theoretically. This facilitated a reduction in the number of scales (from the original fifteen down to five) while maintaining good psychometric properties.
to university. First generation students receive a score of 0, participants who report having siblings attend university receive a score of 1, participants who report having parents attend university receive a score of 2, and those who reported having parents and grandparents attend university receive a score of 3.

- **Parent’s Job**: Participants were asked to state the profession of their father/male carer and their mother/female carer. The professions were classified according to the Australian and New Zealand Standard Classification of Occupations (ANZSCO), where a score of 0 is unemployed, 1 is low skilled, and 4 is highly skilled. The Parent’s Job score is the maximum value of both parents’ scores.

- **Gender**: Gender was recorded using an open text box, and then categorised according to the classification set out by Statistics New Zealand. Of the 693 students who completed the survey, only 1% did not record a gender.

Missing data for the construct items were imputed using Predictive Mean Matching (PMM) using the MICE package in R (Buuren and Groothuis-Oudshoorn, 2010), as PMM offers a suitable method for dealing with non-normal data (Little, 1988a). Cases that were missing scores on at least half the items from a construct (37 cases) were excluded from analysis (e.g., with a construct with five items, cases missing scores on two items would be kept, whilst cases missing scores on three or more items would be excluded). Mature students (those with a recorded age over 24) were also excluded (42 cases) as the measures of social and cultural capital employed are limited to the transmission of capital from parents and high school to university. A further 31 students were excluded from analysis due to missing data on non-imputable variables, such as parent’s job, university generations, or gender. Imputation allowed us to retain 174 cases that would otherwise be excluded with list-wise deletion, leaving a sample size of 583 students. Little’s MCAR test (Little, 1988b) showed that data could be considered missing completely at random ($p = .08$), although patterns of missing data showed that there was attrition bias — questionnaire items tended to have more missing towards the end of the questionnaire. As a robustness check, all models were run on the imputed and non-imputed datasets. We found that both sets of data had similar model fit, reliability, and relationships between variables. We proceeded to use multiple imputation in order to avoid list-wise deletion of cases with missing data and retain sample size.
Confirmatory Factor Analysis (CFA) was carried out to test the validity of our latent constructs. Concurrent and convergent validity \cite{Campbell1959} of these measures were established through CFA, and found to be at an adequate level. We used Cronbach’s $\alpha$ and McDonald’s $\omega$ to test internal consistency, with both providing similar reliability scores. McDonald’s $\omega$ and Cronbach’s $\alpha$ were adequate for all constructs ($\alpha$ ranging from .75 to .85, $\omega$ ranging from .74 to .86), except Science Self-Concept which had an $\alpha$ of 0.68 and an $\omega$ of .67. Whilst 0.70 is usually considered an acceptable level for internal consistency, it has been argued that $\alpha$ below 0.70 are not uncommon for attitudinal scales \cite{Field2012}. The lower internal consistency may also be due to the two negatively worded items (Q1.2 and Q1.5) which had lower loadings compared to the other construct items.

4.3.1 Structural Equation Modelling

Structural Equation Modelling (SEM) was used to analyse the conceptual model outlined in Figure 4.2. We chose to use SEM for several reasons. Firstly, SEM is able to consider hypothetical constructs that are not directly observable (such as self-concept). In practice, this means that we do not derive new variables from questionnaire items through a mean score or aggregated sum. Instead, SEM uses parameter estimates which consider measurement error and covariances between items. This is especially important when we may not expect our items to load on to a latent construct equally. Secondly, unlike simple regression models, SEM is able to model multiple relationships between variables. Doing so enables us to consider many statistical relationships in a single relative context. Finally, SEM is a widely used technique with established guidelines for judging the quality of models \cite{Schreiber2006}, and publicly available software (e.g. \cite{Rosseel2012}).

SEM comprises two parts, the measurement model and the structural model. The measurement model shows the loadings of manifest variables onto each latent construct, while the structural model shows the interrelations between the latent constructs and other variables in the conceptual model \cite{Schreiber2006}. In our model, Science Self-Concept is viewed as a dependent variable, predicted by Science Teachers, Science Peers, Science Parents, and Science Resources. We also include other manifest variables as predictors, including Gender, University Generations, University Years, and Parent Job. We also model correlations between our latent constructs; in addition, University Generations is modelled as a predictor of Science Parents and Parent Job.
SEM with robust standard errors (Huber [1967], White [1982]) was carried out on five imputed datasets using the Lavaan (Rosseel [2012]) and semTools (Jorgensen et al. [2018]) packages in R (R Core Team [2017]). Rubin’s rules (Rubin [2004]) were used to pool point and standard error estimates across our imputed data sets.

4.4 Results

Descriptive statistics, including means and standard deviations are summarised in Table 4.2. Correlations between constructs, shown in Table 4.3 show that Science Self-Concept was significantly and positively correlated with each form of science capital explored in the current study. Science Self-Concept was most positively associated with Science Teachers ($r = 0.35$, $p < .001$), and most weakly correlated with Science Resources ($r = 0.16$, $p < .001$). We now detail the results of the SEM which explores the relationships between these constructs while including other factors present in the theoretical model (Figure 4.2).
<table>
<thead>
<tr>
<th>Item Statement</th>
<th>Loading</th>
<th>Construct</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>Skewness</th>
<th>Kurtois</th>
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<tr>
<td>Q1.1 I understand everything in my science courses</td>
<td>0.62</td>
<td>Self-Concept</td>
<td>617</td>
<td>68.75</td>
<td>19.73</td>
<td>-0.94</td>
<td>0.78</td>
</tr>
<tr>
<td>Q1.2 I find science difficult</td>
<td>-0.40</td>
<td>Self-Concept</td>
<td>606</td>
<td>50.19</td>
<td>24.68</td>
<td>-0.02</td>
<td>-0.78</td>
</tr>
<tr>
<td>Q1.3 I get good marks in science tests</td>
<td>0.72</td>
<td>Self-Concept</td>
<td>617</td>
<td>67.50</td>
<td>18.06</td>
<td>-0.42</td>
<td>0.06</td>
</tr>
<tr>
<td>Q1.4 If I study hard, I will do well in my science courses</td>
<td>0.54</td>
<td>Self-Concept</td>
<td>620</td>
<td>86.69</td>
<td>14.85</td>
<td>-1.59</td>
<td>3.53</td>
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<tr>
<td>Q1.5 I am just not good at science</td>
<td>-0.38</td>
<td>Self-Concept</td>
<td>605</td>
<td>20.41</td>
<td>19.28</td>
<td>0.85</td>
<td>-0.07</td>
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<tr>
<td>Q2.1 My high school teachers recognised that I was good at science</td>
<td>0.75</td>
<td>Teachers</td>
<td>615</td>
<td>69.08</td>
<td>19.10</td>
<td>-0.80</td>
<td>-0.28</td>
</tr>
<tr>
<td>Q2.2 My high school teachers cared whether I understood science</td>
<td>0.72</td>
<td>Teachers</td>
<td>618</td>
<td>70.61</td>
<td>26.34</td>
<td>-0.88</td>
<td>0.01</td>
</tr>
<tr>
<td>Q2.3 My high school teachers explained to me that science is useful for my future</td>
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<td>Teachers</td>
<td>615</td>
<td>65.24</td>
<td>27.05</td>
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<td>-0.55</td>
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<td>Q2.4 My high school science teachers were enthusiastic about science</td>
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<td>Teachers</td>
<td>619</td>
<td>75.74</td>
<td>23.70</td>
<td>-1.06</td>
<td>0.52</td>
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<tr>
<td>Q2.5 My teachers have specifically encouraged me to continue with science after school</td>
<td>0.74</td>
<td>Teachers</td>
<td>593</td>
<td>52.78</td>
<td>32.75</td>
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<td>-1.23</td>
</tr>
<tr>
<td>Q3.1 My parents/carers think science is interesting</td>
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<td>Parents</td>
<td>618</td>
<td>70.62</td>
<td>23.64</td>
<td>-0.75</td>
<td>0.14</td>
</tr>
<tr>
<td>Q3.2 My parents/carers think it is important for me to learn science</td>
<td>0.88</td>
<td>Parents</td>
<td>619</td>
<td>65.73</td>
<td>26.46</td>
<td>-0.48</td>
<td>-0.24</td>
</tr>
<tr>
<td>Q3.3 My parents/carers would like it if I worked in science</td>
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<td>Parents</td>
<td>612</td>
<td>66.06</td>
<td>27.28</td>
<td>-0.56</td>
<td>-0.45</td>
</tr>
<tr>
<td>Q3.4 My parents/carers have explained to me that science is useful for my future</td>
<td>0.80</td>
<td>Parents</td>
<td>592</td>
<td>53.65</td>
<td>31.64</td>
<td>-0.10</td>
<td>-1.16</td>
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<tr>
<td>Q4.1 My friends see me as a “science person”</td>
<td>-</td>
<td>Peers</td>
<td>602</td>
<td>70.23</td>
<td>28.11</td>
<td>-0.86</td>
<td>-0.14</td>
</tr>
<tr>
<td>Q4.2 My friends think that science is important</td>
<td>0.91</td>
<td>Peers</td>
<td>615</td>
<td>68.61</td>
<td>23.47</td>
<td>-0.65</td>
<td>-0.03</td>
</tr>
<tr>
<td>Q4.3 My friends think science is cool</td>
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<td>Peers</td>
<td>617</td>
<td>63.38</td>
<td>25.90</td>
<td>-0.44</td>
<td>-0.48</td>
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<tr>
<td>Q4.4 My friends care about their university grades</td>
<td>0.40</td>
<td>Peers</td>
<td>619</td>
<td>81.10</td>
<td>21.21</td>
<td>-1.56</td>
<td>2.65</td>
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<tr>
<td>Q5.1 Growing up, did you do science activities (e.g., science kits, nature walks, do experiments)?</td>
<td>0.55</td>
<td>Resources</td>
<td>581</td>
<td>2.40</td>
<td>0.87</td>
<td>0.09</td>
<td>-0.68</td>
</tr>
<tr>
<td>Q5.2 Growing up, did you read books or magazines about science</td>
<td>0.69</td>
<td>Resources</td>
<td>572</td>
<td>2.42</td>
<td>1.01</td>
<td>0.03</td>
<td>-1.11</td>
</tr>
<tr>
<td>Q5.3 Growing up, did you look up things online about science or nature?</td>
<td>0.69</td>
<td>Resources</td>
<td>592</td>
<td>2.97</td>
<td>0.97</td>
<td>-0.54</td>
<td>-0.79</td>
</tr>
<tr>
<td>Q5.4 Growing up, did you watch TV programmes about science or nature?</td>
<td>0.62</td>
<td>Resources</td>
<td>599</td>
<td>2.89</td>
<td>0.91</td>
<td>-0.43</td>
<td>-0.64</td>
</tr>
<tr>
<td>Q5.5 Growing up, did you go to a lunchtime or after-school science club?</td>
<td>-</td>
<td>-</td>
<td>579</td>
<td>1.50</td>
<td>0.93</td>
<td>1.65</td>
<td>1.30</td>
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</table>

Table 4.2: **Questionnaire Items.** The table above shows the questionnaire items used in the current study, with loadings onto the relevant latent construct where applicable. Descriptive statistics for each item are also reported. All items were scored on a continuous scale of 0–100, with the exception of Q5 items, which were scored on a Likert scale of 1-5.
We performed a SEM analysis with robust standard errors to test the conceptual model shown in Figure 4.2 on a sample of 583 undergraduate science students. While the hypothesized model appears to be a tolerable fit to the data (CFI = .904; TLI = .885; RMSEA = .053, gamma-hat = .928), model fit was improved with the inclusion of two modifications. Specifically, we added two additional correlations between items Q2.1 (“My high school teachers recognised that I was good at science”) and Q2.3 (“My high school teachers explained to me that science is useful for my future”), and items Q2.2 (My high school teachers cared whether I understood science) and Q2.4 (My high school science teachers were enthusiastic about science). These correlations make sense theoretically, as Q2.1 and Q2.3 may point to possible expectations from teachers, and Q2.2 and Q2.4 may relate more to how personable teachers were. With these modifications, goodness of fit statistics showed acceptable model fit (Hu and Bentler, 1999; Steiger, 2007) ($\chi^2 = 598.38$, df = 258, CFI = .93, TLI = .91, RMSEA = .05, SMSR = .05, gamma-hat = .95). As shown in Table 4.4, the standardized loadings were all significant and acceptable.
<table>
<thead>
<tr>
<th>Latent Construct</th>
<th>Manifest</th>
<th>Estimate</th>
<th>Standard Error</th>
<th>z</th>
<th>p</th>
<th>Standardized</th>
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<td>0.65</td>
<td>-6.99&lt; .01</td>
<td>-.43</td>
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<tr>
<td></td>
<td>Q1.2</td>
<td>-0.80</td>
<td>0.11</td>
<td>-6.99&lt; .01</td>
<td>-.43</td>
<td></td>
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<td></td>
<td>Q1.3</td>
<td>1.03</td>
<td>0.09</td>
<td>11.00&lt; .01</td>
<td>.72</td>
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<td>Q1.4</td>
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<td>0.07</td>
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<td>.55</td>
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<td></td>
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<td>0.08</td>
<td>-7.70&lt; .01</td>
<td>-.39</td>
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<td>1.00</td>
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<td></td>
<td>Q2.3</td>
<td>0.97</td>
<td>0.08</td>
<td>12.80&lt; .01</td>
<td>.72</td>
<td></td>
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<tr>
<td></td>
<td>Q2.4</td>
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<td>Science Parents</td>
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<td>0.59</td>
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<td>.59</td>
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<tr>
<td></td>
<td>Q3.2</td>
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<td>14.05&lt; .01</td>
<td>.88</td>
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<td></td>
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<td>.77</td>
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<td></td>
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<td>0.11 12.69&lt; .01</td>
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<td>0.14</td>
<td>8.84&lt; .01</td>
<td>.63</td>
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Table 4.4: **Measurement Model.** The measurement model summarises the loading of items onto theoretical constructs outlined in Figure 4.2. The results of the measurement model show that items loadings were significant and acceptable.
The structural model, shown in Table 4.5 and visualised in Figure 4.3, shows the interrelationships of the latent variables (specifically the impact of constructs on Science Self-Concept) and the other observed variables in our conceptual model. Results of the structural model show that Science Teachers had the most impact on students’ Science Self-Concept with a significant standardised estimate ($\beta$) of 0.33. Of the other science capital related constructs, Science Peers was the only other significant predictor of Science Self-concept ($\beta = 0.16$). For the other predictors in our model, the number of university generations in the family (Uni Generations) and identifying as male positively predicted Science Self-concept ($\beta = 0.12$ and $\beta = 0.17$ respectively). The number of years a student reported being at university (Uni Years) was a significant negative predictor of Science Self-Concept ($\beta = -0.10$).
### Table 4.5: Structural Model

The structural model summarises the inter-relationships between the constructs identified in the measurement model (Table 4.4) and the other variables included in the theoretical model (Figure 4.2). The results of the structural model show that while all of the science capital related constructs (Science Teachers, Science Peers, and Science Resources) are positively and significantly correlated, Science Teachers and Science Peers were the only significant predictors of Science Self-Concept. Of the other variables included in the model, the number of university generations in the family (Uni Generations) and being male (Male) positively and significantly predicted Science Self-Concept. The number of years a student had attended university negatively and significantly predicted Science Self-concept. These results are visualised in Figure 4.3.

<table>
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<tr>
<th>Regressions</th>
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<th>z</th>
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<td>0.04</td>
<td>5.78</td>
<td>&lt; .01</td>
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<td>&lt; .01</td>
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</table>
4.5 Discussion

Our results show that, while social capital and cultural capital in science are all positively associated with the science self-concept of university science students, the social relationships shared with teachers and peers are the most important. For university science students, parents’ value of science and the science-related resources students had while growing up were non-significant predictors of science self-concept. However, the number of university generations within the family did positively predict students’ science self-concept. Results also show that male students tended to have higher levels of self-concept, and students who had attended university for more years had lower levels of self-concept. We now discuss these results in the context of university study and Aotearoa New Zealand science education.

Experiences with high school science teachers was the strongest predictor of science self-concept for our sample of university students. While positive experiences were linked to increased science self-concept, negative experiences predicted lower self-concept. Previous research suggests that reflected appraisals from significant others, such as those from teachers, play an important role in the way we view ourselves (Bong and Skaalvik, 2003). Tying in with Bourdieu’s theory, an individual’s habitus is informed by the evidence they see in the field they are participating in. Being recognised as someone who can be successful in science, by a teacher, gives students evidence that they belong. On the other hand, students who have teachers who do not appear to care about them, and who do not encourage them, may internalise the idea that science is not for them.

The current study was cross-sectional, which means that it may also be the case that students who have low self-concept in science were less likely to have been encouraged by teachers. With that being said, research shows that teachers influence the interests of their students through the support they show students across education levels (Marjoribanks, 2006). This process starts as early as primary school (Fauth et al., 2014) and through high school (Marjoribanks, 2006; Hazari et al., 2017). In the field of physics for example, the importance of being recognised as good at physics by teachers has been linked to increased intentions to pursue a career in the field (Hazari et al., 2017). Previous research also shows that students who experience high school teachers who are enthusiastic are more likely to be positively predisposed to the field (Keller et al., 2017). The current research builds on previous findings by suggesting that positive high school science teachers can positively impact on the self-concept of their students after they leave high
The Impact of Science Capital on Self-Concept in Science

Figure 4.3: Model results. Results of the original conceptual model (Fig 4.2) with standardised coefficients and significance. Single-headed solid lines indicate a regression, while double-headed dotted lines indicate a correlation. Green arrows indicate a positive association, while red indicates a negative association. Faded grey lines indicate no significant relationship. *p < .05, **p < .001

school and attend university. Teachers are thus integral to providing safe, inclusive educational environments that are recognised as important for young peoples’ well-being (Child Wellbeing & Poverty Reduction Group, 2019).

Peers’ value of science was also positively associated with an individual science self-concept. The mechanism by which peers’ value of science has an influence may be linked to social capital. As outlined by Lin (1999), the value of social capital is not just derived from knowing individuals who can provide access to a broader range of resources and a flow of information. Social capital also helps to build an individual’s identity through shared group norms. As suggested by Adler and Kwon (2002, p.29): “Strong social norms and beliefs... encourage compliance with local rules and customs”. Self-concept may be boosted for students who have more opportunities to talk to others about science in general (Archer et al., 2015a), while receiving increased support from friends (Bissell-Havran and Loken, 2009) and/or belonging to a network of friends at university can have positive impacts
Discussion

on persistence (Thomas, 2000). Through a Bourdieusian lens, having a friendship group where students can act out science safely and productively may signal to a student that they belong in science. Students without the same network of support may be less likely to persist in university study (Thomas, 2000).

It is also likely that individuals with high levels of self-concept in science seek out friends with similar interests. Homophily – the idea that “birds of a feather flock together” (McPherson et al., 2001) – is a common characteristic of friendship networks. In the case of the current study, students were asked to rate the degree to which their friends think science is important, think science is cool, and care about their university grades. It may be that individuals who responded positively to these items also shared these views previously and formed friendships based on these interests. The social comparisons that students make are also an important source of self-concept (Butz and Usher, 2015). Engaging with peers who hold science in high regard and making positive social comparisons to these individuals may be a source of self-concept. Individuals with low levels of self-concept in science may avoid individuals who show great interest in science as social comparisons could make them uncomfortable (Bong and Clark, 1999). The current study is unable to untangle the direction of the relationship between science self-concept and friendship choice, but provides support for future research to investigate this area.

Parental attitudes regarding science and parental job level were found to have no significant impact on science self-concept. Given research suggests that parent-related factors may impact on adolescent students’ academic self-concept (Fan and Williams, 2010), we may have expected parents’ value of science to also positively impact on university students’ self-concept in science. However, the impact of family-related variables tends to diminish as students progress through stages of education (Holm and Jæger, 2011), and the current study specifically focused on university students, which is a late educational stage. It is likely that all three of the family-related factors measured in the current study had a relatively greater impact during earlier stages of a student’s educational journey. Whilst parents’ value of science likely played a role in the interest that students have in science (Archer et al., 2013b), parents’ values are less likely to play a role in students’ science self-concept judgements. The value of social capital is contingent on the context of the task that is being achieved (Adler and Kwon, 2002). As science self-concept is specific to the field of science education, it is reasonable to assume that parents’ influence is not as important as teachers and peers who are active
actors in the field. Parental attitudes towards science may be more predictive of early interest or engagement in science.

In contrast to the results for parental attitudes, the number of generations of a student’s family that attended university was positively and significantly associated with students' science self-concept. The significance of the number of generations of the student’s family who attended university may be related to Bourdieu’s concept of cultural reproduction [Dimaggio 1982]. The values of parents are transmitted to their children and inform the development of habitus. Students who have university educated parents may be more likely to feel ‘at home’ in a university field. For first generation students, the breaking of new ground may be more confronting and challenging mentally [Gardner and Holley 2011]. In psychological terms, the internalisation of the idea that “if my family can do it, so can I”, corresponds to Bandura’s [Bandura 1986] idea of establishing self-concept through vicarious experience. Seeing someone who is similar to you experience success may have an especially strong impact on self-concept. With regards to the student’s habitus, vicariously experiencing success would help students internalise the idea that university is for them. Alternatively, university educated parents may also improve the academic performance of students [Grayson 2011], which in turn may influence science self-concept. Having family members who attended university is also an important form of social capital, in that it provides students with knowledge on the rules of the field, and what is needed to be successful.

The level of a student’s science-related resources growing up, or objectified cultural capital, was found to be non-significant relative to the other factors included in our analysis. It may be that the resources investigated have more importance in generating early interest in science, while students in our sample were already at university. Reading about science and looking things up online about science may relate more strongly to a student’s broader interests in science as opposed to their self-concept or self-belief. It may also be that students’ social relationships with their teachers and peers (which both positively impacted in self-concept) ameliorate any detrimental effects that a lack of resources would have. The questionnaire items used in this study asked students to recall their access to science-related resources growing up. Future studies should seek to employ a longitudinal research design to more accurately capture the impact of resources on future self-concept in science.

Students’ self-reported gender was significantly related to science self-concept, such that male students, controlling for all other factors, reported higher levels of
Discussion

Science self-concept than female students. The lower levels of science self-concept for female students is a common finding in STEM education research (Sax et al., 2015; Ellis et al., 2016). Research has found that students (both male and female) tend to be more likely to make external attributions for a man’s failure in science (i.e., the reason for failure is not due to lack of ability, but a poor test or bad luck), but are more likely to attribute women’s failure to internal sources (lack of ability) (LaCosse et al., 2016).

In a Bourdieusian framework, gender differences in science self-concept can be explained in terms of a ‘gendered’ habitus, a variation of classed habitus (Reay, 2004). This relates to the idea that if individuals are exposed to “homogenous conditions of existence imposing homogenous conditionings” individuals will generate “homogenous systems of dispositions” (Bourdieu, 1984, p.101). In more basic terms, if individuals are exposed to similar socio-cultural norms and environments, they may be more likely to share similar dispositions. While science has historically been a domain in which men have opportunities to succeed, women face explicit and implicit obstacles (Cheryan et al., 2017; Blickenstaff, 2005). These include pervasive negative gender stereotypes (Nosek et al., 2009), and unfair judgements regarding competency (Moss-Racusin et al., 2012; Barthelemy et al., 2016). Men may be more likely to internalise the idea that science is a domain where they belong and can perform, and this may explain why male science students are more likely to hold higher levels of self-concept in science compared to female science students. Although the effect of gender on science self-concept was relatively small, the findings of the current study support the arguments set out by Kost-Smith et al. (2010) who suggest that the attrition of female students from STEM domains is the result of many small effects that contribute to a “smog of bias” where men are bolstered and women face obstacles.

Finally, the number of years a student reported being at university was found to negatively predict science self-concept. There is a lack of previous research investigating the temporal nature of self-concept in science at university, although one study of a mixed university sample found that academic self-concept may decrease after the first year (Isiksal, 2010). Other research has found that STEM students’ self-efficacy does not decrease from first year to graduation, with it increasing for female students and remaining stable for male students (MacPhee et al., 2013). With regards to the current study, it may be that as students progress through science at university, course content becomes more challenging and thus students may be more likely to report finding science more difficult. Future research should
adopt a longitudinal research design to investigate temporal changes in science self-concept in more detail.

4.6 Implications

The current study provides insights into factors that are related to university students’ self-concept in science. The findings reported may inform researchers and policy makers on the cultural and social forms of capital that are required to produce confident learners in science. The current study finds that, for students studying science at university, the social relationships that they have are especially important.

The current study highlights the important role that high school science teachers play in boosting the self-concept of university students. Our results suggest that the impact of high school science teachers continue to be manifested in students’ self-concept even after high school is finished and students have entered into university study. Given the importance of self-concept in future achievement (Uçar and Sungur 2017, Chang and Cheng 2008), the results of the current study suggest that increased teacher support provides a clear method of meeting government aims for increasing the number of skilled workers in science. Massive Open Online Courses (MOOCs) are often cited as a possible solution for teacher shortages, increasing access to education when opportunities are otherwise limited. We argue that even if MOOCs are used, they must still provide students with social connections to teachers who can provide them with real, tangible feedback and recognition. The student-teacher bond should also be the targeted source of intervention to address equity issues in science (Banerjee 2016). The expectations that teachers hold for their students may be particularly important (Rubie-Davies 2006). Research suggests that teacher expectations are an important predictor of students’ transition to university study, especially for students from low SES backgrounds (Gregory and Huang 2013).

Our findings also suggest that social relationships with peers who hold science in high regard are linked to science self-concept. This result is especially important to consider for students who originate from social groups that are underrepresented in science and may find it more difficult to form social bonds with other students. Institutional support networks, such as Women in Science, and other community building equity programmes can play an important role in connecting underrepresented students with one another, and help to build a scaffold of peer support (Ong...
Our results also bring attention to the need to ensure that students who are the first generation in their family to attend university are adequately supported in their learning.

4.7 Limitations

The current study, whilst providing new insights into the factors affecting self-concept of university science students in Aotearoa New Zealand, does have limitations that future studies should seek to address. The questionnaire, short in duration, offered insights into a select group of factors that have been found to be associated with science participation and achievement. The original questionnaire designed by DeWitt et al. (2011) had many other factors that included, but were not limited to; science aspirations, views of scientists, and parental involvement. Furthermore, given the anonymous nature of the questionnaire, it was not possible to link survey responses to administrative data that could give an indication of students’ prior or future achievement, and self-reported measures of achievement contained too much missing information to be useful. Prior achievement is likely to account for much of a students' science self-concept and needs to be considered in the context of the current findings.

The sample of students who responded to the survey also display survivorship bias. These are students who have already demonstrated interest and a certain level of success in science. Our study does not account for students who dropped out of science before university. While this may be viewed as a limitation, it also focuses the current study on an asset-based framework instead of deficit models of student outcomes. Given our sample of students all demonstrated a certain level of success, we focus on factors that were particularly important for students who made the transition to university science education. Our sample and study design also allows us to identify students who are underrepresented in science based on their demographics or access to capital, but who still recorded high levels of self-concept. A follow-up study will employ a qualitative approach to understand the experiences of these students and refine the directions of future research.

While not reported in our results, our analysis did not find sufficient evidence of measurement invariance across subject disciplines, which suggests that the constructs and relationships outlined in our conceptual model may differ for students by subject. This is not surprising, given the sample sizes per discipline and our generalised measure of science self-concept. Nevertheless, these preliminary results
of the SEM suggested that, for our sample, different forms of capital may carry different value across fields, a finding inline with Bourdieu’s theory. Each field has its own unique perspective on what forms of capital are valued. While the more general science-related factors explored in the current study were found to be associated with a general self-concept in science, specific forms of capital may be particularly important in each science sub-field. For example, mathematics knowledge and self-efficacy in calculus may be more important for students studying in physics (Black and Hernandez-Martinez, 2016; Ellis et al., 2016). More research is needed to identify, summarise, and test the forms of capital that are valued in each science domain. We recommend more in-depth and tailored questionnaires are administered to students per subject discipline.

4.8 Conclusion

The current study investigated the influence of science-related cultural and social capital (science capital) on the science self-concept of undergraduate science students at the University of Auckland. A Structural Equation Model (SEM) was used to explore the relationships between a set of latent constructs defining science capital and observed measures, such as university generations in the family, parents’ employment, and self-identified gender. Our theoretical model provided a good fit to our data, and gives some new insights into the relationship between science capital and science self-concept. We found that, for the students in our sample, positive experiences with high school science teachers was the most important predictor of science self-concept, whilst having peers who value science was also found to be important. Interestingly, we found that reported science-related resources and parents’ value of science were not significant predictors of science self-concept, but the number of university generations in the family did have a positive association. These results provide an example of how family culture reproduced over generations may manifest as students’ self-belief in the field of university science education. We also found that students who self-identified as male had higher levels of science self-concept, even after accounting for social and cultural factors in our theoretical model. Finally, we found that self-concept appeared to decay over time at university, a finding that needs to be explored further in future research. We discussed the above findings in the context of a growing body of research regarding equity in the field of science education, and in the context of Pierre Bourdieu’s sociological theory.
Chapter 5

Understanding Capital Accumulation in University Science

Preamble

The analysis of broad level patterns in science enrolments in Chapters 2 and 3 provided some indications of what the field of science looks like. In Chapter 4, I sought to go deeper into the question of why participation in science appears as it does. Through analysis of the questionnaire, I was given some idea as to how different forms of capital may influence the way students see themselves in science. In particular, the results of the structural equation modelling signalled that social capital may have a particularly strong impact on self-concept for university science students. However, as is often the case with statistical models of large and diverse cohorts of students, my model provides a simple lens in which to interpret the experiences of students. I feared that a lot of nuance was lost regarding the interaction between capital and habitus, particularly the experiences of students who are underrepresented in science (and in my sample). To address this, I turned to interviews to provide a more detailed picture of students’ experiences in science, with the aim of building a new, more informative, theoretical model. One piece of minor feedback I received from a reviewer upon the submission of Bourdieu, Networks and Movements (Chapter 3) to PLoS ONE was that the interaction of capital and habitus was not sufficiently captured in the illustration of the conceptual model, an issue that they acknowledged could be a separate article entirely.
Informed by this feedback and the results of Chapter 4, the following chapter reports on the process that I undertook to collect and analyse qualitative data, and build a new theoretical model (Figure 5.1). This final model will be used as a framework for interpreting participant experiences in science, and provide a tool to help us understand how we may make the field of science more equitable.
Figure 5.1: **Chapter 5 Signpost.** Chapter 5 focuses on building a new theoretical model that can offer more answers to the question of *why* we see differences in participation in science education in Aotearoa New Zealand. It seeks to emphasise the dynamic relationship shared between capital and habitus.
Henceforth, the tone and voice of the thesis will feel different to previous chapters. Chapters 2, 3 and 4 followed quantitative research approaches, and focused more on describing broad patterns. These opening chapters were primarily written in the third-person, or with the use of ‘we’, following the established procedures set out by the journals they were submitted to. In keeping with the new qualitative perspective, the following chapters of the thesis are written in the first-person and formatted thematically, rather than in accordance with established structures of academic journals.

5.1 Introduction

Previous chapters have investigated the questions of what science participation looks like (Chapters 2 and 3), and potentially why that may be the case (Chapters 3 and 4). The following chapter seeks to shift the focus of the thesis to the question of why students choose to study science, as well as opening up avenues to discuss possible directions as to how we can help provide equitable outcomes for students. In order to focus on these questions, I made the decision to delve deeper into the personal experiences of students in science by collecting qualitative data. The following sections will discuss the background to the qualitative data collection, the process of thematic analysis, and the development of a new theoretical model informed by the thematic analysis.

In Chapter 3, I pointed to the need for future qualitative work to complement the study’s quantitative approach, pointing to Bourdieu’s [1984] belief that a true social science considers both the larger scale, objective trends in society, as well as the subjective perspectives of agents. Indeed, his seminal work Distinction [Bourdieu, 1984] contains a mixture of both quantitative and qualitative approaches. Qualitative research provides the opportunity to delve into the perceptions of individuals and assess how their actual lived experiences match up with our explanations (and assumptions) regarding participation trends. With regards to research on participation in science education, qualitative work has offered a range of valuable insights.

Much research has used Bourdieu’s [1984] theory as a framework to interpret qualitative data regarding students’ experiences in science. For example, Gokpinar and Reiss [2016] used data collected from interviews with three Turkish immigrant students in the U.K. to develop a research framework that combined Bourdieu’s [1984] theory with Sen’s [1992] capability approach. This work explored how capital, habitus, and field relate to students’ science-related capabilities, and how this
may lead to differential outcomes for students from similar backgrounds. Qualitative data have also been used to compare how experiences in science education may differ for students from different backgrounds. Researchers have examined the intersecting impacts of race, gender, and social class in higher education (Horvat, 2003) and in STEM education (Ong, 2005). Horvat (2003), who points to Bourdieu’s (1984) lack of specific consideration for race, interviewed fourteen black women, prior to and after college, to examine the ties between race and class. The resulting analysis shows how Bourdieu’s (1984) theory, especially the concept of habitus, can be employed to examine the “complex and entrenched” (Horvat, 2003, p.3) ways that race and class interact to shape access to higher education.

In the context of Aotearoa New Zealand, Bourdieu’s (1984) theory has been a strong topic of interest (Bennett et al., 2013), but there are relatively few qualitative applications of Bourdieu’s theory to STEM education. Pomeroy (2016) used Bourdieu’s theory as a framework to understand how students’ social location relates to mathematics learning in Aotearoa New Zealand high schools. In a collection of work that included quantitative approaches and classroom observations, Pomeroy (2016) interviewed students and teachers to understand experiences of learning and teaching mathematics. His work highlighted disparities in mathematics interest across gender, social class and ethnicity. Through this qualitative approach, Pomeroy (2016) was also able to explore the impact of societal discourses on students, including the manner in which Māori, Pasifika, and working-class Pākehā men may be excluded from seeing mathematics as a realistic path forward. Outside of STEM domains, Mila-Schaaf and Robinson (2010) used Bourdieusian concepts to understand the experiences of a sample of fourteen successful, second-generation Pasifika professionals in Aotearoa New Zealand. Through their qualitative approach, Mila-Schaaf and Robinson (2010) were able to provide examples of polycultural capital — “the potential advantage Pacific second generation (New Zealand-born) may experience from ongoing exposure to culturally distinctive social spaces.” — and how this relates to educational advantages.

Building on previous studies, the current chapter seeks to apply Bourdieu’s (1984) theory to understand the experiences of students in science specifically. The current chapter details the methodology used to approach the qualitative research phase of my thesis. Following Bourdieu’s (1992) recommendation of weaving theory and practice, the following sections will detail the procedures used to sample students from the questionnaire, the qualitative approach and paradigms followed to make sense of interview data, and an in depth theoretical description of
the themes that were established in accordance to interview data and Bourdieu’s theory. These themes, which are connected within a coherent theoretical model, will be used to draw meaning from interview data in later chapters. Firstly, I will discuss the context in which the qualitative research phase was situated.

5.1.1 Situating the Qualitative Research Phases

The current qualitative research was one phase of a staggered research design which included preliminary interviews with a small number of students, and the design and administration of a questionnaire to students (detailed in chapter 4), prior to new interviews with questionnaire respondents. The staggered research design has been used in previous research to investigate student experiences in STEM to great effect (Grossman and Porche 2014; Russell and Slater 2011). The following sections will detail the content of each of these phases, and how each research phase informed the development of future phases.

As shown in Table 5.1, my research began with four interviews with students in the Science Scholars programme. This 3 year programme is designed to match aspiring science students with academic mentors at the University of Auckland, with a tangent course each semester consisting of project-work and discussions. As outlined on their website, admissions are competitive: “Entry to the Science Scholars Programme is competitive, and we are interested in both your potential for academic success, and your engagement with activities outside the classroom.” This programme was a target population as the students accepted into this programme are recognised as successful, and would be able to provide knowledge on what resources may contribute to success. These interviews were semi-structured, and sought to gather information on why students chose to study science. The scope of these interviews were broad, with topics ranging from participants’ experiences with science growing up, high school science, and their transition to university study.

1From here on in, participants will be used as a term to refer to the students who were interviewed, while students will be used as a term referring to the general student population.
The Sampling Phase

<table>
<thead>
<tr>
<th>Phase</th>
<th>Year</th>
<th>Purpose</th>
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<tbody>
<tr>
<td>1</td>
<td>2018</td>
<td>Interviews with 4 Science Scholars students at UoA. Results of these interviews were used to inform the design of the questionnaire.</td>
</tr>
<tr>
<td>2</td>
<td>2018</td>
<td>Questionnaire design and administration to science students at UoA. Questionnaire analysis conducted on 693 responses (see Chapter 4)</td>
</tr>
<tr>
<td>3</td>
<td>2019</td>
<td>Interviews conducted with 15 further students. These were selectively sampled from the questionnaire.</td>
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</table>

Table 5.1: Qualitative Research Timeline. Preliminary interviews with four students from the Science Scholars programme informed the design of questionnaire (and contributed to the final qualitative analysis), which was administered to science students at UoA in early 2019. Fifteen students were then purposefully sampled for interviews based on questionnaire responses, resulting in a final overall sample of nineteen participants.

Based on preliminary data from the interviews with the Science Scholars, and a questionnaire provided by the ASPIRES research group in the United Kingdom (DeWitt et al. 2011), a questionnaire was designed. The questionnaire, discussed in more detail in chapter 4, asked students to record factual information about themselves, and answer items regarding 5 latent constructs informed and adapted from the work of DeWitt et al. (2011). The constructs included self-concept in science (Science Self-concept), experience of high school science teachers (Science Teachers), parental attitudes towards science (Science Parents), peer attitudes towards science (Science Peers), and access to science-related resources (Science Resources). Based on the results of this questionnaire, students were then invited to be interviewed about their experiences in science. The procedure used to sample students is discussed in the following section.

5.2 The Sampling Phase

Following the analysis of the questionnaire (Chapter 4), and using scores on the constructs of science capital as a guide to respondents’ life experiences, fifteen consenting respondents were then invited to be interviewed. Whereas previous research has focused on random sampling (Russell and Slater 2011) or purposeful sampling to achieve a balance of gender or ethnicity in interviews (Grossman and Porche 2014), the constructs assessed in the questionnaire allowed me to include more domain-specific indicators of social class as well as self-report measures of
gender and ethnicity in the decision making process. In a similar fashion to methods used by Bennett et al. (2009), I was able to visually highlight the location of participants in terms of their scores relative to their peers (Figure 5.2).
The Sampling Phase

Figure 5.2: Sampling Strategy. The above highlights the distribution of participants who were purposefully sampled when arranging interviews. I aimed to interview students with a range of different backgrounds based on different forms of science capital. Axes indicate students’ level of a particular form of capital, including Science Parents, Science Peers, Science Resources, and Science Teachers (with Teachers and Parents highlighted on the right hand side). The locations of 12 of the 19 interviewee participants are highlighted by their pseudonym. The four Science Scholars participants are not included in this visualisation, while three interview participants were chosen to be interviewed, despite being excluded from factor analysis due to having too much missing data in the questionnaire. Individual data points are coloured and shaped according to self-identified gender and ethnicity. In this case, ethnicity is coded according to prioritised ethnicity, where students who identified with multiple ethnicities were first coded as Māori, then Pasifika, then Asian, then European (following guidelines set out by Statistics New Zealand). I only use the prioritised ethnicity for visualisation and not for any analysis.
Given the goal of these interviews is to reveal variation in the students experiences in science, rather than to discuss the properties of a ‘sample’, a total sample size of nineteen participants is sufficient [Berglund and Wiggberg, 2006] and reflects similar past research studies [Gokpinar and Reiss, 2016; Horvat, 2003]. For participants drawn from the questionnaire, sampling was prioritised based on the constructs of science capital measured in the questionnaire (Figure 5.2), and also according to whether they identified as a member of an underrepresented social group in science, with the goal of representing a wide range of experiences. The purposeful sampling was a deliberate choice informed by research on intersectionality. Intersectionality is a theoretical position which states that different aspects of an individual’s identity (gender, ethnicity, social class) combine and overlap in ways that produce unique life experiences. For example, the work of Kimberlé Crenshaw [Crenshaw, 1990] detailed how the experiences of black women in the United States are qualitatively different from those of black men. More recent work has applied intersectional frameworks to understand the experiences of students in higher education [Duran and Jones, 2019].

The purposeful sampling I employed was informed by these intersectional frameworks, namely the need to over-sample students from groups that are marginalised in science. As outlined by [Duran and Jones, 2019, p.461]: “Even if multiple marginalized demographics are not the subject, they must always be centered.” The social groups I intentionally sampled were as follows:

- Individuals with lower levels of science-related capital. This judgement was made based on students’ reported scores on teachers’ and peers’ value of science constructs, which were found to be the most important predictors of self-concept in science in Chapter 4. I also took into account other indicators of science-related capital, such as number of books at home growing up and access to science-related activities. While these were found to be insignificant predictors of science self-concept, they likely play an important role in students’ educational trajectory [Sieben and Lechner, 2019].

- Individuals with parents who do not value science, or who do not talk about science often. Even though parents’ value of science was not a significant predictor of science self-concept in Chapter 4, other research suggests that it plays a major role in science interest and the development of identity in science [Dou et al., 2019].
• First generation university students. Research suggests that experiences of social capital at university may look different for these students compared to peers who enter into university from academic families (Martin et al., 2014; Birani and Lehmann, 2013). Chapter 4 also signalled that first-generation students may have lower levels of self-concept in science.

• Māori and Pasifika students. While research has explored factors relating to the transition to university (McKinley and Madjar, 2014) and conceptions of success for students identifying as Māori and/or Pasifika (Mayeda et al., 2014), there is little research that discusses their experiences in science specifically.

• Female students in physics and computer science. Through interviews with female students in these fields we can describe why we see gender disparities in student enrolments, such as those described in Chapters 2 and 3.

While the above criteria represent the students of specific interest, the participants interviewed represented a range of social backgrounds, with some students representing multiple criteria and some not representing any. It is also important to note that the categories employed are still relatively narrow and do not encompass a range of other important characteristics (such as religion or ableness), or indeed the complexity of identifying with multiple social groups.

The current work attempts to adopt an asset-based framework (why do students succeed?) and avoid deficit-theorising (why do students drop out?) that is common with studies on minority groups in science. While the life experiences, social connections, and feelings of belonging amongst participants differed, all of the participants that were interviewed were united in the fact that they found science interesting and had chosen to pursue it at university. Participant characteristics are summarised in Table 5.2. The following section will discuss my approach to interviews with these participants.
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<thead>
<tr>
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<tr>
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<td></td>
<td>Female</td>
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<td>University Generations</td>
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<td>Science Teachers</td>
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<td>Science Peers</td>
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<td>Science Resources</td>
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<td></td>
<td>Lower</td>
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</tbody>
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Table 5.2: **Participant Summary.** A table summarising the characteristics of the individuals who participated in interviews following completion of the questionnaire. Aggregated group counts are provided to help preserve anonymity. Participants may have identified with multiple ethnicities or be enrolled in multiple subject disciplines, which means that these counts do not sum to fifteen. Three students who participated in interviews did not provide enough information on construct items to have scores on self-concept and capital scales attributed to them. Information is not presented for the four science scholars students who participated in the first interview phase of the study, prior to administration of the questionnaire.
5.3 The Interview Phase

As with the interviews with the four Science Scholars, the interviews with questionnaire respondents were semi-structured. One key difference is that I drew from participants’ questionnaire responses as an object to guide conversation. The use of questionnaire items as prompts reflects a deductive approach, where previously established theory guides questions (Braun and Clarke 2006). The deductive process was sometimes conducted explicitly, for example: “Me: On this section - my friends see me as a science person - you scored quite highly. How do you feel about that?” While interviews were directed by participants’ questionnaire responses, the semi-structured nature of the interviews meant that participants were encouraged to lead discussion and talk about what they felt was important. The discussion of topics outside of the scope of the questionnaire reflects a more inductive approach, where the data collected is not guided by previously established theory (Braun and Clarke 2006). To give one example, the questionnaire did not ask any questions on participants’ relationships with significant partners (e.g., boyfriends or girlfriends), but many participants recalled their importance in the interviews.

As Māori were invited to be interviewed, and given my responsibilities as a research under Te Tiriti o Waitangi, the inductive approach to interviews was also informed by Kaupapa-Māori-Consistent (KMC) practices (Walker et al. 2006). Due to my position as a Pākehā researcher conducting independent work as a part of a PhD, I can not say that my research practices were KMC. My goal was to ensure that all participants were made comfortable in the interview, and that my practice was conducted with, and not on, participants. The conceptualisation and operationalisation of research procedures were discussed with Māori representatives throughout the research process, and results were shared and discussed with established Māori and Pasifika individuals with interests in this field of research. Echoing the procedures of Mayeda et al. (2014), questions regarding sensitive topics, such as personal experiences of discrimination, were avoided. While many participants did discuss these types of experience, I endeavoured to provide them with the choice to share those experiences. Participants were also offered transcripts of interviews and manuscript drafts, and invited to remove, edit, and add responses after the interview. Participants were also given access to the manuscript prior to finalisation to ensure that their voices had been represented accurately, and to provide any additional insights.
5.4 The Analysis Phase

Following the conclusion of the interview phase, I began the process of analysing transcripts. Firstly, an inductive approach to thematic analysis was used to analyse the interview transcripts, following the general guidelines set out by Braun and Clarke (2006). Interviews were coded in accordance to three established research questions: what forms capital are available to university science students? How do students leverage the value of capital to gain advantage in the field of university science? And finally, how does students’ habitus contribute to the accumulation of capital? Once all interviews were fully coded, themes were established and developed into a coherent theoretical model. Using Bourdieu’s sociological theory as a conceptual “toolbox”, the theoretical model draws primarily on Bourdieu’s (1984) concepts of social capital, habitus, field and doxa. Developing theory in tandem to the analysis of data corresponds to Bourdieu’s goal to combine theory and practice (Bourdieu and Waquant 1992, p.34): “[Bourdieu] advocates for the fusion of theoretical construction and practical research operations. He does not seek to connect theoretical and empirical work in a tighter manner but to cause them to interpenetrate each other entirely.” Doing so may more succinctly capture the complexity of students’ experiences in the field of science education. The following sections of the current chapter will outline the theoretical model (Figure 5.3) in detail.
The theoretical model consists of five main themes that were established following the analysis of participants’ interviews. The theoretical model is designed to have themes flow sequentially from theme one to theme five, describing how students’ social relationships (social capital) impact on internal dispositions (habitus) and vice versa. The key themes I discuss are: the availability of social capital, how the value of social capital is leveraged by students, how students internalise capital, how discourses in the field impact on students, and how students’ students engage in future generation of capital. My goal in organising these themes as component stages in a holistic model is to make the reciprocal relationship between capital and habitus stand still. In reality each of the themes may be complexly interwoven, as the process in which students accumulate capital is continual [Jensen and Jetten 2015]. The goal of the following sections is to provide a summary of
how these themes fit within the context of past research and theory. Following this chapter, I will then highlight the manner in which the theoretical model, and its component themes, were demonstrated in the lived experiences of participants. In doing so, I can seek to answer my research questions of why we see different trends in science participation across social groups (Chapter 6 and 7), and how we can potentially improve outcomes for students (Chapter 8).

5.4.1 Availability of Social Capital (Theme 1)

Theme 1, which refers to the availability of social capital, provides the starting point to the theoretical model (Figure 5.4). While the model as a whole is cyclical and constant, this Theme is chosen as a point of entry as it sets the initial conditions for a student as they enter into a new field. As described by Bourdieu (1986), the acquisition of resources that can be used to gain advantage in a field (i.e., economic and cultural capital) is informed by an individual’s social relationships. Whether it is through family, educators, or peers, students, including participants in the current study, access educational resources through their social relationships. When applied to science education, Theme 1 considers the initial levels of social capital students hold as they enter into different fields, such as high school or university. In the following section, I detail the manner in which I operationalise social capital following the work of Bourdieu, as well as theorists such as Putnam et al. (2000), Burt et al. (2013), and Adler and Kwon (2002).

5.4.1.1 Operationalising Social Capital

Social capital is defined by Bourdieu (1984, p.248) as: “the aggregate of the actual or potential resources which are linked to the possession of a durable network of more or less institutionalised relationships of mutual acquaintance and recognition”. In more simple terms, Bourdieu saw social capital as the sum of an individual’s resources that they are able to mobilise through their connections with people they know. Bourdieu’s (1984) definition focuses on a “bridging” view of social capital, where capital is viewed in terms of the external resources that other individuals can provide. However, other theorists, such as Putnam et al. (2000) and Coleman (1988) highlight its value as “bonding” social capital. While bridging social capital refers to social networks that bring together people from different communities (i.e., individuals in different fields, with different resources), bonding social capital refers to connections within a community that bring individuals closer together through a shared group identity.
Following the argument of Gelderblom (2018), different aspects of social capital can be considered under a single theoretical framework. I consider bridging social capital to refer to the manner in which social capital can be transformed into economic and cultural forms of capital (i.e., the mobilisation of resources through connections), and bonding social capital as a direct influence of relationships on individuals’ habitus. Access to each of these forms of social capital brings with it different benefits, which will be discussed in Themes 2 and 3. The current theme solely considers how access to social relationships may differ.

Figure 5.4: **Theme 1.** The first theme of the theoretical model refers to the initial availability of social capital for an individual.

### 5.4.1.2 Science as Sticky Knowledge

Social capital can be viewed as the starting point for students studying science due to its epistemological nature. According to Bernstein (1999, p.159) scientific knowledge can be considered a form of vertical discourse: “a coherent, explicit, systematically principled structure, hierarchically organised”. This means that scientific knowledge is built on foundations, and generated according to explicit rules (i.e., the scientific method). Thus, science is inherently a social process, where individuals are required to learn the ideas of others before advancing to more complex ideas, and follow the conventions of a wider community as they progress in the field. As students progress through science, they are required to rely upon
prerequisite knowledge before being able to grasp new concepts. Students who are less able to access prerequisite knowledge are thus excluded from accessing other forms of scientific knowledge.

Given its vertical knowledge structure, science can also be considered a form of “sticky knowledge” (Blackman and Benson 2010). As outlined by Von Hippel (1994) sticky knowledge refers to knowledge that, once originally explicit, becomes tacit with repeated interactions. When individuals with similar skill-sets discuss the same topics repeatedly, knowledge that would originally be explicitly defined becomes assumed, and this limits individuals who do not have the assumed knowledge from engaging with information. As students progress through science, the meanings of technical terms are progressively assumed to be understood and are used in the definitions of progressively more complex ideas. For individuals who do understand these (now) tacit forms of knowledge, the foundations of discussion become automatic and they may access the flow of information. When individuals do not have the same tacit knowledge, the flow of information is halted. Families with many connections within the field of science can thus offer close-knit ties where scientific knowledge flows more regularly, and this may enable them to understand better what they already know (Burt et al. 2013 p.530). Individuals who grow up with access to science-related capital in their family may thus seem precocious in that they are able to understand tacit forms of knowledge at earlier ages - these students are born into families where scientific knowledge has stuck. Individuals who do not have the access to scientific knowledge within their family will be unable to access flows of information where prerequisite knowledge is tacit. The accessibility of scientific knowledge, and the manner in which it sticks to certain communities provide one explanation for how inequities in science are transmitted across generations (social reproduction) and why children who have scientists as parents have a greater chance of being a scientist themselves (Bui and Cain Miller 2017).

Given that access to capital within the family can be highly differentiated and inequitable, the role of educators may be especially important. The importance of increasing available relationships with educators has been demonstrated in prior research, which shows that this can improve student outcomes (Aikens et al. 2016). With that being said, equal access to social capital does not mean that the value leveraged from a relationship is also equal. In institutionalised education,
where it can be argued that access is generally equal, the value derived from social capital can be highly inequitable. For example, in university engineering [Martin et al. (2014)] found that the social capital accessed by first-generation students looks different to their counterparts from academic families. The contradiction of how equal access to social capital through educators may still provide inequitable outcomes was highlighted by [Yosso (2005) p.74], who stated that: “schools most often oppress and marginalize while they maintain the potential to emancipate and empower.” The second Theme moves beyond the discussion of access to capital, to a discussion of how students leverage value from their social relationships.

5.4.2 Leveraging the Value of Social Capital (Theme 2)

As outlined by previous theorists, access to social [Smith (2005)] and cultural [Rios-Aguilar et al. (2011)] capital does not necessarily equate to activation of resources, and the value gained from accessible relationships may also look different across individuals. For example the number of books in the home is a relatively insignificant predictor of children’s early learning outcomes compared to the frequency at which parents actually read books to children [Meissel et al. (2019)]. For this reason I move beyond the first theme, which highlighted the importance of having access to social relationships, to a second theme: the value that can be leveraged from social relationships. As highlighted in Figure 5.5 I point to the manner in which social capital carries translatable value in the economic and cultural capital that can be mobilised through connections with others. In defining the value of capital that can be derived, I draw upon several criticisms that move beyond Bourdieu’s (1984, 1986) traditional definitions of capital. I will firstly describe value derived from families, educators, and friends in their mobilisation of resources, both in terms of what has been traditionally valued by educational institutions [Lareau (2011)] and in science education (e.g., Science Capital), and in terms of the community cultural wealth [Yosso (2005)] that is valuable for students, if less recognised by educational institutions. Following that, I outline my justification of learned knowledge as another form of cultural capital that can be used to gain advantage in field.
Figure 5.5: **Theme 2.** The second theme of the theoretical model refers to ways in which the value of social capital is leveraged. This theme describes the value of social capital in terms of its utility in mobilising cultural and economic capital.

### 5.4.2.1 Unpacking the Value of Cultural Capital

The value of capital can be defined in many ways. While the value of economic capital is relatively easy to trace, the value of cultural capital is more difficult to quantify. I consider cultural capital to be any non-financial resource that students may use to gain advantage in the field. In terms of science, the concept of science capital [Archer et al., 2015a](#) provides a useful framework for summarising capital that is typically valued in the field. Theorists have also considered the ways in which families go about accumulating capital, and how this may differ across social class, with [Lareau (2011)](#) pointing to the way that middle class parents employ strategies to boost their children’s acquisition of capital valued by education institutions. It is also important to consider critiques of Bourdieu and of science capital that highlight the value of capital that is typically excluded from traditional, white, middle class perspectives [Jensen and Wright, 2015](#) [Yosso, 2005](#). In the field of science, the concept of science capital provides a useful framework for understanding the forms of capital that are typically valued in the field. As outlined in previous chapters, science capital has been defined as any resource that has “the potential to generate, use, or exchange value for individuals or groups to support and enhance their attainment, engagement and/or participation in sci-
ence.” (Archer et al., 2015a). Following this definition, researchers have quantified science capital in terms of consumption of science-related media, participation in out of school learning contexts (such as going to science museums), and knowing people with science qualifications or who work in science (Archer et al., 2015a). While some students are able to access and leverage value from science capital, many students, especially those from low socio-economic backgrounds, may find it more difficult due to the unequal distribution of resources and the different ways in which families engage with educational institutions. This may explain why students who have parents with more years of education and higher occupational status are more likely to report enjoying science and holding interests in studying science in the future (Hampden-Thompson and Bennett, 2013).

Bourdieu (1984, p.134) saw education as a prime example of how middle class families are more able to leverage value from educational institutions which helps maintain their position in society: “The reconversion of economic capital into educational capital is one of the strategies which enable the business bourgeoisie to maintain the position of some or all of its heirs”. Education is an investment, and families that have resources to support that investment may be more likely to see education as a viable strategy. This may explain why students with academic parents with high levels of cultural capital are more likely to see high graduate premiums associated with graduating from university and intend to pursue further study (Davies et al., 2014). On the other hand, students from less affluent backgrounds or from families without an academic background may find it more difficult to receive support and guidance when making the transition to university study (McKinley and Madjar, 2014).

Well-resourced families may feel more freedom of choice when choosing their pursuits, while under-resourced families are more constrained to fulfilling fundamental needs that have immediate demands (food, housing, safety etc.) (Bourdieu, 1984, p.178). Under-resourced families thus have reduced opportunity to cultivate tastes for non-essential things. While the original argument Bourdieu (1984) set out referred to the manner in which individuals cultivate preferences for food and clothing, one can carry the same argument to subject disciplines. The field of science has been criticised as being poor in establishing its value to students (Claussen and Osborne, 2013). Historically, students in the field of science may be expected to hold motivations to progress the scientific enterprise for its own sake (Traweek, 2009), and this may be insufficient motivation for individuals who face demands to fulfil fundamental needs. However, the field of science can provide
opportunities (i.e., employment) that can benefit all students, even if that information is not well known (Claussen and Osborne, 2013). Families with backgrounds in science may be more able to communicate the value of science qualifications to their children.

Contemporary theorists have built on Bourdieu’s (1984) theory to understand how families from different social classes go about leveraging capital that is valued in educational institutions. One such theorist, Lareau (2011), outlined how some parents seek to engage in the concerted cultivation of their children and others seek the accomplishment of natural growth. These two parenting styles distinguish between the different ways in which working-class and middle-class families invest and leverage value from educational institutions. Concerted cultivation considers the way in which some parents, typically middle class, control their children’s schedules to develop their talents through organised activities. Through these activities, children become more used to interacting with institutions, feel more comfortable speaking on level terms with adults, and overall, build a repertoire of capital that is valued by western educational institutions. In contrast, parents who develop their children with the aim of accomplishing natural growth tend to set boundaries between adults and children, using more directives to control behaviour whilst placing fewer demands on their children in terms of organised activities. Instead, children control their own leisure activities and spend more time playing with their friends and relatives. As described by Lareau (2011), a key implication from these two parenting styles is that concerted cultivation mobilises capital that has been traditionally valued in western education systems. While children of concerted cultivation are more likely to take to educational institutions like a fish in water, children raised with the accomplishment of natural growth may feel more constraints and an “emerging sense of distance” (Lareau, 2011, p.3) from institutions.

While it can be argued that more science capital and an upbringing that involved concerted cultivation are the most beneficial to students wanting to study science at university, there is also a wealth of literature that points to the benefits of natural growth and “non-traditional” forms of capital held by students of underrepresented communities. In a multicultural society such as Aotearoa New Zealand, it is especially important to consider the value students can derive from ‘non-traditional’ forms of capital. Doing so challenges the idea that in order to boost the participation of underrepresented groups in science we need to boost their science capital so people at the “bottom end” can pull themselves up (Jensen.
and Wright (2015). As argued by Jensen and Wright (2015), a concept of science capital should also consider the manner in which the definition of value is struggled over in the field of science, and not to legitimise the existing (and unfair) power structures.

Critical theorists in education point to the need to also consider the funds of knowledge that students of underrepresented groups already have at their disposal (Moll et al. 1992). Although it may be more difficult for students to engage with educational institutions when they do not reflect the culture they were raised in, the ability to do so successful can be considered an important form of capital in itself. Mila-Schaaf (2011) describes this ability in terms of polycultural capital: “Polycultural capital is associated here with cross-cultural resources, knowledge, skills and agency to potentially realise cumulative advantage”. The importance of cross-cultural resources is also emphasised by Yosso (2005). Through the concept of community cultural wealth, Yosso (2005) details valuable forms of capital that are often excluded from traditional white, middle class perspectives. Community cultural wealth includes aspirational capital (the strength to draw on one’s own aspirations in the face of obstacles), linguistic capital (the skill to communicate in multiple languages/styles), familial capital (a commitment to family and community well-being), navigational capital (the ability to maneuver through institutions that were not designed with minorities in mind), and resistant capital (skills developed through oppositional behaviour to inequality). These conceptions of family, friends, and community as important sources of capital for success in education point to the benefits gained through natural growth (Lareau 2011). While children of concerted cultivation may be less able to develop kinship ties, children of natural growth have more autonomy to develop these relationships.

5.4.2.2 Learned Knowledge as Cultural Capital

Social capital can provide students with knowledge on the rules and logic that operate within the field of science. Students with many connections and/or know individuals who are highly ranked in the field, within their family context or outside of it, “will be better informed on market needs and demands” (Lin 1999, p.31). These students may be more knowledgeable on what tertiary institution is the best for them to attend, which courses they should take, and how they can get employed. For example, parents from more advantaged backgrounds may be more likely to provide information on tertiary costs to their children (Grodsky and Jones 2007).
Through bridging social capital, especially with educators, students are also able to leverage value through the knowledge and skills they learn. This knowledge, a form of embodied cultural capital (Claussen and Osborne, 2013), may be linked to the subject area of the field (i.e., content knowledge). The successful completion of educational assessments and qualifications concerning these knowledges and skills results in the acquisition of institutionalised cultural capital (Bourdieu, 1986). Some students may not acquire the prerequisite institutionalised cultural capital (i.e., a high school qualification) to enter university, and other students may enter into university with gaps in their knowledge. As outlined previously, the vertical structure of scientific knowledge means that gaps in knowledge can be especially detrimental for students seeking to progress in the field of science. If a student enters into university without knowledge needed to access a new flow of information, they are required to catch up.

While student-level characteristics, such as motivation, may contribute to gaps in learning (Hattie, 2012), it is important to highlight the structural factors that contribute to this issue. High schools located in less affluent areas may be more likely to focus on vocational pathways (Boyd et al., 2001), while schools located in affluent areas may be most able to provide resources to improve learning outcomes. As outlined by Thrupp (2007)

Predominantly middle class schools really may be advantageous to attend because they provide their pupils with better pathways to tertiary institutions, better access to networks of power and information in the future labour market (the ‘old school tie’), and extra resources.

This may explain why school SES is associated with university performance, even when controlling for individual SES (Konstantopoulos, 2005). In Aotearoa New Zealand, schools on the decline predominantly serve students from low SES backgrounds (Thrupp, 2007), and serving these students often comes with additional pressures that other schools serving well-resourced students do not face. Students attending low decile schools are also more likely to encounter difficulties when transitioning to university due to poor preparation, such as taking high school subjects ill-suited to a degree pathway, or failing to take prerequisite assessments (McKinley and Madjar, 2014). Students who attend schools that are less well-resourced (e.g., fewer science teachers) may also enjoy science less and be less motivated to learn science in the future (Hampden-Thompson and Bennett, 2013). As outlined by McKinley and Madjar (2014, p.248), the gap between the school and university can become internalised by students:
The greater the disconnection, not necessarily of the students’ making, the more challenging the transition process which, nevertheless, comes to be embodied in individual students’ experiences, as their inability to cope with, or their failure to succeed.

This points to a school system that is stratified, where some students, predominantly middle-class, are able to leverage more advantage from their schools than other students, disproportionately working-class, Māori, and Pasifika attending struggling schools (Thrupp, 2007).

The value of the knowledge that students gain is also dependent on the rules operating in the field. As with other forms of cultural capital, some forms of knowledge may be recognised as legitimate and championed by educational institutions, while other forms of knowledge may be considered less valuable. Some schools may have content and assessment that aligns more closely with university than other schools. Students who have access to knowledge that is valued in the field of university will be more likely to make a smooth transition from high school to university (Rach and Heinze, 2017). This may be a particularly important issue in Aotearoa New Zealand, where multiple forms of high school assessment are employed and students may enter into university with different knowledge bases and different experiences with assessment. The National Certificate of Educational Achievement (NCEA) is the assessment framework for most high schools. However, many elite schools, resisting a shift to a non-traditional assessment system (Thrupp, 2007), use Cambridge International Examinations (CIE), a traditional norm-referenced assessment designed by the University of Cambridge. While some research suggests that the relationship between CIE and first year university performance is relatively weak (Shulruf et al., 2008), research also suggests that the way NCEA is employed can lead to gaps in content knowledge (Tewkesbury, 2017), and this may be particularly salient for students attending lower-decile schools (Thrupp and Alcorn, 2011).

In the field of science, the struggle to determine which perspectives of knowledge have worth has been the subject of considerable debate (McKinley, 2005). The Western Modern Science (WMS) worldview has dominated the field of science. However, as with any form of cultural capital, scientific knowledge exists within a cultural context (i.e. the field). Hikuroa (2017) outlines how science can be viewed through Mātauranga, an indigenous knowledge system grounded in the Māori world view:
Both mātauranga Māori and science are bodies of knowledge methodically created, contextualised within a world view. As demonstrated herein, some mātauranga Māori has been generated according to the scientific method, and can therefore be considered as science. While there are many similarities between mātauranga Māori and science, it is important that the tools of one are not used to analyse and understand the foundations of another.

Whilst Hikuroa (2017) acknowledges that science is contextualised within a world view, the WMS perspective is typically viewed as universally applicable. As outlined by Quijano (2007), the ubiquity of the WMS perspective is a form of colonial domination, where knowledge may only be produced by following methods legitimised by western culture. WMS is legitimised as the dominant view of science as its recognition within the educational curriculum provides it with a symbolic value (Bourdieu, 1985) which reinforces its position as the dominant point of view. Historically, indigenous knowledges do not carry the same value in the field of science education (Aikenhead, 2001). In the context of Aotearoa New Zealand, there is an increasing drive to recognise the value of Indigenous Knowledges, such as Mātauranga, in science (Hikuroa, 2017; Harris et al., 2013), and in the high school science curriculum. However these efforts may not be successful if the way that science is taught still affirms a ‘hidden’ Euro-centric philosophy (Stewart, 2017) and positions indigenous knowledge at the periphery (Kidman et al., 2013).

While the value that students leverage from the social capital provides advantages that are external to the individual, an important aspect of Bourdieu’s (1986) theory is that this capital becomes embodied. Over time, the objects, knowledge, and skills that students access become an integral part of the self, physically and mentally. The following theme highlights the ways in which students internalise their contexts through habitus.

### 5.4.3 Habitus (Theme 3)

Theme 3 refers to the ways in which students internalise their contexts, in a process where the external becomes embodied as a student’s internal disposition towards science and their perception of their chances of success in the field. Out of all the steps to be discussed, this theme is the most similar to the research conducted in Chapter 4, where I investigated how different sources of capital were related to students’ self-concept in science. The capital that students accrue not only serves
as resources that can be used to garner advantage, but it also influences the way that students see themselves in the field and their internal dispositions (i.e., the self-belief that “science is somewhere that I can succeed”). Students who perceive that they lack valued capital in the field may see progression as unrealistic and choose to switch fields or drop out. In contrast, the accumulation of capital may signal to a student that the field is somewhere they belong. For example, if a student attends university and receives a qualification (institutionalised cultural capital), they will not only be able to gain more advantage in the field (i.e., increased employment opportunities), but they will also be more likely to believe that the field is somewhere that they belong and can succeed.

Bourdieu argued that external structures (including capital) are internalised and embodied by students (Figure 5.4.3) and considered within a system of dispositions which he labelled habitus (Nash 1999). Habitus refers to the space in which the internalisation of class conditions are transformed into dispositions towards action. Individuals still have the capacity to make a choice to follow certain courses of actions, but agency is carried out within a range of possible trajectories (Bourdieu 1984, p.110). As summarised by Cockerham and Hinote (2009), external societal structures are internalised and considered in terms of a conception of the chance of success which can either constrain or enable action. Habitus thus allows Bourdieu to transcend the dichotomy between objectivism (external structures) and subjectivism (agency), and escape structural determinism — the idea that we have no choice in what we do, and that our actions are simply the consequence of external structures. Instead, habitus provides an opportunity for researchers to look at how the outside social world becomes an internal aspect of the person, and how this shapes what pathways are thinkable or unthinkable (Reay 2004). The following sections will describe in more detail the way in which external structures are internalised, and how habitus can be used as a lens to understand the overlapping social locations in which an individual is situated.
5.4.3.1 Internalising Capital

Previous research has found that students who have higher levels of economic capital and cultural capital may be more likely to see university as a place where they belong (McClure and Ryder, 2018; Nguyen and Herron, 2020), and a realistic pathway associated with greater returns (Davies et al., 2014; Boneva and Rauh, 2017). Those who have higher levels of science capital may see the field of science as somewhere they belong and aspire to be (Archer et al., 2014). These findings were also reflected in chapter 4, which showed that undergraduate students from families with academic backgrounds may be more likely to see science as something they can be successful in. In contrast, some theorists argue that poverty may place constraints on an individual’s capacity to hold aspirations matching their actual potential (Dalton et al., 2016), while students who have less financial capital can feel excluded from social relationships at university (McClure and Ryder, 2018). As described by Birani and Lehmann (2013), students who perceive that they do not have the bridging capital of more privileged peers (e.g., relationships with peers, family members who attended university) may feel more uncertain about their position in the field.
Students with high levels of social capital may be more informed on what it takes to be successful in the field (Lin, 1999), and consequently they may also adopt ways of thinking that have been historically valued in the field. This process reflects the way that cultural capital is gradually embodied within the individual over time (Bourdieu, 1986). In science, these ways of thinking may be reflected in a *scientific habitus*, described by Bourdieu (2004, p.38) as: "a practical sense of the problems to be dealt with, the appropriate ways of dealing with them, etc." Bourdieu’s definition of the scientific habitus is brief, but I extend it by considering John Dewey’s definition of the *scientific habits of mind*. Dewey (1910) argued that understanding the process behind the construction of scientific knowledge is most important for students to consider, rather than the accumulation of ‘scientific’ facts. The scientific habit of mind thus moves beyond science-related cultural capital, and points to a deep internalised understanding of science as a lens to view the world. The internalisation of capital is a time consuming process (Bourdieu, 1986), a point that (Dewey, 1910, p.125) highlights: “One’s mental attitude is not necessarily changed just because he engages in certain physical manipulations and handles certain tools and materials. Many a student has acquired dexterity and skill in laboratory methods without it ever occurring to him that they have anything to do with constructing beliefs that are alone worthy of the title of knowledge.” What Dewey sees as the scientific habit of mind is a learned critical perspective of the world, a concept that can be considered akin to scientific habitus.

The impact of cultural capital on a scientific habitus has been the subject of prior research. For example, research has shown that sustained exposure to research projects may help undergraduate science students acquire a scientific habitus, a process (Hunter et al., 2007, p.44) refer to as “becoming a scientist”. In a study of undergraduate biology students, (Thompson et al., 2016, p.963) highlight the value that students can gain through connection to scientific research projects. Through relationships with academic mentors, students learned to “think and work like a scientist”. The acquisition of skills and knowledge, especially when institutionally recognised, can open doors for students to progress and increase the scope of their progression within a field. This accumulation of cultural capital may enable students to see progression as a realistic goal.

As summarised above, social capital impacts on habitus indirectly through the way that cultural and economic capital is then embodied and internalised. However, the concept of “bonding social capital” also allows us to consider a direct relationship between social capital and habitus. As previously discussed in
Theme 1, bonding social capital refers to the way that shared connections within a group can reinforce a group identity (Adler and Kwon 2002). Research shows that bonding forms of social capital can impact on students’ identity development at university. The bonding social capital students gain through identifying as a member of the same demographic group can also carry advantages to students. For example, Birani and Lehmann (2013) discuss how the bonding social capital that ethnic minority students access within their family and community can foster a commitment to education, while developing relationships with other ethnic minority students can make the transition to university feel more comfortable. This form of bonding social capital within the family points to the value of community cultural wealth that students may draw upon to boost their educational trajectories (Yosso 2005). In a study of university students, Jensen and Jetten (2015) investigated the ways in which bonding social capital with peers and educators impacted on students’ academic and professional identity development. They found that a shared peer group identity can facilitate academic identity, as students develop an increased sense of belonging. However, identification as a “student” may also hinder professional identity development as students feel more disconnected from their educators. As a result, students may be less likely to seek relationships with their educators, which highlights the way that our internalisation of our context (i.e., our peer group relations) can also place constraints on students freedom of action.

5.4.3.2 Classed Habitus and Overlapping Social Locations

The determination of life chances within habitus is not only informed by the internalised embodiment of capital, but also by other class conditionings such as gender, ethnicity, age etc. As outlined by Reay (2004), the habitus is not limited to just the mental dispositions and perceptions, but also inscribed in the physical. In addition to objectified forms of capital, our physical and sexual presence is always “entwined” with our experiences of societal structures, and this contributes to the shaping of habitus (Skeggs 2004, p.21). Individuals who have shared experiences, for example by having similar physical characteristics, may thus have similar experiences, and internalise the world in similar ways. This points to the idea of a classed habitus, as described by Reay (2004, p.434): “because there are classes of experience there are also classes of habitus or the habitus of classes.” For Bourdieu (1984, p.101), the classed habitus takes on a collective quality where individuals are exposed to “homogenous conditions of existence imposing homogenous condition-
The Analysis Phase

ings”, which in turn produce “homogenous systems of dispositions”. An example of how classed habitus may be used to understand disparities in science education is provided in chapters 3 and 4, where it is used to interpret gender differences in the enrolments of physics students, and in science self-concept. I argued that, while science has historically been a domain in which men have opportunities to succeed, women share the experience of explicit and implicit obstacles (Cheryan et al. 2017; Blickenstaff 2005) that hinder their progress. These “conditions of existence” may result in a collective gender disparity in science, where men feel more confident and women less so.

Habitus can be a powerful conceptual tool as it allows us to consider the ways in which different aspects of an individual’s social location overlap, interact, and impact on a sense of belonging. Each student does not belong to one group but many, which means that the idea of a “shared” experience is complex. Horvat (2003) described the relevance of habitus in the context of students’ progressing from high school to university study. In their study, the experiences of young black women demonstrate the way in which race and class carry different value in different contexts. Different aspects of students’ habitus were made salient as they progressed into new educational fields. Changes in field may bring to light aspects of habitus that were previously subconscious (Davey 2009), and students may experience conflict between different aspects of habitus which can leave students “stranded between worlds” (Baxter and Britton 2001, p.99). For example, Birani and Lehmann (2013) detail the discomfort that first generation students feel transitioning to an unfamiliar university context, while additional feelings of a ‘culture-shock’ may also be felt for students who also identify as an ethnic-minority. As students engage with new relationships, conventions and practices, they may be more consciously aware of how “conditions of existence” relating to gender, class, and ethnicity are internalised and embedded within their dispositions. Another aspect of an individual’s experience that operates across social groups is an exposure to societal discourses, or doxa, that signal who does/does not belong in a domain. These discourses are summarised in the following theme.

5.4.4 Doxa (Theme 4)

The fourth Theme considers the pervasive societal discourses that shape the experiences of students in each of the first three themes. General discourses may influence the capital that students are able to access, the value that society places on the capital that different groups hold, and the perception of belonging that
informs habitus. In the field of science, a wealth of research has shown that value is often defined by those who have held power in the field — historically white, male, and western (Traweek, 2009; Archer et al., 2012). Through these types of discourses, the dominant group in a field is able to maintain their position of power, as argued by Pomeroy (2016, p.170): “If certain groups of students are discursively positioned such that it is difficult to develop successful academic identities then these students are excluded from dominant definitions of success”. The dominant group in a field may be viewed as inherently meant for it, as that has traditionally been the case, while students who do not fit the dominant discourse may not be seen as someone who can be successful. For example, subjects such as physics (Traweek, 2009) and computer science (Ensmenger, 2015) are often stereotyped as a ‘masculine’ domain, and, as detailed in Chapter 3, trends in enrolment reflect these discourses — female students tend to be less likely to pursue these subjects. The following theme incorporates Bourdieu’s (1984) concept of doxa to explain the impact that general societal discourses may have on students’ sense of belonging in the field (Figure 5.7). Through doxa, I am able to consider how the various ways in which public feelings and “common sense” (“they don’t belong here”) perpetuate disparities in science education, and lead to private individualised judgements (“I don’t belong here”).
Figure 5.7: **Theme 4.** The fourth theme of the theoretical model highlights the impact doxa has on students. In simple terms, doxa refer to pervasive societal discourses that appear to be self-evident. Students, their family, and their educators are often aware of ‘common-sense’ notions of what scientists appear to be like, and which subjects are for different individuals. Theme 4 discusses the impact of these discourses on how students identify with science.

Doxa is a Greek word referring to common beliefs or popular opinions, specifically referring to a body of established or unquestioned beliefs held generally within a particular society, community, or group (OED Online 2020). For Bourdieu (1984, p.473), doxa refers to the way social structures become embedded in general discourses in society and are often taken for granted:

One of the most important effects of the correspondence between real divisions and practical principles of division, between social structures and mental structures, is undoubtedly the fact that primary experience of the social world is that of doxa, an adherence to relations of order which, because they structure inseparably both the real world and the thought world, are accepted as self-evident.

In more basic terms, doxa refer to the way in which commonly-held beliefs around how the social world should be structured echo commonly held perceptions of the way the social world is structured. In this sense, existing social divisions lead to principles of division that guide what is expected of people. Individuals who are
underrepresented or under-served in a field may perceive that they do not belong, and this means that “objective limits become a sense of limits” (Bourdieu 1984, p.473). Doxa thus serves as another constraint within habitus, which can lead to one excluding their self from resources from which they are already being excluded.

Previous research has highlighted certain doxa that are prevalent in the field of science, serving as obstacles in the paths of specific groups of students. As summarised in previous chapters, science is more likely to be stereotyped as a male domain (Nosek et al. 2009). These stereotypes are perpetuated through the media, which has historically tended to depict scientists as white, male, and western (Kitzinger et al. 2008, Dudo et al. 2011), and science as a field characterised by a masculine culture of “rugged individualism” (Ensmenger 2015). The prevalence of gender stereotypes in science extends to perceptions of competence, with women being less likely to be viewed as competent when applying for jobs in science fields (Moss-Racusin et al. 2012), teaching science (Potvin and Hazari 2016), or simply just based on their appearance (Banchefsky et al. 2016). Misogyny (Ensmenger 2015) and sexual harassment (National Academies of Sciences, Engineering, and Medicine and others 2018) are also prevalent in STEM and this places barriers in front of women seeking to progress in science. The combination of these factors may explain why, in life sciences, elite male faculty based at leading institutions in the US tend to employ fewer women (Sheltzer and Smith 2014).

The same negative discourses are prevalent in the context of Aotearoa New Zealand. Some recent notable cases include a Massey University chancellor resigning in 2016 after stating that a female veterinary graduate was worth only “two-fifths” of a full-time veterinarian (Schroeter and Forrester 2016), and in 2018 a chemistry tutor at Victoria University was accused of sexual misconduct and making inappropriate comments (Duff 2018). More recently, in 2020, an investigation of AUT University by Stuff (Mau 2020) revealed a “toxic culture” where female academics were sexually harassed, but allegations were continually ignored by AUT’s senior management.

In Aotearoa New Zealand, Māori and Pasifika students also face a culture where they are subjugated, both in wider society and in education more specifically. Students from these groups face persistent racist discourses suggesting they are less capable of succeeding in education (Webber et al. 2012), and tend to be excluded from discourses of who can pursue ‘intellectual’ subjects (Hokowhitu 2008), such Victoria University faced backlash for allowing the tutor to continue teaching after the sexual misconduct complaint against him was upheld (Duff 2018).
as mathematics (Pomeroy, 2016). These discourses, including experiences of “everyday racism” continue to be prevalent for Māori and Pasifika students studying at university (Mayeda et al., 2014).

By viewing the examples of negative discourses above through Bourdieu’s (1984) concept of doxa, I begin to unpack the manner in which stereotypes and preconceptions about who is ‘good at science’ are historical, systemic, and self-fulfilling. The final theme considers how individuals go about building their capital in science, in the context of their established dispositions and exposure to doxa.

5.4.5 Generating Social Capital (Theme 5)

Following the internalisation of class conditionings and doxa within habitus, students will set upon courses of action to advance their status in the field. Theme 5 refers to the way in which individuals seek to generate further capital, something that is influenced by each of the previous themes (Figure 5.4.5). Habitus, which is developed in relation to students’ socio-cultural context (Themes 1 to 4), provides the “feel for the game” (Nash, 1999) which points students towards certain trajectories. The ways in which students engage in the future generation of capital is informed by three key three factors. The first relates to their motivation to do so, the individual’s self-belief that the “game” is actually worth playing. The second factor, assuming that the individual does hold motivations to be successful in the field, is whether they have the knowledge of what can improve their chances of success. Does the student know how to build their capital, and do they feel comfortable doing so? Finally, I also consider that while habitus leans students towards certain actions, students still have choice when determining their future.
Figure 5.8: **Theme 5**. The fifth and final theme of the theoretical model. This theme refers to the manner in which students go about generating capital. The manner in which students go about accumulating capital will be guided by their habitus, which is influenced by the prior internalisation of capital and doxa.

### 5.4.5.1 Motivation

Previous research has discussed the various motivations that students may hold for studying science ([Claussen and Osborne, 2013](#)), and this can allow us to understand whether a student sees science as a game that is actually worth playing. I draw upon Self-Determination Theory (SDT) to discuss the different forms of motivation that students may hold. SDT is theory that emerged from the field of psychology, and offers a well-established lens for exploring factors related to motivation. According to SDT, a student’s motivation may be characterised as either intrinsic or extrinsic ([Ryan and Deci, 2000a](#)). In the context of Bourdieu’s (1984) theory, extrinsic motivation may refer to a student’s belief that the field provides the opportunity for students to acquire and accumulate capital. They may choose to study science because it provides the means to acquire income (economic capital), build social relationships (social capital), acquire qualifications (institutionalised cultural capital) or prestige (symbolic capital). In this sense, the motivation is drawn from the consequence of an activity, and not from the activity itself ([Ryan and Deci, 2000a](#)).
Building on this Bourdiesian perspective of motivation, intrinsic motivation refers to the extent to which science aligns with dispositions that the student has already internalised. Intrinsic motivation refers to the source of motivation that a student receives from the activity itself, regardless of the outcomes (Ryan and Deci, 2000a). Intrinsic motivation thus signals an alignment between a student’s habitus and the activity that they seek to engage in. In science, students may be intrinsically motivated as they have developed a taste for it (i.e., they enjoy it) and see science that is something that is ‘for them’. Students who have developed a scientific habitus may be interested in pursuing science as they have developed dispositions leaning them towards activities that fulfil their curiosity and foster their critical thinking skills. Bourdieu’s (1984) theory provides an important perspective that aligns well with SDT, in that the intrinsic dispositions held are actually the product of the capital they have already accessed. Thus, overtime, extrinsic sources of motivation may be characterised by a degree of personal endorsement, and extrinsic sources of motivation can be internalised (Ryan and Deci, 2000b). An example of this may be the manner in which institutionalised cultural capital (an extrinsic source of motivation) signals to students that they belong in the domain (an intrinsic source of motivation). Positive feelings associated with receiving good grades may lead to feelings of pride, which then boost students’ enthusiasm for participating in the field in the future (Covington, 2000).

5.4.5.2 Knowing How

Assuming that a student does want to progress in the field, knowledge of what can improve chances of success will be important to their efforts to generate capital. Do they know how to build their capital, and do they feel comfortable doing so? Both of these questions are informed by students’ past experiences considered in previous themes. Students need knowledge on how to go about generating capital, where to find information, who to approach, and which conventions to follow. As outlined in Theme 2, which concerns the value that may be leveraged from social capital, the process of concerted cultivation from parents can play an important role in equipping students for engaging with educational institutions (Lareau, 2011). Previous research has found that the manner in which undergraduate science students generate capital differs greatly depending on their existing capital. For example, Thompson et al. (2016, p.986) found that students were most likely to engage in a social network of research scientists when they had existing professional connections, embodied a sense of the importance of research experi-
ences for their future success, and had developed skills recognised as important by the network. Each of the points raised by Thompson et al. (2016) reflect the manner in which students access, leverage, and internalise capital. Those students who are the most privileged in terms of the capital they embody may be the most prepared to generate further capital in the field.

5.4.5.3 Sacrifice and Resistance

Students who face obstacles in accessing and leveraging value from capital may need to make sacrifices in other aspects of their life to progress in the field, a point highlighted by Bourdieu (1984, p.334) when he states: “‘Taking off’ always presupposes a break”. For example, Ong (2005) describes how women of colour in science must engage in additional strategies to be viewed as competent members of the scientific community, in the face of doxa that has historically excluded them. Marginalised students may “relegate their own social and cultural identities to the margins” (Ong, 2005, p.597) to emphasise the ways in which they fit into the domain. In contrast, students who have lots of capital are enabled to advance in the field without needing to adjust their identity to match the field or justify their position within it. Students who are also economically privileged can also focus more on progressing their studies as well as building social relationships (McClure and Ryder, 2018), while those who do not share the same privileges are required to navigate additional barriers, whether that be keeping up with technology (Nguyen and Herron, 2020), taking on extra work, or seeking financial assistance (Ziskin et al., 2014). As a result, students with less financial capacity may feel a diminished sense of belonging at university (McClure and Ryder, 2018; Nguyen and Herron, 2020).

Although the barriers that students face in the field of science make progression in the field more difficult, the manner in which students demonstrate resistance to these barriers can lead to additional opportunities to generate capital. Students who occupy marginalised identities in science may be able to gain confidence when they exert their own cultural identity in opposition to what has been traditionally valued in the field (Ong, 2005). For students that have fewer sources of recognition and belonging, the ability to draw strength from one’s own aspirations can be considered a form of capital in itself (Yosso, 2005). Students who hold reserves of aspirational capital may be more resilient in the face of external structures, including doxa, that signal that they do not belong. While this type of resilience should be celebrated, I seek to avoid shifting the onus onto marginalised students...
to build their capital to combat inequity. Instead, following arguments set out by Penehira et al. (2014), I choose to focus on the resistance that students demonstrate — the “collective fight-back” that exposes inequity without accepting it. A major strength of Bourdieu’s (1984) theory is the manner in which it focuses on positioning the whole individual (both physical and mental aspects) within wider societal structures. Doing so allows researchers to celebrate the sacrifices and resilience that disadvantaged individuals demonstrate, whilst also emphasising the inherent unfairness in the system in which they are placed.

5.5 Summary

This chapter has discussed the efforts I made to delve deeper into the question of why we see the trends in science participation outlined in Chapters 2 and 3. It outlined the sampling procedure I employed to collect qualitative data from students from a range of backgrounds, using analysis of questionnaire responses from Chapter 4 as a guide to sampling students. Through a combination of inductive and deductive application of thematic analysis, I formed a cohesive theoretical model that can be used to explore students’ experiences accumulating capital at university. More specifically, this theoretical model emphasises the importance of the reciprocal relationship between social capital and habitus. I also introduce Bourdieu’s (1984) concept of doxa as a way to consider the influence of prevalent societal discourses on students’ sense of belonging in the field of tertiary science. Using my theoretical model as an interpretive lens, I can seek to explain why we see differential trends in the field of science by gender, ethnicity, and social class. Through habitus, I can unpack the complex interactions between external structures and internal dispositions and agency, bringing to light the way that external factors both enable and constrain students’ progression in the field of science. The following chapters will now seek to demonstrate the relevance of this model to the life experiences of participants studying science at university.
Chapter 6

Experiences of Science Capital

Preamble

The following chapter will explore the experiences of undergraduate science students, drawing on the interviews with the four science scholars students and the fifteen interviews with questionnaire respondents. While Chapter 5 summarised the theoretical framework that I followed to make sense of the interview data, the following chapter will show what the theory looks like in practice. With this qualitative work, I focus on tackling the question of why students choose to study science. I endeavour to avoid paraphrasing participants recollections, instead relaying as much context of the conversation as possible. This is done in an effort to help participants tell their own stories, and minimise my role in structuring their recollections. The following chapter discusses some of the experiences that participants recollected that come under the first three themes in the theoretical model (Figure 6.1). These themes include the manner in which students access to social capital, the way that value is leveraged from social capital, and the role of habitus in how students see themselves in science. In order to give immediacy to the results, my discussion is blended into the sections that detail participants’ experiences.
Figure 6.1: **Theoretical Model (Themes 1-3)**. The first three Themes of the theoretical model point to the importance of having access to social capital (Theme 1), being able to leverage value from a social relationship (Theme 2), and the manner in which capital is internalised and influences students’ sense of belonging in the field (Theme 3)

### 6.1 Introduction

The goal of the following chapter is to detail what the theoretical model outlined in Chapter 5 looks like in practice. The integration of theory and practice was a key aim for Bourdieu ([Bourdieu and Waquant, 1992](Bourdieu1992)), who felt that theory should not be generated in the absence of data, and that data should not be interpreted with an absence of theory. As detailed by [Bourdieu and Waquant, 1992](Bourdieu1992) p.34), Bourdieu “does not seek to connect theoretical and empirical work in a tighter manner but to cause them to interpenetrate each other entirely”. I will outline the various ways in which my theoretical model is echoed in the recollections of the undergraduate science students I interviewed. In presenting these experiences, I describe the ways in which experiences are informed by a “layering” of different aspects of students’ lives. [Horvat, 2003](Horvat2003) p.9) neatly summarises this goal by pointing to the ways in which habitus can be used to consider the interacting aspects of race and class:

One way to visualize the distinction that I am trying to draw is by thinking about different color lenses or transparencies. If you look
through a red (race) colored lens what you see looks red. If you look through a blue (class) colored lens what you see looks blue. However, if you place the red and blue lenses on top of one another what you see looks purple. By using a single lens we are missing the color that is produced when we overlay these lenses one on top of the other.

Echoing this sentiment, I seek to look through multiple lenses when describing the experiences detailed by participants. Through these lenses I will describe participants’ perceptions of the availability of social capital, the ways in which participants leveraged value from social relationships, and finally, how these social relationships relate to participants’ internal dispositions towards the field of science. Following the process of thematic analysis, I consider each of these three Themes according to three key social relationships: family and whanau, educators, and peers. My discussion begins with the first Theme in the theoretical model, which summarises participants’ perceptions of their access to social capital.
6.2 Access to Social Capital (Theme 1)

Bourdieu (1984) highlights the way in which inequities are grounded in the fact that capital is not distributed evenly across society. This is especially true of social capital in science, where some students are born with connections to individuals with power in the field, and others may lack any kind of social capital until they enter the education system and develop relationships with educators. Theme 1 of the theoretical model, outlined in Chapter 5 (Figure 6.1), refers to the inequity that is embedded in students’ access to social capital. In this first section I will discuss how access to social capital differed across participants. We can define access to social capital as being determined by a structural position in a network (Burt et al., 2013) (i.e., having available connections to others), and also the potential of those relationships to mobilise some kind of resource Bourdieu (1986). Following the thematic analysis of interview transcripts, the social relationships detailed by participants can be categorised into three main groups: family and whanau, educators, and peers.

6.2.1 Family and Whanau

Participants detailed different levels of social capital held within their family and whanau. An individual’s family upbringing provides them with their first source of social capital, and it has been argued that this form of “family social capital” is the most important in influencing well-being (Parcel and Bixby, 2016) and educational outcomes (Dufur et al., 2016). While some participants were born into a family that may be considered strong sources of social capital in education and science (i.e., they went to university, or work in science), other participants did not have the same immediate exposure. The following sections seek to untangle the different levels of social capital that participants were exposed to.

6.2.1.1 “I try to tell them something and they go: ‘Oh that is nice’, and just start talking about something else”

Some participants felt that their family did not hold interests in science. It may be that while a family provides a source of general social capital, participants are less able to access social capital that is valued in the field of university science.

1The te reo Māori term whanau refers to extended family or a community of related families (Māori Dictionary, 2020b), and therefore this theme considers the social capital participants held via their parents and siblings, and also through aunties, uncles, and grandparents.
Chloe recalled that her family, who valued education and other academic fields, did not see value in science: “...my family isn’t interested in science and that is cool, I am not interested in banking... I think they have no idea of science because they don’t do science, so they don’t really know what science is, so it is kind of like not normal to my family”. Many participants felt that their family was indifferent to science, such as Aubrey. She felt that her parents “switched off” whenever she tried to talk to them about science: “I try to tell them something and they go: ‘oh that is nice’ and just start talking about something else.”

Even if family members held an interest in science, it may be more difficult to talk to them if do not have experiences in education. Patrick recalled the conversations he had with his father about science documentaries (“I used to talk to him about stuff like that.”). Patrick’s father was highly receptive and supportive of his education, but Patrick recognised that he had fewer opportunities to talk about his university degree and plans for the future in detail:

Me: So you talk to your dad about this stuff?
Patrick: Yeah only a little bit, not really about computer science stuff.
Me: Do you talk to him about your degree now?
Patrick: Yeah, and he always shows me videos of like robots and stuff, and maybe that is what I want to get into.
Me: So you can talk to him about your degree and stuff, or just generally about the topic?
Patrick: Yeah and he will listen.
Me: He will listen, what kind of conversation?
Patrick: Well most of the time he doesn’t know what I’m talking about, but he will still listen to what I’m talking about. So like what I’m doing at uni for my assignments and stuff like that.

Patrick’s experience highlights how parents can serve as valuable sources of bridging capital to science (i.e., “he always shows me videos of robots”), and these types of informal science discussions have been shown to be a strong predictor of identity within STEM domains (Dou et al., 2019). The level of engagement and support that Patrick received from his father would provide a tacit yet fertile familial context which likely contributed to Patrick’s positive disposition towards

\footnote{All participants are referred to in text by a pseudonym.}
Experiences of Science Capital

science. Patrick’s father was less able to engage in discussions about Patrick’s degree, which can also provide additional benefits to students. Other participants detailed how they were able to access this form of cultural capital within their family.

6.2.1.2 “When the science questions do come up between me and my Sister, then they sort of hop in”

While it is important to emphasise that parental involvement in education is a beneficial source of social capital regardless of social-economic status (Jackson and Remillard, 2005), students who have families with backgrounds in science and education have the greatest access to social capital. An academic background provides access to the cultural capital that is valued in institutions (Lee and Bowen, 2006) and provides the foundational knowledge needed to access conversations. Families who have science backgrounds may be able to offer a bridge to “sticky” knowledge (Von Hippel, 1994) related to science as they are more familiar with the conventions, language, or processes involved. Sean, whose mother worked in a science lab and whose sister did the same degree as him, recalled how his parents were able to join in conversations that he and his sister had about university science:

Me: Did you have lots of experiences with your parents growing up? Did they talk about science at all or stuff like that?
Sean: Sort of, not really. My mum she has a science degree.
Me: What did she do?
Sean: I’m not really sure. She worked in a lab somewhere until she had her third kid, and then she stopped working. But other than that I haven’t really had much science discussions with my parents, but when the science questions do come up between me and my sister, then they sort of hop in.
Me: You talk to your sister about science and stuff?
Sean: Yeah I am always asking her questions because she graduated with her degree last year.
Me: In what subjects?
Sean: Biomed.
Me: She did biomed as well?
Sean: Yeah she did a full degree yeah, so I would just ask her questions if I’m stuck.

For Sean, science-related capital was easily accessible within his family. Sean’s parents had the capability to “hop in” on discussions about science, and Sean was also able to access valuable knowledge on his future educational trajectory through his sister who had modelled it previously. The norms and values that a family holds offer an important source of social capital for students (Coleman, 1988; Parcel and Bixby, 2016), and these can either enable or constrain an individual’s access to science-related social capital.

6.2.2 Educators

Unlike family related social capital, most students (if not all) will have access to science-related social capital through their educators, from primary school, to high school, to university lecturers and tutors. The relationships participants shared with these types of educators were highly influential in shaping their experiences of science and university. While students from well-resourced families can draw upon their family members for information, students from less affluent areas may be more likely to draw upon schools to provide advice and information about future careers (Boyd et al., 2001). However, the idea that educator-related capital is distributed evenly may be an illusion. While public schooling has the potential to reduce inequity, institutionalised education can serve to exacerbate it. Some participants recalled educators who seemed inaccessible and served as poor sources of social capital. In contrast, other participants recalled educators who were highly approachable and highly able to mobilise resources.

6.2.2.1 “He Kind of has a Reputation for Being a Hard Guy”

Some participants recalled the manner in which educators could be unapproachable, and seeking help from them was more difficult. Belvia was unable to leverage value from a social relationship with a lecturer who did not want to answer questions:

So there is this guy called [Educator]. He was one of the lecturers on [Course] and everyone was like: ‘be careful of this paper. If [Educator] is doing it, don’t do it.’ But I had to do it for this paper, and I did it and he was just a really bad lecturer. If anyone asked a question he
would be like: ‘that is a dumb question’ or something. He would be like: ‘you should find that out yourself’.

In Belvia’s case, her lecturer was a poor source of social capital. By demeaning students (‘that is a dumb question’) the lecturer exerted power over the students and signalled that they should not engage with him. Belvia’s lecturer also explicitly stated that he was not interested in serving as bridging social capital for their students by telling students that they need to find things out for themselves. Patrick recalled a similar experience:

Me: When you say he’s not approachable what do you mean?
Patrick: So like on Piazza and stuff like that he used to like not really be rude but give really blunt answers. Yeah so students didn’t really ask him much, and he kind of has a reputation for being kind of a hard guy.
Me: And is that normal for your lecturers?
Patrick: Not really most of them are really good.
Me: The other ones that are good, what do they do better?
Patrick: We actually get taught stuff in lectures. Yeah that is a step up from the other one, and they are really approachable.

Similar to Belvia’s experience, Patrick’s lecturer was felt to be unapproachable. Blunt answers suggest he was a poor source of bridging capital. A negative “reputation” may serve as a barrier to connection with educators. In comparison, Patrick was able to access more information through teachers who were approachable. The following section will describe how participants characterised educators who were more accessible.

6.2.2.2 “We all could engage in a conversation with him”

Educators, and the institutions they belong to, have the power to enable access to social capital for students they teach. As previously described by Patrick, it is easier to make connections with educators when they are perceived as approachable. Alicia remembered how, even when she did poorly in English, her teacher helped her stay motivated: “the teacher always encouraged me that you can do well, and I liked her personality. Beyond just studying [the] subject I have more

\footnote{Piazza is an online learning platform used in many courses at the University of Auckland.}
personal attachment to that person.” The importance of personal attachment was echoed by Stephen:

He had four things he would always talk to us [about]: his Hilux [car], university days, space, and Christmas. So obviously I engaged more with space so we would always talk about the alien conspiracies and stuff. We would always go on tangents about that, and he would have cool university stories he would tell us... But I think the fact that we all could engage in a conversation with him is probably the best thing that a teacher could have.

Stephen was able to connect with his teacher as they shared common interests, which may relate to the concept of homophily; the idea that “birds of a feather flock together” (McPherson et al., 2001). The more similar two individuals are, the more likely they are to make a connection. Thus, students who share the cultural capital of their educators may find it easier to access social capital, and this may improve students’ levels of achievement (Gehlbach et al., 2016).

6.2.3 Peers

Participants recalled varied experiences of the peer networks open to them. Unlike educators, from whom the value of social capital is mainly derived in an academic context, peers can mobilise both academic and non-academic resources. While some participants entered into university study with a cohort of students from the same school, other participants entered university with limited peer networks. This tended to be the case for participants who attended high schools located in different geographic regions to the UoA, especially rural areas, or for participants from high schools where university was not a common or expected pathway.

6.2.3.1 “Only four or five people from my school came to Auckland”

Participants who originated from geographic regions outside of Auckland may enter into science at university with fewer connections. This may be due to rural communities having smaller cohorts of students (and even fewer studying science), while geographic distance from university may also negatively impact intentions to study at university (Cooper et al., 2017). Stephen found the move from a rural area to Auckland difficult due to the lack of an established peer network: “It was harder this time to transition back into the city life though, because going from the
small town only four or five people from my school came to Auckland.” Of these students, Stephen was the only one studying science, which put more pressure on him to make friends with people he did not know: “I didn’t know anyone doing science, especially my major. No one I knew from my old schools... I was kind of pushed into that idea of having to make new friends and having to try and socialise with people that I didn’t know.” Stephen recognised the importance of integrating into the university community, while he also felt like he was “pushed” into doing so. Students’ who have an established social network will have access to resources through their peers, while other students, like Stephen, are required to engage in strategies to build their connections. Belvia, who entered into university with many friends, recognised the benefit of her peer network once her friends started to graduate:

I wouldn’t really go to lectures, I would just like hang out with my friends and stuff, and then they all graduated last year and my degree is only three years, and shit now I want to get out of uni. I really like uni, I don’t really want to work yet because I don’t know what I’m doing exactly, it’s like going along with the flow. But now since most of my friends have gone, I have only like four of my original friends here, and shit everyone is graduating I need to get out of here. I need to actually start moving on with my life and stop being in the comfort zone of mine.

Having an established network of friends may have contributed to Belvia’s experience of university as a “comfort-zone”, while its decline created a sense of trepidation.

6.2.3.2 “If we are in the common room we can all get together”

The structure of physical spaces at high school and university may facilitate students’ access to social capital through their peers. Sean was able to connect with other students by hanging out in the same places: “The MAPAS\textsuperscript{4} students, they always hang around the MAPAS house so I just ask those guys. They are always helpful like to answer questions from the first years.” Participants with the resources (i.e., economic capital) to stay in student flats or university accommodation were connected with other students based on physical proximity. Mark suggested that staying in the same space made it easier to make connections with

\textsuperscript{4}Māori And Pacific Admission Scheme
others studying the same degree: “Since I’m staying at halls there are lots of engineers within my own floor. So we are able to just casually if we are in the common room we can all get together”. Proximity is thus a key factor in providing access to social capital with peers. The following section will now seek to expand on the ways that participants were able to leverage value from the social relationships that they were able to access.
6.3 Leveraging Value from Social Capital (Theme 2)

While students may have similar access to forms of social capital, there can be substantial differences in whether the value of the relationship is leveraged, and the extent to which that value is substantiated. Using a basic example, most, if not all, students have access to high school teachers who can provide access to resources, facilitate the acquisition of knowledge, and provide students with future opportunities to progress in the field. Despite equal access, much research points to the fact that some students are able to leverage more value out of their relationship with their educators than others [Hampden-Thompson and Bennett, 2013; Thrupp, 2015]. The second Theme of the theoretical model discusses the value that participants gained from social relationships, and their differential experiences in seeking to leverage this value.

6.3.1 Family and Whanau

The value of family connection is highly important in fostering interest in science and educational success. The following sections will discuss how family and whanau, and especially parents, were able to mobilise resources for participants that helped them develop as science students. Family members were often the first source of science-related capital that participants had, whether this came in the form of objectified cultural capital (e.g., books) or through talking about science. The value of family also extends beyond the provision of educational and science-related resources as they are also a source of general support and familial capital [Yosso, 2005]. Familial capital emphasises the way that kinship ties, with parents and extended family, help develop connections to the community and its resources. While sources of general support within the family were widely acknowledged by participants as valuable in their educational journeys, other participants recalled a more hands-on and concerted advocacy from parents when it came to their education.

6.3.1.1 “She would always tell me if something on the news happened that is very nerdy”

For some students, family will provide the first source of exposure to science. Many participants recalled the different ways that their relationships with their family led to their initial interest in science. Parents were a key source of bridging social capital for participants as they provided access to science-related objectified
cultural capital, such as books or other media. Alicia felt that family environment would be a key factor in determining science interest for most students, even if family members did not have qualifications in science:

family is the environment where you grow up. For example, even though my mum and dad haven’t achieved any degrees, my dad has always [helped me] explore that problem solving environment... He can help me. So if I don’t have that, I don’t think I would be into science because nobody would help me.

Parents may make a concerted effort to give their children access to science-related capital by teaching them personally or providing them with tutors or resources. Kate recalled the support she received from her father:

If I was stressed my dad would go out and buy what food I was craving at that time and give it to me, so that would just take some pressure off, and then if I was needing help with stuff because I don’t understand it or something my dad would always find articles on it. If you go through my emails there is a lot from my dad like how to learn well, like how to study well.

Kate’s experience highlights how parents can support their children on a fundamental level as well as on an academic level. The mobilisation of resources by a family may also help spark interest in science, as was the case for Stephen: “she would always tell me if something on the news happened that is very nerdy. She would say ‘oh look at that’ and I am like ‘oh cool’ and I would go and research on it and then I’d come back with this whole like essay full of stuff about it.”

While having family who talk about science may help spark curiosity or interest in science, having conversations with family from educated backgrounds may be especially valuable for students studying at university. Through this type of relationship, students may more readily access a flow of information on what is needed to be successful in university and/or science. Sean was introduced to people studying in his field through his iwi:

I was just sitting with the adults during some dinner or something and the subject of me would come up somehow and my parents were like

\(^5^\)As defined by Maori Dictionary (2020a), iwi refers to an “extended kinship group, tribe, nation, people, nationality, race - often refers to a large group of people descended from a common ancestor and associated with a distinct territory.
‘oh he wants to be a doctor’ and they would be like ‘so you need to do this and this and this if you really want to be a doctor’.

Sean’s ties with his iwi provided familial capital as he was able to draw on experiences from his wider family connections (Yosso 2005) to gain access to knowledge held within his community. Students may also leverage family connections to get employment opportunities, but this is not possible if family connections are not there, as Hakeem recalled: “It was hard to get the work hours, but also I knew people that did get decent work - they had connections with their family, their dad was an engineer.” Hakeem, who had to amass 800 hours for his engineering degree, highlights how students with access to social capital within their family may be more able to leverage opportunities, and this can help them meet the institutional requirements.

6.3.1.2 “My mum made herself very known at parent-teacher interviews”

For many participants, having the support of their family was viewed as most important to their progression through university. Some felt that their parents did not interfere too much with their education and just wanted them to do something that made them happy. As described by Paul: “My parents are pretty hands off, so yeah it was pretty much up to me. All they wanted was I did what I want and there wasn’t even any pressure to excel I guess”. Lily recalled how her parents allowed her to find her own pathway:

I think it was just they didn’t want to put too much pressure on me to go in any certain direction. I think they have always taken the stand that I can dictate where my future goes... My dad had expressed a few times that because he knew I was good at science and maybe I would want to go into something that involved science, but neither of them really pushed me towards any career in particular.

The autonomy that Paul and Lily’s families fostered can facilitate positive outcomes in education, especially when parents are able to balance autonomy support with an involvement in their child’s education (Guay et al. 2008).

Some participants recalled how their parents would get involved with their education by providing encouragement and setting expectations. For some participants, parents were hands-on in their involvement, echoing the practice of
concerted cultivation (Lareau [2011]), a process that can provide students with resources that will be highly beneficial as they progress through education. Chloe summarised this practice by referring to the way in which she had been “groomed that you go to university”. Some participants recalled how their parents kept tabs on their academic progress and advocated for them when they felt the school was not meeting expectations. Jay recalled how his mother taught him mathematics at home when she felt that his school was not teaching him enough:

I told them we weren’t doing anything [at school] and they went: ‘okay we are going to need to do your stuff now at home’... Ever since primary my mum used to help me with my reading in maths, so I would otherwise be well above what I should be at school, just to make my life easier, and then she kept doing that up until Year 9

Similarly, Chloe’s parents ensured that her teachers knew they had to teach her well:

Chloe: My mum made herself very known at parent-teacher interviews, and they were always with your form teacher. So he knew I had an environment where like excellence was the only option.

Me: So how did your mum put that across?

Chloe: I suppose she would question when I didn’t get it and why I didn’t get it, she was very upfront with teachers. I always got a really good report card, but if I got something that was slightly off she would always go to a teacher and ask why and they would tell her why... she removed me out of a few classes just because some teachers, you know, not everyone in this world likes everyone and I was a very loud bubbly kid and some teachers don’t agree with that. My report card wasn’t looking so good with some teachers so they just moved me around.

Me: Until you found the spot that kind of worked for you?

Chloe: Worked for the report card I suppose yeah.

Jay and Chloe’s experience highlights the benefits that students can gain from having parents who are highly aware and involved in their education. Jay’s mother acted as a source of social capital herself to reduce gaps in Jay’s mathematical knowledge. Chloe’s mother demonstrated an advocacy that ensured that Chloe was able to leverage the most value out of her relationships with her teachers. The
process of concerted cultivation may place a lot of pressure on students to succeed academically, but it does expose students to forms of capital that are valued in institutionalised education and employment. Chloe hinted at the pressure and expectations placed on her when she mentions that the advocacy “worked for the report card”.

6.3.2 Educators

There is much overlap in the value that can be leveraged from educators and family. Much like family, educators are able to mobilise educational resources for students to engage with, and may be a source of general non-academic support for students. The unique value of educators may come in their capacity to serve as bridging capital to educational resources not available in the home environment. The ability of educators to prepare students for university is also important, as gaps in knowledge, especially in science, can significantly hinder progression. Beyond the curriculum, participants also recognised that educators can divulge knowledge of the field of science itself. The value that students derive from educators is varied, with some participants being aware that some schools had it better than others. The experiences recounted by participants highlight the contradictory nature of educational institutions, in that access to social capital appears more equal, while the value derived can perpetuate inequality.

6.3.2.1 “Other people already had an advantage”

The quality of science education seemed to differ markedly for participants. Some participants regularly got to engage with opportunities for learning using resources not readily available in a home environment, such as scientific experiments. Well-resourced schools were more able to provide these experiences for students, as Kate described:

There are some schools that are really rich and they allow the students to gain more experience than other schools. With my experience, I went to this science open day at Massey [University] and other people from other schools were going there. What we were doing was centrifuging and using agarose gel to sequence DNA, and we had to deal with a lot of equipment that the people from my school who went we didn’t know about, but there were some girls in the other schools like the richer schools that were like: ‘oh yeah we did this the other day’. And
then my friend and I were just like we had no idea how to use this and there are other people already had an advantage because they know how to use it.

Kate’s recollection shows how well-resourced schools are more able to transmit advantages to their students. By providing equipment to carry out experiments, schools can help teach their students specific content knowledge, and give them more time to develop the embodied cultural capital (i.e., knowledge of carrying out procedures) that they can use to their advantage. Furthermore, students may feel more engaged when carrying out these forms of hands-on activities (Hampden-Thompson and Bennett, 2013).

Stephen also saw large differences in the way he was taught science compared to his friends at higher decile schools:

We didn’t have the resources I guess to make it fun, because I was getting all these [messages] on like Snapchat, all these [Private School] people were posting all these cool things they were doing in science, and I’m here — teacher just teaching me stuff on the whiteboard because we didn’t have as much of the resources that they could have had to make it probably more fun and more intriguing for us to actually be interested in.

Well-resourced schools may be more able to make science something that is “fun” and “intriguing” (Hampden-Thompson and Bennett, 2013), something that participants often cited as an important influence in their choice to study science. In contrast, participants “turned off” (Kate) when faced with teachers who were confusing or appeared enthusiastic.

6.3.2.2 “You just continually get spoon-fed academic information”

Upon entry to university study, some participants felt they had gaps in their knowledge, and this meant that they had to put in extra work to catch up. For example, Hakeem recalled not understanding what a term meant in one of his mechanics tutorials in his first year:

I was like getting stuck on some of the language they were using. Everyone else was like getting into it: ‘oh yeah we’ll do that’, and I was like ‘hold on’, but they are getting into it, they are solving it quickly... It was just a little thing like that. Yeah, like I haven’t been brought up in an environment where conversations were had a lot.
Hakeem’s experience shows how growing up with exposure to the language used in a field can enable students to engage more with it. It is important for high schools to prepare students for the transition to further study by ensuring they have acquired the cultural capital (including knowledge) that universities value. Stephen, whose educational journey saw him attend both a private, urban school and a public rural school, felt that some schools may adopt a culture geared towards preparing students for university above all else:

Stephen: ...at [Private School] you just continually get spoon-fed academic information making you go and do [university], like I know people in Knox College, Cambridge, doing like space engineering and Oxford and I’m like at Auckland because I didn’t have the grades to go to Cambridge. So there is a difference.

Me: There seems to be a drive from [Private School] or private schools in general maybe?

Stephen: Yes definitely. I like to call it spoon-feeding.

Me: Spoon-feeding yeah?

Stephen: You get spoon-fed a lot at [Private School].

Me: So is it the choice of the students to study that stuff do you think?

Stephen: I think it is a mixture. So basically your choice of studying what, but then you get spoon-fed. Basically the information gets you good grades and everyone goes off and does high stuff — so like engineering, law, or medicine those are literally mainly the three things majority of [Private School] students go and do those main three things.

In contrast, Stephen’s rural school did not offer the same breadth of content as his private school, and the subjects that he was taught were missing content. Similarly, Chloe felt that at her rural school “[university] wasn’t really a thing unless you wanted it to be a thing”. These experiences may be related to inequities in resourcing between schools, as suggested by Stephen: “at [Private School] I think they had like three or four chemistry teachers. At [Rural School] one chemistry teacher.” In contrast, Susan was given increased opportunity to study at the private school she attended: “They created our own class for us, which was taught by the physics and the chemistry teacher. [They] would alternate with us and
we would focus on scholarships and also do the rest of the internals.” The contrast in Stephen’s and Susan’s experiences demonstrates how inequality is built into the educational system. While middle/upper class families can afford to send their children to private schools that tailor education (“spoon-feed”) to prepare for them for high status jobs (“the high stuff”), schools that primarily serve working-class families may lack the resourcing to adequately prepare students for the same pathways (Thrupp 2015).

6.3.2.3 “He was a fantastic teacher, really got me into outside of just ‘science as the curriculum’.”

Participants enjoyed teachers who provided information on real life applications of science. Mark found that his teacher’s discussions about science outside of what was being assessed valuable:

He was a fantastic teacher, really got me into outside of just science as the curriculum. He would really try to show us what the real-life things of science were, what you could do in your day to day life, what science meant outside of just what they want you to learn for an exam.

Through these discussions, Mark was able to leverage value from his teacher beyond the value of passing an assessment. As described by Osborne et al. (2003) knowing applications of science in day to day life is valuable, while knowledge on the value of science in future employment is also an important form of cultural capital (Archer et al. 2015). Some participants were aware of the value in having social relationships with educators outside of the classroom context. Educators were able to answer questions on course content, provide advice on study techniques, and give insights on academic pathways. Susan, who developed strong connections to her lecturers at university after participating in a chemistry olympiad during high school, described the benefits of having connections with those with power in the field:

He is quite high up in university so he knows a lot… I just recently talked to him and so I don’t know if I’m going to be doing honours or masters, but I would consider masters first of all, but he suggested there is another pathway… He knows a lot about scholarships and stuff and had given advice about that. So none of it has really played out yet, because I’m still an undergrad, but it will be helpful especially next
year when I start applying for stuff to go overseas, and just insight into how that sort of thing works, because he went overseas for his PhD as well.

Through this social relationship, Susan was able to seek advice on pathways that would facilitate her future acquisition of institutionalised cultural capital in the form of degrees, and economic capital in the form of scholarships.

### 6.3.3 Peers

Unlike family members and educators, a student’s peer group offers a unique relationship in that they tend to be present across academic and non-academic contexts. As students progress through education, relationships with peers become increasingly important. While the value derived from peer relationships may overlap with that derived from family and educators, the dynamics are different. Students may feel a sense of solidarity with academic peers who are undergoing the same process, and the support and advice they receive from these social relationships may be more contextually relevant and tacit. Having peers who have studied at the same institution is especially valuable as they may be considered the most valuable resource in terms of providing insider information on an academic trajectory. A student’s peer network may also be an important source of both academic and non-academic support.

#### 6.3.3.1 “I can always ask how she got to where she was”

Through relationships with friends and academic peers, participants were able to gain more information on academic pathways, the support groups available to them at university, and what future careers looked like. For example, Mark recalled his Resident Advisor (RA) recommending that he attend lectures for more advanced courses to give him some idea of what the future could hold:

Mark: ...I know what English teachers do, [so] there is a sort of gravitation towards that [path] that an engineer doesn’t have, because there is a sort of a mystery of where that path is going.

Me: Well if you want to solve that mystery and try and figure out what an engineer does how would you go about that?

Mark: A suggestion that my RA had was that I go to lectures in later years for later years. So I go to stage 2 or stage 3 or stage 4 lectures
for possible different degrees, so I can see what they are actually learning, what their degrees entail, which I thought was really interesting because I still don’t really know what specialisation I could go into or where it is going to go.

Mark was able to learn a new strategy from his RA that could boost his knowledge of the field. Participants were also able to leverage value through the bridging capital offered by friends who had transitioned from university to employment. Alicia appreciated being able to share “thoughts and experience” with an experienced computer programmer she was friends with, while Belvia received valuable advice from one of her friends who had got a job in a field that Belvia was interested in:

...I can always ask how she got to where she was. I know what she did, like I helped her first get her starting place. Yeah it’s good because I can always [ask]: ‘so what did they actually ask in the interview’, ‘what is your job actually like?’ ‘Was it like uni, was it like what we learned and stuff?’ And yeah and she is really helpful. She said ‘maybe you can join, because this is what you have to learn, this is what you have to do and this is like the actual thing, and they will give you training and stuff.

Belvia’s connection to her friend was beneficial as it offered a model of Belvia’s potential trajectory should she choose to enter the same field. Through this relationship, she was able to learn more on the capital that is valued in the field.

6.3.3.2 “As long as you have got people you are close to, that’s fine”

Participants saw the benefit of having close peers who they were able to study with. Stephen, who recalled experiencing a lack of support in one of his high school classes, was able to draw upon the support of his classmates to help him: “[the teacher] teaches at a very high level to the point that he only chose specific people to work with, and it kind of got like the other 6 of us or whatever we kind of all fell back. But then we were able to manage to help each other out.” Lily recognised how the support she gained through her peer group with the MAPAS programme gave her an advantage in a context where students are typically isolated from one another:

...I feel like a lot of students are in their individual space in the course, and I have that support group there from the people I know from my
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course and from MAPAS, but you don’t see that for students who are not a part of that programme. I think there is a tangible difference between the group of us who have come through MAPAS and then the rest of the students who don’t really have that support group. So we always sit together as a group during lectures, and we all support each other through our learning, and we help each other out if we don’t understand things, have little study groups.

Peers may also offer support in a tacit manner, by offering role models for learning, or through vicarious learning experiences (e.g., learning through the questions that peers asked). Hakeem modelled his study technique on a classroom peer who was a high achiever:

...he just completely made use of his time, he got dux he got everything excellences. So I applied a bit of that, not as hard out as him, but from after crazy stuff happened in the second year, third year when I decided to switch to computer science, I really understood that I had to get good grades from now on, I had to really try.

Beyond academic support, participants were grateful for friends that offered them a general, everyday support, especially if they were lacking support in other areas of their life. Belvia turned to her friends for academic support because she felt unable to share her academic identity with her family because of their high expectations (“I didn’t want them to worry and stress”), while Stephen valued the support for his trans identity from his friend and their family: “She helps me and her family helps me through getting my identity right, and helping me through when times were tough with my family.” Hakeem, who sometimes found it difficult to connect with other students at university, found that having a strong relationship with his partner and a consistent group of friends outside of his university context was important to his success:

Hakeem: I am in computer science now and there is barely anyone who looks like me again, but I have gotten used to hanging out with different types of people. You can feel there is always this little gap there.

Me: What do you mean?

Hakeem: Between races in general, but it is not anything to be alarmed about, it is just natural. I think that racism and different types of
people are just distanced in a way from each other. That is just the way of life. As long as you have got people you are close to, that’s fine. My girlfriend has been huge in my life. As long as I have her and a few good friends I have had for a while since primary, I believe I am fine. I am not on an effort to make heaps of friends at uni, you know, as long as I am friendly to people and civil I can work with them then that is good enough for me. It is not really about that. It is true there is that gap but you can’t do anything about that really.

Hakeem acknowledged the difficulty in dealing with a context where he felt a gap between himself and his peers, and this experience has been echoed previously by other students attending university where they are in an ethnic minority group (Birani and Lehmann, 2013). Hakeem points to the strong forms of bonding social capital he holds with his girl friend and friends outside of university as valuable protective factors in his progression through university. This demonstrates the value that non-academic forms of social capital still carry within academic fields (Yosso, 2005).

Hakeem’s experience points to the way in which different aspects of ourselves are made salient when we are confronted with new fields of interaction. Feelings of difference may be exacerbated when there is a perceived lack of similarity between habitus and the culture in the field (Horvat, 2003). Although Hakeem felt separated from the culture of his university class, he was bolstered by other sources of social capital. The complex interactions between the different aspects of our identity play out in the internal system of dispositions that Bourdieu (1984) called habitus. The following section will provide a further examination of habitus. In doing so, I demonstrate the manner in which societal structures such as social class, gender, and ethnicity impact on the way in which students see themselves in science.
6.4 Habitus (Theme 3)

The social capital that students accrue not only provides access to resources, but it also influences the way that students see themselves in the field. Capital, which determines students’ position in the field, is internalised by students over time, and becomes embodied mentally within students’ dispositions towards the field (Bourdieu and Waquant 1992). The following section seeks to explore how students’ exposure to different forms of capital, as well as experiences of gender and ethnicity, are internalised and contribute to students’ sense of belonging in the field of science. This perception of belonging may relate to questions such as: What should people like me study? Will I be successful? How am I likely to be treated? Through habitus, we can reveal the different ways that these internal questions are informed by the external socio-cultural contexts in which students are placed (Reay 2004).

Students who hold high levels of capital in university science may feel an affinity with the field and see progression to university as “a path already drawn out” (Chloe) or “inevitable” (Susan). Students who identify as “smart” (Paul) or “academic” (Mark) may even feel like they have an obligation to study science. Those who have fewer connections may not feel like they belong, which may be manifested in feelings of not being “smart enough” (Patrick), questioning “should I be here?” (Renee), or not feeling “good enough for that space” (Hakeem). These feelings can be conflicting, as Helemonga described:

Helemonga: I feel like I belong in science but I haven’t convinced myself that I belong there.

Me: What would it take to convince you?

Helemonga: I don’t know. Probably someone, no I don’t think I need that.

Me: What were you going to say?

Helemonga: I was going to say like I need someone to convince me, but no I don’t think so. I think I just have to convince myself.

Me: And how would you do that?

Helemonga: I think I would do that by, I don’t know. I don’t know how to convince myself.
In this extract, Helemonga tries to put words to something that he does not necessarily understand, but just feels. This extract may offer an example of how habitus, whilst mostly operating “below the level of consciousness” (Bourdieu 1984, p.466), is brought to the surface through introspection. In many cases, the interviews provided an opportunity for participants to engage in a process of self-reflection. Helemonga initially described needing someone to convince him, but then he checks his response as he grapples with what he really feels. In this extract, Helemonga is not discussing a matter of access to capital or its value, but he is seeking within himself to what has been internalised. Helemonga’s response brings to light a key aspect of habitus, that while relationships with others are important, we also perceive that our convictions are self-directed. We hold within us both the internalisation of external structures as well as our agency. Following Bourdieu’s theory, I seek to highlight the manner in which our internal dispositions are influenced by our social relationships and access to other forms of capital. The following sections expand on the ways in which social relationships with family, educators, and peers may have been internalised by participants and shaped perceptions of belonging in science.

6.4.1 Family and Whanau

As outlined by previous theorists the role of family and whanau extends beyond being a source of social capital (Bourdieu and Waquant 1992; Dimaggio 1982; Archer et al. 2013a; Nash 1999). The values and culture espoused by the family are important in molding the internal dispositions that we hold, and the way in which we experience the world around us (Archer et al., 2012). As neatly described by Hakeem: “You are just shaped purely from who you are with your family.” Family upbringing provides one of the most important contexts for the development of habitus (Tomanovic 2004), and the values passed on through the family may either reflect or contrast with students’ own aspirations (Archer et al., 2012). The following sections discuss how some students felt an alignment between their educational aspirations and their family’s expectations, while others felt more of an obligation to their family to study science. Participants who felt an alignment tended to be those who wanted to study science and had high levels of science-related capital in their family. Those who felt an obligation to study science may not feel a complete affinity with the field, despite recalling how their family set them up to study in it. These two perspectives reflect previous research by McKinley and Madjar (2014, p.245), who point to the way that students may
be “pulled” to university by their own aspirations, or “pushed” towards it by their parents’ expectations.

6.4.1.1 “I feel like it was inevitable”

Having family or whanau who value science may help students see the field as somewhere they belong, and it may result in an alignment that makes progression in the field seem like somewhere they are destined to be. Stephen felt that exposure to science through his mother led him towards science: “…my mum has bought me books that are like science books, or taken books out of the library for me based on science. So I guess that is where I was kind of led to go.” Students who have family that went to university may be more likely to have a habitus that also aligns with that pathway [Bodovski 2014]. Susan recalled her parents’ excitement when discussing studying mathematics at university:

my parents loved to talk about it. I was very excited when I learned you could do maths at university when I was about 10. So I think it was always going to happen. I was going to kind of, I mean it wasn’t something I decided then, but I feel like it was inevitable.

From an early age, Susan was exposed to the idea of a university trajectory, and even though she did not make any decisions until later, the alignment made it seem “inevitable”. Lucy felt the same way:

I wanted to study physics since I was 7 years old I think. I used to be really interested in astronomy when I was younger and I told my parents when I was 7 that I wanted to be a physicist and I always stuck to it. I think I kind of see it all around me.

Given that early childhood experiences cast a strong influence over the development of habitus, students who have early exposure to the science may be more likely to develop an affinity with the field. With a strong embodiment of science within their habitus, students, such as Lucy, may also be more likely to see the relevance of science in their everyday life experience (“I think I kind of see it all around me”).

Beyond traditional depictions of family-related science capital [Archer et al. 2012], participants also reflected on how broader familial values may signal that science is a good path forward. Sean recalled how his decision to study medicine was in part influenced by his family’s religious values (“I’m encouraged to be more
Christ like in our church, and one way to do that is to help people.”) and an urgency to address health inequities in the Māori community:

One big reason I did pick medicine as well is because I wanted to help people out, not just the general population, but more my family and stuff. So there is like a huge difference in like the health of Māori and Pacific compared to other ethnicities, other populations. That is one thing that did influence me a bit.

Awareness of inequity and the need to contribute to addressing this issue was a common driver for many participants. Lily felt that studying health was a “logical pathway” once she became more aware of how she could help Māori by being a part of the health workforce:

I wasn’t really introduced so much to the health disparities until I came to university, but I knew there was an idea I could actually make a difference and kind of help people out by going into a health profession. That was my main thing was I wanted to go into a profession where I help people. I was quite strong in sciences while I was at school as well, so it kind of seemed like a logical pathway.

These experiences highlight the value of cultural assets related to community cultural wealth, specifically the value in serving Māori and, as Chloe described, “breaking the cycle of poverty” and reducing inequities. This brings attention to the opportunity that science education has to align with communal utility values (Osborne et al., 2003).

6.4.1.2 “It was not my choice it is my family’s choice”

Some participants signalled that their study decisions may not be fully reflective of their own aspirations, but may be mainly informed by an obligation they felt to their family. While these participants may still see the value in the subjects that parents led them towards, often participants were still trying to discover what they really wanted to do. This was stated explicitly by Alicia, who recalled originally enrolling in a commerce degree because “it was not my choice it is my family’s choice”. Pressure was not always explicit, and may just be felt vicariously. Paul felt the pressure of following in his father’s footsteps from his grand parents: “there are constant reminders, your dad has done all this stuff”. Some participants felt
“pushed” (Diana) towards areas of study that aligned with parents’ perceptions of which domains are prestigious, mainly medicine, law, or engineering.

Some participants felt implicitly pressured to continue the social mobility that their parents had undergone, a theme common in other research (Convertino and Monarrez, 2020). Diana, who was the first in her family to go to university, recalled the expectation her mother put on her:

She wanted to go to university but she couldn’t because they didn’t have enough money or anything. So she kind of worked her way up, a lot of self-taught stuff... she really pushed me to go to university, like no matter what I was doing. She didn’t care what I was doing as long as I went to university, but my dad was like you don’t need to go you can just be a tradie.

Diana’s experiences hint at the ways in which parents may share their perception on what it takes to be successful in the field, and how university provides a gateway to further social mobility.

Bourdieu stated that in order to get ahead, some families may sacrifice aspects of their lifestyles to boost their accumulation of capital in other areas (Bourdieu, 1984, p.334). Some participants described how their parents changed their lifestyle so that they could attend university. Belvia’s family emigrated to Aotearoa New Zealand for this reason:

...the way I grew up, you need to have money, you need to have like a good job in life, and others need to see that you have a good job in life.

Me: Do you feel like you had a choice?

Belvia: No it is not like they forced me, but because the way they hinted it, and the way they were like: ‘we only came to New Zealand so we can go to this uni.’ I feel like I kind of didn’t have a choice, even though I did, but they would be disappointed. It would be like coming to New Zealand would be a waste if I didn’t even do what my parents wanted me to do.

The cultural values held by her parents were internalised by Belvia, including their expectations that she would attend university. While she acknowledges that she was not forced, we can see how Belvia’s habitus leaned her towards a certain pathway and it may not fully be her “choice”. The responsibility felt by students
may be more conflicting when students hold aspirations that differ from what is expected of them. Mark, whose mother in particular viewed him as the “academic child”, felt a responsibility to study engineering at university:

Mark: ...my later years at school my best subjects were English and classics, not maths and physics. Yet I’m still here doing an engineering degree.

Me: You never thought of doing English?

Mark: I considered it, I thought that I could, but I think I may have put in my survey how it was, I guess, sort of pressure... I felt more so from my mum that I would have to do engineering, that engineering was a better degree to have because obviously there would be better job prospects and all those sorts of things. I could have really enjoyed becoming an English teacher or something because I enjoy that aspect of it, but I guess I am able to do engineering — like both literally able to do it and in a more mental academic sense I will get through that, and I do enjoy maths and that side of it... I feel when I say the social pressure to get the good degree, I still know inside that I feel like if I really wanted to, if I was really held against my will, I could do a different degree, but it is not that science it is like my only choice. Like I have definitely gone into this willingly and it is my decision.

Mark’s introspection on why he chose engineering over English reveals how habitus guides the decisions we make. While placing emphasis on the agency he had making his decision, Mark also considers how various aspects of his life experience, especially his mother’s expectations, played an influential role in his idea of what he should be studying. His habitus, informed by his embodiment of capital (“I am able to do engineering”) and social pressure to enter into a prestigious domain, lent him towards engineering.

6.4.2 Educators and Role Models

A wealth of research has shown that educators play a large role in influencing students’ identification with a field of study. Following the analysis of interview data, the role of educators in influencing participants’ belonging can be split into two sub-themes. Firstly, participants commented on the importance of seeing role models in their field who they can aspire to be like. Secondly, participants also reported on the impacts of feeling seen, or not feeling seen, by their educators.
6.4.2.1 “I never had someone in real life that I could look up to”

Identifying with an educator may help students identify with a field of study (Crosby, 2000). In the current study, some participants recalled their happiness when they realised that lecturers were just regular people, such as Renee: “seeing they’re normal people that just spend their lives doing the things they are passionate about was cool”. The perception of lecturers as “normal” points to the importance of reducing the common perception that science is a career that is only open to individuals who are ‘one-of-a-kind’. Identification with educators provides students access with bonding forms of social capital that signify that what scientists do is actually realistic and achievable. While students who grow up with academics in their family already have access to these sources of bonding social capital (Bodovski, 2014), students who are first in their family to attend university may experience more discomfort and find it more difficult to acquire (Jensen and Jetten, 2015).

The bonding social capital that students access through their educators may be especially important if a student perceives that they do not represent the typical student in the class. Stephen, who is trans male, felt inspired when he had a lecturer who openly identified as trans.

Stephen: I find that science it doesn’t matter who you are, like even for one of the lecturers — [Lecturer] — I just had her for the stars part of physics [Course], and honestly I look up to her so much because I would not be doing it...

Me: Have you spoken to [Lecturer] at all?

Stephen: I spoke to her once which was after the first lecture we had. I went up to her and said thank you so much for being who you are and I shook her hand and then I left and like fan girl mode, oh my god.

Me: So it really helps having a role model?

Stephen: Yeah because I never had someone in real life that I could look up to, when I wanted to be looked up to from all these young people, I never had someone older than me I could look up to and see myself becoming someone like them one day. I was like oh finally someone I know I can look up to.

For Stephen, exposure to a role model acting out their identity in a position of power signalled to him that his identity was accepted in science. In terms of
habitus, seeing this lecturer would provide Stephen with evidence that he does belong in the field of science.

6.4.2.2 “He looked at me and did that little like smile thing, like a recognition”

Explicitly supportive actions on the part of educators can signal to students that they belong in the field, while feeling seen by educators can be particularly powerful. Renee detailed one such experience:

Renee: ...he looked over at me and he must have recognised me, because when I went up to see [previously] him I tripped over. So that was like another thing that just ingrained my face, and he looked at me and did that little like smile thing, like a recognition, and I was like that is cool he remembers the conversation we had and he remembered me.

Me: So he knew who you were?

Renee: Yeah in a big lecture hall full of people a first year course — that is cool.

Educators may signal to students that they do not belong in the field, intentionally or otherwise. Belvia did not want to engage with her tutors due to unpleasant past experiences: “sometimes the tutors weren’t [very nice], some of them I felt I was dumb asking questions.” The reactions of Belvia’s tutors to her questions made Belvia feel that her attempts to build capital were disparaged, and this was internalised as feelings of inferiority (“I felt I was dumb”). In other cases, negative interactions with educators may explicitly tell students that they do not belong. Patrick was told by one of his teachers to drop out of school. While this comment would obviously be detrimental to Patrick’s motivation in education, the perception of apathy that Patrick felt from his teachers is an especially damaging indictment of his educational context:

Patrick: I used to tell all my friends back home I would never go to uni.

Me: Why would you say that?

Patrick: Because I had a bad experience at school, I didn’t like high school. So I didn’t really think I would come here.
Me: If you could go back and talk to your teachers now, what would you say?
Patrick: I probably wouldn’t talk to them honestly.
Me: You just wouldn’t talk to them?
Patrick: Yeah.
Me: Would they be surprised that you came to uni?
Patrick: Most of them wouldn’t probably care honestly.

The lack of expectation and care that Patrick felt from his teachers at high school was a powerful signal that he did not belong in education. The apathy he felt from his teachers suggests a total disengagement from institutions towards Patrick, to the point where Patrick felt like he had no position in the field, let alone a trajectory to follow.

6.4.3 Peers: Support or Competition

Participants’ relationships with their peers played a significant role in how they saw themselves in science. Participants’ identification within a group of friends or cohort of students could be both beneficial and/or debilitating. The context of university played a role in students’ identification with the field of science, with some participants feeling comfortable at university, and others reporting feeling isolated from their peers whilst simultaneously in competition with them. Group work provides an opportunity for students to increase their social connections and sense of belonging in the field, and the experiences detailed by participants highlight how these engagements may be internalised positively and negatively.

6.4.3.1 “We all support each other through our learning”

Participants recalled the way in which their lifestyle could be influenced by the norms of their friendship groups. This reflects a “bonding social capital”, where individuals derive value from inwards-looking networks that reinforce a group identity. Having friends who were also academic allowed participants to share their experiences of education, making the academic aspects of habitus salient. This in turn may lead to the development of attitudes that are valued by educational institutions, as Kate recollected: “they called us the angels because we were quite like the goody goods... I started to have more responsible and disciplined mindset, not just academics wise but like social wise”. Kate’s recollection describes the
manner in which peer groups reinforce different aspects of habitus. Kate recognised how her friendship group transformed her ‘mindset’ to one that saw value in education, as opposed to non-academic pursuits. Signals of encouragement in response to academic pursuits may help boost a student’s belief that science is what they should be doing.

Group work provides one context where students are able to build social capital with their peers and develop a group identity. Group work benefited students when they had the opportunity to get to know each other, as Hakeem outlined:

I had the same group, I had two girls in my group and yeah I guess we got to know each other and I found out they are not super geniuses. They are not this level above me. We all just got along and solved [the problem], and we got a good mark in the final assessment. Yeah so maybe it was just the fact of getting to know the people more as engineering got along. Yeah I got to know people and you get more confident.

Having the opportunity to form connections with other students helped Hakeem build a bonding social capital that built his self-confidence. It also gave him knowledge that his position in the field was not under threat, he was not competing with “super-geniuses”.

Voluntary tutorials offered to Māori and Pasifika students (such as Tuākana and the MAPAS programme) offer good examples of how group work can foster a collective group identity. As Lily pointed out: “we always sit together as a group during lectures and that, and we all support each other through our learning”. These tutorials helped build a community of learners. As Chloe highlighted, Tuākana offered an environment where things are not as “cliquey” and students are able to develop relationships more easily:

I find in Tuākana labs everyone talks to everyone, and everyone sits everywhere. It is a lot more intimate I suppose, because there are normally like 15 or 20 of us as opposed to like 50.

Me: How does that make you feel as a student who is learning?

Chloe: Just a lot more included and relaxed, and just eager to participate rather than being scared to say something wrong.

Providing this environment can facilitate the formation of social relationships and help develop a supportive group identity.
6.4.3.2 “You are worried about what they are thinking of you, and how you perform.”

Many participants recalled the manner in which university fostered an environment of competition and isolation. For some participants, peer interactions were high stakes, high pressure, highly uncomfortable engagements. Hakeem described his feelings when he first started his degree in engineering: “the environment kind of like engineering, if you got into engineering you should know your shit... because the entry was so high, I just felt everyone had to be onto things”. Chloe detailed the extent to which competition led to an unwelcoming, and explicitly unfriendly, atmosphere: “people just stealing people’s notes, or if you left your room unlocked like your laptop would go missing. You could not trust anything at any point” In most cases, the negative impacts of competition were felt implicitly: “you can just sense it” (Chloe).

In other cases, group work could heighten the pressure to perform or exacerbate feelings of being different. Chloe felt that certain students dominated group work:

Chloe: I find myself gravitating towards people who are not so outspoken. I suppose being in second year now you know faces, you know people, lecturers blah, blah, blah, so everyone knows, there are certain students who want it. So most people will find themselves avoiding them when in groups because you won’t get any say or you won’t get any input, it is kind of like driven by the people who are competitive.

In other cases, students may not get a choice in who they work with, which can make it more difficult to find like-minded peers. Hakeem discussed how changing groups regularly was a daunting experience: “you are worried about what they are thinking of you, and how you perform.” Changing groups regularly was also confronting for Stephen, who recalled needing to “take a step back”:

...the studio physics two hour [tutorial], that kind of scares me because obviously since we get new tables every four weeks only the people that knew me the first four weeks would know I’m trans, and now I’ve got a whole new set of people and I’m like a bit confronted by them.

In representing a minority group in science, Stephen was continually faced with the task of justifying his identity to new people, while the chances of him being referred to by his dead name were also increased. Perceived conflicts between a participant’s identity and their peers may lead to feelings of being an imposter...
in the field. For example, Belvia described her feelings of being the only girl in a computer science test: “the room was full of guys and they were all like Asian... I was the only girl and I went oh my god... I felt so intimidated, like I am the only girl here I feel like I am going to be so dumb.” Feelings of imposterism following peer comparisons may relate to common sense notions of “who a scientist is” and “who is good at science”. The pervasive discourses that permeate society relate to Bourdieu’s concept of doxa. The concept of doxa is discussed further in the following chapter, which summarises participants’ experiences interacting with the field of science, both in terms of the common discourses they perceived, and the way that they navigate relationships with those in power to further their accumulation of capital in the field.

6.5 Summary

This chapter has discussed the experiences that undergraduate science students have in accessing social capital, leveraging value from those social relationships, and how their access to capital influences their internalised dispositions and feelings of belonging in science. The recollections of participants provide an activation of the theory outlined in Chapter 5, and provides a more detailed picture of how science capital impacts on students. Through these interviews, I provide some ideas of why students choose to study science, and why students may feel that science is a field that is ‘for them’ or not. These interviews also add a more nuanced description to the key findings from Chapter 4, which pointed to the key influence of social relationships with teachers, peers, and family (in particular, academic family background), on students self-concept in science. The following chapter will now explore the lived experiences of participants in relation to the final two themes in the theoretical model, which concern students’ experiences interacting with the field of science.
Chapter 7

Experiences Interacting with the Field

Preamble

The following chapter follows on from the same qualitative analysis discussed in the previous chapter. The focus of this chapter is to now look at how general discourses in the field impacted on participants’ sense of belonging, and how this may influence future interactions in the field. It is in this chapter that I try to provide individualised details to the broad trends discussed in Chapter 2 and 3. For example, these trends showed that medicine seemed to be a more sought after field of study for students (especially high-achieving students), and female students tended to be underrepresented in physics and computer science. With Chapter 7, I now provide some insights from students in the field that can make more meaning out of these trends. This chapter focuses specifically on Themes 4 and 5 in the theoretical model (Figure 7.1) which cover the influence of doxa (societal discourses) on students, and the manner in which students accumulate capital. I must also acknowledge the contribution of Loreen Sonji Magariño¹¹ who provided valuable feedback on this chapter.

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Figure 7.1: Theoretical Model (Themes 4-5). The final two Themes in the theoretical model point to the significant and pervasive influence of doxa on students’ experiences in the field (Theme 4), and the manner in which students seek to accumulate capital in the field (Theme 5).

7.1 Introduction

The previous chapter discussed the manner in which students access social capital, leverage its value, and internalise capital via habitus. I closed the previous chapter with a brief discussion of the feelings of imposterism that may occur when students see a mismatch between who they are and their common sense notions of “who a scientist is” and “who is good at science”. As outlined previously, students who are able to utilise the value of capital may be more likely to feel an affinity with the field, while those who are less able to leverage value from capital may be more likely to see progression in the field as unrealistic. The following chapter seeks to dig deeper into the way in which ‘common sense’ discourses present in the field of science education impact on students’ affinity with the field. Through the voices of the participants interviewed, I will explore how pervasive discourses in the field, or doxa as Bourdieu (1984) labelled them, can either enable or constrain students’ progression. The current chapter will then describe how participants’ experiences of doxa, along with factors related to capital (outlined in Chapter 6), influence the future generation of capital in the field.
7.2 Doxa (Theme 4)

Outside of the social relationships that students hold, general discourses in society influence the development of habitus. Feelings of being an “imposter” in a domain are often viewed as individualised, private issues, isolated from social contexts, but it is important to emphasise that these experiences are grounded in public discourse (Breeze, 2018). Bourdieu referred to these general societal discourses as doxa, beliefs that are taken as a given. For example, science is often viewed as a male discipline, and arts are often viewed as more feminine (Nosek et al., 2009). Doxa may refer to common perceptions of different subject disciplines, and the ways in which they are valued or devalued in society. Doxa may also refer to common stereotypes of what is expected for members of different social groups. In the current study, participants were well aware of the common societal stereotypes that operate within the field of science. Mark described how even though stereotypes do not make sense, they still inform the world that we see: “I know that it doesn’t make any sense and that is dumb, but then I still kind of from a distance view that”. The following sections will discuss the participants experiences of doxa. It will begin by detailing the influence of a hierarchy of legitimacy that operates across subject disciplines that serves to channel students in and out of science. It will then discuss the various depictions participants had of scientists and how these may align with their own self-images. The following section will then highlight the potential overlapping influences of ethnicity, gender, and social class on the relationship between doxa and students’ aspirations, using the cases of Chloe and Patrick as comparative cases.

7.2.1 “Arts would have been more easy, but I just hate arts”

Many participants recalled a sense of what subjects tended to be held in the highest regard. Some participants, such as Lucy, saw value across both science and art domains: “I would say if you are an artist I think it would be easy to be good at physics, because it is like you create your own little world.” In general, however science was often perceived as being held in a higher regard than art subjects. This doxa is manifested in a Hierarchy of Legitimacy, where arts subjects are denigrated and science subjects are elevated. Some participants endorsed this idea themselves. Sean felt that studying art at school would have been easier than science, but ultimately less useful:
Sean: Yeah oh arts would have been more easy [than science], but I just hate arts.

Me: Why do you hate arts?

Sean: They seem like such a waste of time to me.

Me: Why is that?

Sean: A waste of my brain.

Me: A waste of your brain?

Sean: A waste of time for me.

Me: Is that because you knew you wanted to do the medicine side of stuff before?

Sean: That, and it just seems like not as structured as science things are.

Me: Can you tell me what you mean by structure?

Sean: Structure as in there is a set answer for this, like there are certain ways to go about working out this problem and you can’t use something else. Arts just seems like just whatever you want it goes I guess.

Sean’s response reflects a commonly held discourse that art subjects deal more in value judgements that are contentious and contextual. Scientific knowledge, at least as it is defined through the perspective of Western Modern Science (WMS) (McKinley, 2005), is perceived as having a “structure” that is universal and applicable across contexts. It may be that the imposition of this structure brings with it a legitimacy, while art is not perceived as an area that requires an institutionalised approval (“whatever you want goes”). WMS, with its perception as a formalised process, may be more amenable to being presented as absolute knowledge (Bleazby, 2015, p.674) that is worth more. The perceived structure of science may also lead to the view that university education is needed to legitimately engage with the subject, as Diana mentioned: “I was pretty much told like science would be a better option if you want to do it, like I would probably have a waste of time to go to university and study art when if you really liked it you could just do it by yourself.”

While historically, subjects such as mathematics and science have dominated the hierarchy of legitimacy in terms of subject area (Bleazby, 2015), participants in the current study often pointed to medicine, law, and engineering as those
commonly known as the most prestigious\footnote{This perception reflects the findings from Chapter 2, which found that high achieving students from high school, especially high achieving female students, tend to pursue pathways towards medicine, rather than subjects such as physics.}. Some participants felt encouraged, or even pressured, to enter into these domains. As described in the previous chapter, Mark felt the pressure from his mother to enter into engineering (“I felt more so from my mum that I would have to do engineering, that engineering was a better degree to have because obviously there would be better job prospects and all those sorts of things.”). Although Mark felt equally capable of doing English or engineering, he may have felt that not pursuing the more prestigious subject would lead to him missing out on the best returns for his investment in education. As summarised by \cite{Bourdieu1984}: “The more legitimate a given area, the more necessary and profitable it is to be competent in it, and the more damaging and ‘costly’ to be incompetent.” Fields such as medicine, law, and engineering are be commonly viewed as the investment that can return the most capital for students (and their families) by providing increased job prospects. Jay theorised on what drives this discourse:

Jay: it is like a stigma I guess that if you don’t do one of those three [medicine, law, engineering] you are ‘sort of below’. I’m not saying I believe that, it is just what was going around, especially at my school. I guess for sort of the people who were a bit smarter.

Me: But you didn’t have that same kind of belief?

Jay: No I don’t think that, but a lot of people I know would sort of, not so much look down on people, but they would look down on themselves if they were to do something that wasn’t those three.

Me: Where did that idea of looking down on yourself, or looking down on people to studying subjects, but where does it actually come from? Do you have any hypothesis for why that would be?

Jay: I guess it would be to do with money I guess. They see somebody earning more money, you know, everybody wants to maximise the amount of money they earn. So take an artist for example they would see that as art. They don’t earn as much money as I could as an engineer, and the engineers are superior to an artist sort of thing.

Jay’s comments suggest that prestige is determined mainly by returns on economic capital, where success is viewed in terms of “maximising” the amount of money

being earned. Entering into illegitimate fields may not only mean fewer returns, but it may also become an internalised status indicator — that you are “sort of below”. Jay’s hypothesis reflects how it may be seen as “costly” (especially economically) to enter a field that is not viewed as legitimate, something that Belvia felt her parents believed:

They think science is where you get the money, and they just want the whole security stability thing. So they are like: ‘science is the better option than like commerce’ or whatever. They would never let me do art, I guess they would but they would be so disappointed.

The prevalence of this doxa can thus constrain students’ choice, especially if the doxa is endorsed by the family. Brenda argued that this hierarchy of legitimacy may be especially limiting for students who do not have the finances to risk investing in a less legitimate field, such as arts:

I think people who can afford to follow their interests are the ones who do things that are not as well paid, unless they are really passionate. It is hard to give up making a living for something you actually like if no one gives you that opportunity. Like people don’t take arts degrees because they don’t think they can get a job afterwards, even though they might even love the arts. People take art subjects and people take science subjects but I don’t know if people take science because they love science or because it might pay more.

While the hierarchy of legitimacy concerns a doxa that operates across different subject disciplines, many participants discussed common discourses that are prevalent within the discipline of science.

7.2.2 “You want to basically be the guy in the white coat”

In addition to the general discourses participants felt in terms of the legitimacy of science as a subject area, participants also presented different suggestions of what a typical scientist looks like. Many participants depicted scientists as being “nerdy”. While these points of view were often informed by typically held stereotypes, they were also realised in participants’ everyday experience. Renee felt that one of her high school science teachers manifested many characteristics of a stereotypical physicist:
He was a very eccentric teacher. He was definitely a physicist, like he fitted the part. He wore a suit and a very eccentric tie every day, and at the start of every lecture he would like talk about his tie and a story about how he got it, and he was bald and he had a little physics mono brow going on, you know, that stereotype.

Renee’s reference to her teacher “definitely being a physicist” and fitting a stereotype points to the prevalence of a commonly held discourse. The eccentric tie and the “physics monobrow” echoes common depictions of scientists as “mad” in historical western literature (Haynes 2003) and media (Weingart et al. 2003), something which Renee touched on:

Me: You mentioned the phrase physics mono brow and I really enjoy that. Can you tell me a bit more about what do you think a physicist looks like?

Renee: Kind of like, I don’t know, it is a very stereotypical view, but quirky, a bit of like nerdy. I don’t know, the people in my physics class like half of the blokes wear like knitted grandma jerseys and they are very much like spectacles. I don’t know, just the typical what you see in movies is the physicist. Yeah that is what I picture, that is why I sometimes sit in class I’m like should I really be here? Should I be looking more like them? I don’t know it is very odd.

Renee’s recollection provides an example of how stereotypes are manifested in real life, and how this impacts on students’ sense of belonging. Discourses referring to scientists as white, male, and nerdy are common (Dudo et al. 2011; Nosek et al. 2009), and this doxa may render the field of science as “unthinkable” for students who feel they do not fit this ubiquitous notion of who a scientist is (Archer et al. 2013a).

Participants in the current study also tended to view scientists as hard working and clever. Participants who held a high affinity with science felt more comfortable with the idea of embodying these depictions of a scientist. Some purposefully chose to physically embody a value of science (e.g., having a science-related tattoo), while others aspired to develop into their image of a scientist. As discussed by Paul:

Paul: I was really against the idea of becoming an engineer just because I don’t want to wear a hard hat.

Me: Why is that?
Paul: I don’t know, I never pictured myself as the outdoors field guy, I always pictured myself as, you know, indoors.

Me: What do you think influenced that perception of yourself?

Paul: I guess growing up in the Philippines and seeing all those urban development’s going on, and how hot it was outside. Growing up there was, you know, I always thought of myself as a smart kid growing up, and you do what the smart kids do I guess, you know, you want to go to Harvard, you want to basically be the guy in the white coat.

We can see how Paul sought to follow his preference for working indoors while aligning himself with what the “smart kids” do. For Paul, the common perception was that smart people go to prestigious institutions and wear “the white coat”. While some students, like Paul, are comfortable with discourses portraying scientists as smart individuals and seek to follow that path, these discourses may make other students more uneasy. Renee suggested that introducing science to students earlier in school would give students more time to realise that you do not not have to be a “one percentile kind of person” to succeed in the field:

Me: How do you think that [teaching science] could be improved then?

Renee: Definitely introducing the three sciences to Years 5 and 6, the last years of primary school, just to familiarise the students with the concept of like this is a possibility, this is a thing, this is how the world works, rather than getting to Year 10 and doing the subject called science and then hearing the word physics. When you grow up, you hear physics and you are like ‘Albert Einstein’, like real smart, one percentile kind of a person and being a bit overwhelmed by that.

Me: So that is what you see when you think of physics?

Renee: When I think of physics I think you have got to make discoveries to get somewhere, but then slowly as I’ve gone through uni I have realised that is definitely wrong, do you know what I mean? But that is what I thought all the way up until enrolling in my second year of uni.

Renee’s depiction of the ‘hero-scientist’, the idea that science is a discipline produced by a selection of geniuses, is a common discourse (Traweek 2009). As a result, students may be fearful that their own capabilities will not match those of
“real scientists” or be inadequate to “win admission to the community” (Traweek, 2009, p.75). As Renee suggested, students who are exposed to science late may be more reliant on doxa to inform their perceptions of a subject. Indeed, students who learn about the struggles and failures of scientists, countering the notion of the hero-scientist, have improved learning outcomes (Lin-Siegler et al., 2016). The following section will expand the various ways in which doxa impacts on students who do not feel that they match typical representation of who a scientist is.

7.2.3 A Culture of No Culture?

In her book *Beamtimes and lifetimes*, Sharon Traweek details an ethnographic study of high energy physics laboratories in the US and Japan (Traweek, 2009). She observed how the world of high energy physics presents itself as having a culture of no culture: “an extreme culture of objectivity: a culture of no culture, which longs passionately for a world without loose ends, without temperament, gender, nationalism, or other sources of disorder - for a world outside human space and time.” (Traweek, 2009, p.175). This represents a common depiction of science culture, where it is often assumed that scientific knowledge is generated dispasionately, outside the influence of social context or politics (Stewart, 2017). This perception was shared by Alicia when she described what computer programmers are like: “Well they are kind of nerdy. Their personality is very simple, you don’t need to involve any office politics.” Discourses suggesting science is an unbiased field with no discerning culture are common, but this does not reflect the experiences of those individuals who do not fit in the ubiquity. For example, science has typically reified the idea “that science is the product of individual great men” (Traweek, 2009, p.78), whilst simultaneously perpetuating negative stereotypes regarding the competence of women in the field (Blickenstaff, 2005; Moss-Racusin et al., 2012) and devaluing indigenous knowledge (McKinley, 2005). Furthermore, efforts to bring attention to faulty biases and negative doxa may be interpreted as political acts. As argued by Bourdieu (1984, p.426): “The advocates of change are forced to spell out their heretical opinions in broad daylight, in defiance of the doxa, the ordinary acceptance of the usual order which goes without saying and therefore usually goes unsaid.” Students from underrepresented groups can thus face demands to fit their appearance to what is typical in the field of science, as Ong (2005, p.598) suggests: “matters of gender, race, ethnicity, social class, immigration status, and sexual orientation have no acknowledged place in
this cultureless culture”. The following sections will discuss how participants saw themselves fitting within the culture of their respective fields.

Some participants detailed how the conventions in a field dictated what was expected from them in terms of physical appearance. Helemonga, a biology student from Tonga with aspirations of becoming a forensic scientist, recalled his experiences working in nursing, where he was in the minority in terms of gender and in the way he wanted to present himself appearance-wise:

Helemonga: ...there are only 5 to 4 male nurses every year, in every class, and I was one of them and usually you have to, in Tonga, you have to be proper. Like your hair has to be short, you don’t wear makeup plus you don’t have like tattoos and nose ring and earrings if you are a male nurse. But I don’t give a damn I still wore my uniform with my tattoos and stuff like that.

Me: Do you think people reacted to the rules in the same way that you did?

Helemonga: No it was just me, because I don’t think tattoos and long hair affects your working skills. I think being with patients, that is up to your brain, and your hand, and your heart. Because I don’t think your physical appearance affects anything at all, do you think so?

Helemonga was required to confront how aspects of his identity did not fit with the common discourses about who can be successful in the field. Helemonga persisted in presenting himself in a way that aligned with his own values and not the prevalent culture of the field (“I don’t give a damn”). The doxa dictated that nursing is for female students who are “proper”. “Proper” points to Helemonga’s recognition of the dominant cultural capital in the field which may not be entirely explicit, but still guides how individuals in the field should present themselves. Helemonga demonstrated a resilience to this doxa, which highlights how manners are the “stake in a permanent struggle” ([Bourdieu](1984) p.61) to establish what is valued in the field. Helemonga argued that appearance should not be dictating success in the field, and that cultural capital should be defined solely in terms of how you treat patients (“I think being with patients, that is up to your brain, and your hand, and your heart”).

While Helemonga’s experience reflects the impact of more formal and explicit rules on appearance, doxa related to appearance can be felt more implicitly. Mark, an engineering student with a high level of science self-concept, discussed why he
gave a low score on a questionnaire item which asked whether his friends saw him as a “science person”:

Me: ...you don’t see as much that your friends see you as a science person — can you unpack that a bit?

Mark: Yeah so some of these I was in two minds. I think there were a couple I put directly in the middle because some people would put me at this end, at the high end of the scale, and others would put me at the very low end of the scale. I was unsure with science because some of my group from high school, most of them are doing engineering and might class me simply because I did those subjects at school. But then in terms of recognition, like when they joke about who looks like a nerd or fits those sorts of stereotypes, they often don’t really think of me as someone who is highly academic. I somehow manage to do well in school, but they are like I don’t study as much. Some of my other friends are really studious, they put in lots of hard work and have whole exams and all that and I guess my relaxed approach can put me as more as someone not so focused, not so engaged as a scientist. And I guess more recently a part of me has changed my style — classic high school-to-university student changes the whole look about them — and I guess to some of my new friends and people I don’t fit the whole archetype of like nerdy engineering kid or something, I don’t know I’m just relying on stereotypes and how prevalent they are.

Mark’s experience details how doxa are realised in conversations with his peers (joking about who looks like a nerd), and passively felt when he considers how his “new friends” may perceive him when compared against the archetype of the “nerdy engineering kid”. At the same time, Mark sensed that his appearance may be at odds with these discourses, and against this archetype. Mark also felt that his embodied cultural capital did not fit (being relaxed as opposed to studious). Similarly, Belvia, who saw herself as an extrovert during high school, felt judged for being herself in her computer science class where students were not social:

Belvia: ...I just wanted to talk to people. Yeah I don’t know, I feel that experience of people not as open about themselves, and I feel like I became a bit more introverted. Like I can only be myself when I was in high school — they were like: ‘oh are you okay?’ and stuff. But here
I feel like people judge me — they are going to be like ‘what’s wrong with you?’ So I feel like I have to tone down myself, so yeah because of that I became much more quieter, and I try and make friends but wasn’t successful.

Me: Do you feel like that is a computer science thing or is that a University of Auckland thing?

Belvia: Sometime I feel like maybe it is a computer science thing, but I feel like if I did biomed as well — I heard stories about how people are just like trying to get into biomed it is like a competition. I feel like it would be the same in engineering. Again, I heard that in engineering people are just concerned with studying. Maybe if I did the papers with less people, some arts papers — you know how they have less people, I think it would be much closer.

Belvia’s recollections point to her perception that the embodied cultural capital that she holds is devalued in the field of university science. While it may be that the field of arts is more congruent with the outgoing aspects of Belvia’s habitus, the typical culture of competition and isolation within STEM fields, which are echoed in the “heard stories”, forced Belvia to change herself to fit in. The phrase “tone down myself” suggests that Belvia feels unable to be who she actually is, and has to offer a lesser version in order to fit in to the group.

Participants recalled the various ways that science, specifically subjects like physics and computer science, were signalled as being a subject “for guys”, while subjects such as nursing, as in Helemonga’s case, may be perceived as the opposite. Alicia, a computer science student, originally studied commerce following discourse prevalent in her family:

It is like a family choice, like okay girls need to do [a] girl’s job, like an office job. And my background, I’m the first one in my family [to] have a university degree. So they had no idea what to choose, and at the time I was 17 and I had no idea of what I’m going to choose. So that is why I just said to my mum, okay girls do [a] girl’s job. Actually when I was in high school I chose science subjects but I didn’t do [a] science degree.

Alicia’s perceptions about what a “girl’s job” is reflects pervasive public discourses that view science careers as masculine (Traweek 2009; Archer et al. 2013a). As
evidenced by Alicia, this doxa can lead to students excluding themselves from a domain, which in turn then reinforces that same doxa.

7.2.4 “You get put into a little bubble that you are going to be lazy”

Experiences of negative discourses were particularly salient among participants identifying as Māori and/or Pasifika, with these operating across the field of education and not just in the field of science. In general, Māori and Pasifika participants recalled experiencing a “lazy” stereotype. Chloe remembered the prevalence of this stereotype in high school: “you get put into a little bubble that you are going to be lazy, that you are going to drop out of high school, you are not really going to care about your chemistry grades.” This racist stereotype is a common experience for Māori and Pasifika students in Aotearoa New Zealand. In wider society, Māori and Pasifika are more likely to be stereotyped as less competent (Sibley et al., 2011), with mainstream media often unfairly promoting negative stereotypes depicting these groups as unskilled (Pack et al., 2016). In education, Māori and Pasifika students commonly report encounters with the same negative stereotypes (Webber et al., 2012; Mayeda et al., 2014). High school teachers may expect less from Māori and Pasifika students academically compared to their Pākehā and Asian peers (Turner et al., 2015), while experiences of “everyday colonialism and racism” continue to be prevalent at university (Mayeda et al., 2014, p.175).

In addition to stereotypes regarding laziness, and somewhat paradoxically, Māori and Pasifika students also have to simultaneously navigate discourses that suggest that they are “inherently physical and biologically advantaged” (Fitzpatrick, 2011, p.36). Consequently, Māori and Pasifika students may be more likely to be channelled into physical education subjects (Fitzpatrick, 2013). These subjects may provide increased opportunities for Māori and Pasifika students to experience success, whilst, as argued by Hokowhitu (2008, p.81), it can also limit their potential as learners in other domains. Hokowhitu (2004, p.268) outlines how this form of “positive racism”, has been historically used as a way of excluding Māori men from ‘intellectual’ pursuits: “Confinement to manual labor, combined with a general discourse that described tāne as inherently physical, led to generations of tāne thinking of themselves as ‘practical-minded’ and unable to relate to abstract thinking.” Consequently, Māori, Pasifika, in addition to working-class Pākehā boys, may be excluded from historically high status domains, such

3Māori men
as mathematics (Pomeroy, 2016). This doxa was touched on by some of the participants in the current study, who commented that male students from lower SES or rural areas tended to be pushed towards vocational careers instead of university. As noted by Stephen: ‘I think [boys] get stereotyped, especially from where I live, they get stereotyped into being a tradie or going for that and not going for the academic route... they should be because they are smart they don’t get encouraged’. This lack of encouragement was felt by Hakeem within his family:

Hakeem: From like primary to Year 10 Year 11 I wasn’t even remotely interested in getting good grades at all. The environment I was in, my family — I am an Islander guy — every Islander household I go to there is no focus whatsoever on education. It is non-existent. They say: ‘how is your day going?’ ‘oh yeah it went all right I got excellence in this’ — ‘oh cool’. But if I made the first 15 rugby, I win the game and I get player of the day it’s like big celebration big lunch. So the priorities are very different for Islanders. So that environment kind of shaped how I was from a young age right. You are just shaped purely from who you are with your family. So from primary to Year 11 it was all kind of rugby, rugby is a huge part.

Me: But science isn’t?

Hakeem: There was no kind of push, there is no push at all for me to join science engineering. It was just purely because I enjoyed physics and maths and I knew there was a good future for it.

Hakeem’s story shows how doxa manifest deferentially across cultures and contexts, and how it may be embedded, endorsed, and reproduced with the family. Even when feeling an affinity with science, the prioritisation of sport within his family was difficult for Hakeem to navigate. In choosing to study science, Hakeem may be viewed as an “edgewalker” (Krebs, 1999; Tupuola, 2004) — someone choosing to pioneer new ground and going beyond what was expected from his family (Mila-Schaaf, 2011 p.8). In a similar vein, I will now look to focus on the stories recounted by two participants in particular: Patrick and Chloe. The following section will detail how Patrick and Chloe sought to forge their own paths through science education. By focusing on these two specific accounts, I hope to highlight how students’ ethnicity, gender, and social class are complexly interwoven and result in unique academic journeys.
7.2.5 Exploring Overlapping Layers: The Stories of Patrick and Chloe

The recollections of participants emphasise that the impact of negative discourses are felt at the various, overlapping aspects of habitus, be that gender, ethnicity or social class. Individuals who represent more than one marginalised group in science may be the subject of “double jeopardy”, where feelings of not fitting in are especially salient. In a discussion of the impacts of social location of feelings of imposter syndrome, Breeze (2018, p.192) emphasises that:

> it does not follow that [feelings of imposterism] are felt equally or that the affect carries the same meaning across discipline, career stage, contract type, and intersections of class, gender, race and ethnicity, sexuality, disability, and factors such as caring responsibilities or first generation in higher education (HE) status.

For example, while discourses regarding science often refer to it being a masculine domain (Archer et al., 2014), it does not hold that these the expectations apply to male students from different ethnic groups and/or less affluent backgrounds. In order to describe the manner in which different layerings of habitus overlap and how this relates to the experiences of doxa, I draw upon two specific interviews with Patrick and Chloe.

Patrick and Chloe are two students who both identify as Māori, and moved from somewhat rural locations to study science at the University of Auckland. They both shared experiences with dealing with negative stereotypes regarding Māori growing up, but share very little in common in terms of their educational trajectories, other than the fact that they have both ended up at the university.

7.2.5.1 Patrick

Patrick is a computer science student. Although his father held interests in science as he was growing up, Patrick’s parents did not attend university, and Patrick recalled having very few links to people in science. Patrick found mixed support at school, which he felt was “sports-orientated” with less focus on science. His dean encouraged him, but another teacher signalled to him that he did not belong in education:

> Patrick: One of my teachers he literally just told me to drop out and start working.
Experiences Interacting with the Field

Me: Really?
Patrick: Yes, and that is something a teacher shouldn’t be saying.
Me: Why did he say that? Did he say that in a nice way or was it in a bad way?
Patrick: No it was a bad way. It was because I was really lazy as well I suppose, and then I hadn’t gone to school for like two weeks. So I was kind of behind on work and stuff, and then he just told me at the end of the class like maybe it is time for you to find a job.

The reaction of Patrick’s teacher to Patrick’s gradual disengagement with education was not met with a duty of care, but instead reflects the pervading doxa on what is expected for young Māori men — that pursuits such as manual labor (Hokowhitu, 2004) are a more realistic path forward than academic pursuits.

Patrick, who originally intended to join the navy like much of his family, left school at 16 and worked various manual labour jobs. It was this experience that convinced him to go to university to study computer science: “I worked in a saw mill with my dad for like two years, and it was a really hard job and I hated it. So that is probably why I ended up coming to uni.” However, this was not a pathway that Patrick originally saw himself going down. He recalled the way that negative stereotypes regarding Māori were felt deeply by his friends and family, and signalled to him that he did not belong at university:

Patrick: ..back home because I’m Polynesian, I’m Māori, whatever, a lot of Māori people back home think they are not smart enough to do science. So that is the reason I did science as well — just for that.
Me: Can you tell me a bit more?
Patrick: Growing up, because my parents didn’t go to uni and growing up, I don’t know, well for me I just thought I wasn’t smart enough to go to uni and smart enough to do a science degree and stuff like that. It is just kind of what is drilled into your head when I was growing up.
Me: How is it drilled? Like where does that come from?
Patrick: I don’t know, a lot of my family too, they just end up doing like labour jobs as well because I don’t know, they feel like they are not smart enough to do like science or whatever.
Me: How can that change do you think?
Patrick: I don’t know honestly. It is just really bad, a lot of people think that way. Well back home I know for a fact a lot of people think that way. Most of my friends were like ‘I’m not smart enough to do that, why would I go to uni, I’m just going to do a tradie job or whatever, a labour job’. I don’t know how that would change, but that is kind of the reason why I want to study science as well because a lot of people think oh you are Māori, you are Polynesian, you are not smart enough to do stuff like that.

Patrick’s experience illustrates how Māori and Pasifika continue to be subject of negative discourses that they are not “smart enough” to go to university. These discourses serve as an obstacle that disproportionately impacts on Māori and Pasifika students and shapes their educational trajectories. As detailed by Patrick, experiences of feeling not “smart enough” may point towards vocational pathways (Hokowhitu 2008), whilst simultaneously discouraging involvement in ‘intellectual’ domains such as science or mathematics (Pomeroy 2016). He recognises that his state of mind of thinking he is not smart enough is similarly felt across members of the same social groups (“a lot of Māori people back home think...”) which reflects Bourdieu’s concept of a classed habitus. Whilst, broadly speaking, classed habitus may explain why members of the same social group hold similar dispositions and potentially behave in similar ways (Reay 2004), it is important to highlight that students may be exposed to similar experiences but react differently. In an effort to elucidate the diversity of ways that students grapple with negative doxa, I will now discuss the experiences of Chloe.

### 7.2.5.2 Chloe

Chloe is a psychology student. Chloe comes from a family of three generations of Māori academics. Her parents attended prestigious institutions and she felt strongly that her family have always expected the same of her:

So growing up, I actually don’t know anyone in my family who didn’t go to university, except probably I know one person and he ended up in jail. So my family it was very like university education is the only way to go. I was brought up I was groomed that you go to university you get a job and that is how you become successful.

While Chloe’s was “groomed” to go to university, she still felt that her choices were limited by her parents expectations. She originally wanted to become a dancer:
I was actually a dancer for a very long time, probably for about 15 years, and that was like where my passion lied and that is what I wanted to do. I wanted to dance, but dancing doesn’t bring money nor does it bring financial stability or success long term. So that was, I suppose, crushed by the expectation that I would go to university. I remember I must have been really young but my father said to me I will pay for you to go to university but not if you dance.

Chloe’s father’s actions reflect those of many middle class families, where education may be viewed as a long term investment that could return “financial stability”. While obtaining financial stability necessitated that her passion for dance was “crushed”, Chloe acknowledged how this expectation was related to her position as Māori:

Chloe: ... being Māori it was drilled into me that the only way you are going to get ahead in your life is if you have a degree. That is the only way you are going to continue to break the cycle of poverty and living off the benefit and what not. Growing up in a very strong minded successful Māori family, they attributed their success through having degrees which is what was reined into me and still is to this day. Until I get my degree, it won’t be celebrated until, but that is what happens you go to university you get a degree and then you are successful.

Me: And that is your whole family saying that is the done thing?

Chloe: Yes if you don’t get a degree you are a loser or you won’t be able to get ahead, you won’t be able to be successful — whatever that really means. Yeah my grandparents, my aunties, my parents everyone went to university. That was my path already drawn out for me.

Chloe’s family context may be characterised in terms of concerted cultivation. Throughout her life, her family has made a concerted effort to put Chloe in a position where she would be able to go to university and attain success long term. In addition to the traditional aspects of concerted cultivation described by Lareau (2011), Chloe’s family also equipped her with a strong source of community cultural wealth (Yosso, 2005). In particular, Chloe’s family gave her resistant capital, a knowledge of what it takes to resist the cycle of oppression that targets Māori. Chloe did her best to meet the high expectations of her by adopting a strong work ethic, which she attributes to her family:
Me: Where does that work ethic come from?
Chloe: My family.
Me: That is your family?
Chloe: Yeah my family. Yeah you don’t get anywhere if you don’t work hard.
Me: That has just been there.
Chloe: Yeah, and to me I am grateful for that. Having that drive and that work ethic, I think it helps to get you places. I don’t see it as a negative.

Previous research has found being recognised as high achieving may help students who are marginalised feel less socially vulnerable and over-ride the preconceptions that others hold (Ong, 2005). In high school, Chloe had to actively resist being stereotyped as lazy, and her ability to interact with teachers helped her achieve this:

At school I was recognised as Māori which never really is a good thing.
Me: Can you explain a bit more why was that?
Chloe: I think you get put into a little bubble that you are going to be lazy, that you are going to drop out of high school, you are not really going to care about your chemistry grades. But it wasn’t that, I really wanted medicine therefore I really wanted to do well at high school and my teachers recognised that I worked my arse off. I just worked, and I was probably more of a loud shooter in the sense that I always asked questions when I didn’t understand something. I always questioned what I didn’t understand. I went to extra office hours or whatever you want to call it, or stayed after class and asked questions.

Chloe’s strong motivation and ability to leverage value from her relationships with her teachers meant that she did well in school. Chloe felt that her teachers labelled her as one of the smart kids, which enabled her to garner even more benefits:

just having that label does help, so that when you are struggling and you are like annoying them by asking questions, they know it is because you want to do well, or you have the potential to do well if it is helped...
So I think I was fortunate that I was bubbled in a positive bubble by teachers.
With the transition to university, Chloe now feels a strong responsibility to continue the upward social mobility of her family, and serve the wider Māori community. This is an important source of motivation for Chloe, but she felt conflicted in how she could meet these responsibilities in her own way:

Chloe: I went through a teenage rebellion period which is why I ended up doing psychology up here. I just went through a phase of: ‘I’m going to do whatever I want to do’.

Me: I think as far as teenage rebellions go, going to university and doing psychology is a pretty good outcome.

Chloe: Yeah I think so too. I think that was where no: ‘I’m going to do whatever I want to do and just let me do it’, and I did do it, and it is fine, but it is not there yet.

Me: Do you feel like a kind of responsibility?

Chloe: Absolutely yes there is a big responsibility. I mean my family are very successful in whatever they do they all are, so it is expected I don’t just be part of the middle working class for the rest of my life I suppose, and do something bigger and better and help this world in some way.

Me: Help this world in some way?

Chloe: I think my whanau do whatever they do to benefit Māori in Aotearoa New Zealand, and it is expected that I do the same with my skillset I suppose. In their eyes it is a waste if I don’t become a doctor because I do have the academic potential to do so. But I am still battling if that is what I really want to do.

Me: So you kind of have this responsibility placed on you because you are Māori and academic do you think?

Chloe: Yes, and it is a waste if I don’t use my potential.

Chloe’s recollection points to how doxa regarding the hierarchy of legitimacy of subject areas shaped the direction of her academic pathway. Chloe felt that “a waste” in her parents eyes if she did not become a doctor, but she wanted to do psychology. For Chloe’s parents, entering into a high status domain was especially important as it provides Chloe with increased opportunity to give back to the wider

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4This extract has been redacted to help maintain Chloe’s confidentiality.
Māori community, break the cycle of oppression, and fulfil her potential as a Māori academic. Her account echoes the previous recollections of other participants who were pressured to enter into high-status domains, whilst also demonstrating the compounding effect this has on Māori who face increased demands for social mobility in the face of systemic oppression and pervasive negative doxa (i.e., being “bubbled” as lazy). Chloe faces a dilemma to find a pathway that aligns with various aspects of her habitus — to meet expectations of entering into a high-status domain, to fulfil the responsibility placed on her as a Māori academic, and follow a pathway that she actually wants to do.

7.2.5.3 ‘Homogeneous Conditions of Existence’?

In discussing why individuals from similar social groups tend to hold similar dispositions, Bourdieu (1984) discusses how “homogenous conditions of existence imposing homogenous conditionings” lead to similar systems of dispositions (i.e., habitus). It is this similarity in the system of dispositions that gives habitus a collective quality, and may result in members of the same group having similar practices (i.e., classed habitus). An important implication of unpacking the experiences of Patrick and Chloe is the fact that conditions of existence are complex. It is difficult to explain an individual’s disposition in terms of one aspect of an their life experience. The experiences of Patrick and Chloe instead highlight the importance of viewing educational trajectories through a layering of different aspects of habitus (Horvat, 2003).

While there are similarities in the doxa Chloe and Patrick have been exposed to, its impact was felt differently. While Patrick had it “drilled” into him that he would not be smart enough for university, Chloe had it “drilled” into her that she needed to go to university to be successful. Each of these experiences show how negative discourses may limit the scope of students’ dreams, but for different reasons. Patrick’s negative experience of high school cast him as an outsider, and he consequently dropped out of high school. For Chloe, the responsibility of breaking the cycle of oppression and serving the wider Māori community, whilst a protective factor in her education, also shaped the paths that were open to her.

One of the key similarities shared between Patrick and Chloe’s reaction to doxa is the drive they felt to prove the common discourse wrong, to prove that they were smart enough and capable. This motivation has been discussed in previous research of Māori (Webber et al., 2012) and Pasifika students (Mayeda et al., 2014). The inherent unfairness of these experiences of discrimination shows the
additional labour that marginalised students take on when navigating their academic pathways. In demonstrations of resistance, Patrick and Chloe were able to use negative experiences of doxa to help drive their education forward. The ability to rechannel negative emotions related to experiences of racism and colonialism into sources of motivation may be a constructive strategy for Māori and Pasifika students in education (Mayeda et al., 2014).

The development of strategies to cope with doxa leads on to the next theme in the theoretical model. We can now consider the ways in which students’ internalisation of capital and doxa are considered in the generation of future practices in the field. While previous Themes concern individuals’ past and present experiences, the next step considers the future. The following Theme in the theoretical model seeks to explore how students’ go about generating new forms of social capital in the field, based on their position in the field (i.e., volume of capital held), and their disposition towards the field (i.e., habitus) (Bourdieu and Waquant, 1992).
7.3 Generating Social Capital (Theme 5)

Following the internalisation of capital and doxa, habitus is then what generates future practices. The final Theme of the model explores what practice looks like in terms of the generation of social capital. Based on habitus, there are several important factors that may lead to a student’s decision to build their capital. The following section will discuss three key factors that were reflected in interviews with participants. Firstly, what are students’ motivations for pursuing science? Students who see the value in the field may be more motivated to progress, while students who are more disillusioned with the field may choose to drop out. Secondly, does the student know how to play the game? Student’s who lack social capital with those with power in the field may be less familiar with interacting with institutions and individuals with power, and as a result feel less comfortable forming connections. Finally, within habitus students’ practices are informed by the perception of chance as well as a choice. How does an individual’s generation of capital relate to agency?

7.3.1 “Why am I even bothering?”

Student’s motivations for pursuing science were wide ranging, and related to extrinsic and intrinsic factors. Most participants mentioned how they were motivated by an intrinsic interest in science, often characterised by a sense of curiosity. Having intrinsic motivations can help protect students who start doubting themselves when they compared themselves to others, such as Aubrey:

Sometimes you start doubting yourself, you lose self-confidence. There are so many people... that are doing so much better at it than me, why am I even bothering? I’m like it is not really about other people and what they are doing I guess. So I’m interested in this.

Many participants recognised how science could help students achieve their individual goals (e.g., to attain their desired job), and community-orientated goals (e.g., address health inequities in society). Kate described how a condition she suffers from sparked her interest in science: “I started researching what causes this, what causes that, and then I think after a while I’m like: ‘hey maybe I got given this so that one day I could be the one to cure it.’ ” The value of science in serving society and addressing inequality was also mentioned by many participants.

Hakeem felt primarily motivated by his enjoyment of science (“I am a very self-person, like it is not too many factors outside, you know?”), but he also recognised
the utility value of science in providing for him and his girlfriend’s future: “Just the fact of having to provide something for the future, making [my girlfriend] happy to be with me that is a huge thing.”. The utility value of science was important to many participants. However, extrinsic sources of motivation may not always be a sufficient driver of success, as Diana suggested:

> When I was choosing what I would do at university, it was kind of like: ‘okay what will give you the most money, what job prospects look good, and what is the easiest’. So I was like: ‘okay geology how hard can it be’, but I just did not find it interesting enough to like want to study for it.

This reflects prior research, which suggests that extrinsic sources are poorer sources of motivation than intrinsic sources (Ryan and Deci 2000a)

Some participants reported motivations to prove the negative discourses or stereotypes they were subject to wrong. These experiences were previously highlighted in the stories of Patrick and Chloe, but were also felt by other participants. Hakeem’s introspection on what motivates him touched on the need to prove himself against discourses held within his family that suggested that he is not capable of being successful:

> I have always had in the back of my mind as well, like my family have always thought of me when I was younger as a clumsy guy, a clumsy kind of guy who is not very bright and all that, and it has always motivated me to prove them that I can do things. So that also is something. I often think of that.

While for many students, doxa will serve as a signal that they do not belong in a field, other students may be able to draw upon aspirational capital to pursue their goals regardless (Yosso 2005).

7.3.2 “I think it should be something as a student I should get over, you know, go forward and just go talk to them.”

While students may have a motivation to be successful in science, students may follow up on these motivations with various degrees of success. Brenda felt that the process of gaining a qualification would adequately prepare her as a scientist, but recognised that additional value could be gained through contact with lecturers:
I think I would talk to the lecturers eventually if I wanted to do postgraduate which I probably will. I assume once you enrol in an honours degree or a masters they would tell you what to do. I thought that might be part of the degree, I didn’t think too much about learning all the ins and outs of being a scientist.

For some students, it can take a strength of will to pursue strategies to accumulate capital and learn the “ins and outs”. Belvia was worried about wasting her lecturer’s time and felt her questions were “not worth it”, while Hakeem, on the other hand, acknowledged that there was value to be gained through seeking connections with lecturers, but did not want to “bother” them:

Hakeem: I go straight out after lectures. I should be doing that I guess. I guess it would be a mix of reasons. Yeah it could be stuff that I don’t notice, but I guess it could be just not wanting to, I feel the lecturers, I don’t want to bother them, so that is probably the main reason.

Me: Where does that come from? Do you think other students would worry about bothering them?

Hakeem: I think it should be something as a student I should get over, you know, go forward and just go talk to them. Yeah because now you mention it, it should be something I should be thinking about really getting to know the lecturers because they obviously have connections and all that would be helpful.

Me: Do your friends do that or do you see people doing that and stuff?

Hakeem: I see a few people doing that, yeah. I just never thought about doing it myself. Probably you just feel I didn’t need to do it. I don’t know, I can’t really explain, but yeah as I become more certain of going into postgrad or not then I feel it would be. Because if I am just graduating with bachelors this year I am just going to leave uni behind. I have thought at some point to go and talk to lecturers, but I think there are benefits but I don’t want to. Too lazy to I guess. I haven’t thought about supervisors or dissertations or any of that stuff.

Hakeem’s reflections on why he does not approach his lecturers are conflicted. In vocalising the importance of making connections, especially in the context of post-graduate study, Hakeem tried to figure out why he has not yet taken the step to connect with lecturers. He suggested he may be "too lazy to", but nothing
about his interview suggested that would be the case — he was highly motivated and hard-working. Instead there appears to be “something to get over”, an inertia that may be related to not wanting to impose on (or “bother”) those with power in the field.

Stephen, who entered university with a limited peer network, felt daunted by the prospect of connecting with other students, especially because he was anxious about revealing his gender identity to people he did not know:

I’m proud of myself because I’m usually quite a shy person, especially when it comes to new people, and them not knowing the fact that I’m trans and I haven’t transitioned at all. So it is like quite confronting and nerve wracking for me to open up to people.

Connecting with others in the field may have a powerful impact on students still deciding if the field is where they belong. Renee recalled the moment that she decided to go talk to a senior academic after a lecture had finished:

I don’t usually like going in front of the whole lecture hall of people down to speak to the lecturer, but the fact that I did have the confidence to do that and the conversation I gained from it literally changed the rest of my uni days, like that is quite significant. That was the defining moment.

Directly following that interaction, Renee made the decision to switch to physics from arts. This provides an example of how habitus mediates between structure and agency. While habitus would previously constrain Renee’s action (“I don’t usually like going in front of the whole lecture hall of people down to speak to the lecturer”), her ‘range of possibles’ was enabled by her choice to make a connection with her lecturer. Renee was then able to make an informed choice that would significantly impact educational trajectory.

7.3.3 “You contact and learn as you go.”

While some students may feel more discomfort in seeking to build their capital at university, other students may just know that the field is where they belong and seek out opportunities. Some participants recognised that the responsibility also lay on them to access social capital. Sean felt it was his job to approach his teachers when he needed help: “All our teachers were way good, so you always had really good teachers and it was just up to you to get what you wanted, just get what you
wanted out of them”. While it may be more common for high school educators to ensure that students access social capital, the field of university may place more responsibility on students to drive this process. Lily discussed the transition to more independent learning at university: “Obviously you are in lectures, it is not just a classroom and it is very independent learning, and lecturers are not always on your back saying ‘you need to get this in’ or ‘this is overdue, why is it overdue’.” Lily’s experience suggests that students’ may be more expected to approach those in power independently to cultivate relationships.

Students who have a high affinity with science may be more likely to proceed into uncomfortable situations in order to build their social capital. Lucy applied for an internship at CERN\footnote{European Organization for Nuclear Research} despite having little experience in programming:

I think [science] opens many doors. Yeah, for example I finished high school like a year ago, but I had a year before uni started and I was looking for internships and I ended up being a programmer for CERN which is probably random. I have never been into programming before, but I think that is one of the type of things, you may not directly use what you learn, but it is ways of thinking that help you do other stuff and I think that is what science does a lot of. So I was able to do the programming. Yeah just like you can put yourself out there.

Lucy had developed a scientific habitus (“ways of thinking”) that enabled her to put herself “out there”. She perceived that science is about learning, and that motivation enabled Lucy to put into practice a strategy to build capital. This same desire to build capital can help students develop relationships, even when they are less sure about what conventions to follow. For example, Paul saw the benefit in trying to contact his lecturers at university and learn about conventions in the process:

I haven’t emailed anyone. I think about it, but again I don’t know how I am supposed to approach anyone... I’m never really sure how things work in a university environment, how polite can you be, how do you contact these people in the first place... I think just trying in the first place, you know, you contact and learn as you go.

Students who are more familiar with university science and have a habitus that is congruent with the field will be the most likely to view social relationships with
Experiences Interacting with the Field

those with power as realistic and normal, and know how to go about leveraging value from these relationships. Chloe realised her luck at having her chemistry teacher as her form teacher, and made the most of the opportunity: “I think you just develop a relationship with your form teacher, and therefore I had form time I could ask chemistry questions or I could use that to my advantage”. Students who have knowledge of how to garner advantage are more able to do so. Susan, a student in the Science Scholars programme, chose to move from Christchurch to Auckland as she felt it would give her more connections and opportunity:

Susan: I got to know the Auckland laboratories. I’ve seen Auckland’s laboratories, as well Christchurch’s old laboratories — I think they have changed now but it was too late for me, and Massey’s and Auckland’s are just nicer in general.

Me: So they are better resources basically?

Susan: That was the first thing, and also because I was connected to lecturers, and most of the professors are up in Auckland. So I just had a few more connections up here than I would have had in Christchurch. Auckland just in general I feel from my very limited perspective it had better international connections and also Science Scholars was more influential in my decision than I think it should have been now from my perspective now, but it was quite a perspective. It was pretty much, I thought this was the university that would set me up best for going overseas and doing well afterwards.

Susan’s motivations for studying in Auckland reveal a strategy to build capital that is informed by knowledge of the field, such as what resources are available (“Massey’s and Auckland’s [laboratories] are just nicer in general”), where those with power in the field are located (“most of the professors are up in Auckland”), and what is needed to be successful in the future (“set me up best for going overseas and doing well afterwards”). Susan still had to make the sacrifice of moving away from her home town and her family in order to build her capital. Many participants decided to make tough choices in order to enable their progression in the field, a topic that will be discussed further in the following section.
7.3.4 “It is like when you hold a spring down and it has got so much potential”

Some participants felt that their motivations and aspirations did not necessarily align with what was expected of them, or where they were placed at certain points of their life. While some participants knew they wanted to study science from an early age, others realised their interest later on. Some participants had to make significant life changes to follow their renewed sense of potential. Alicia was able to pursue her aspiration of studying computer science after immigrating to Aotearoa New Zealand from China. In China, she faced a working culture that limited the progress she could make as a woman:

Alicia: the working culture in China is not that friendly to women.

Me: Have you noticed the difference between that kind of culture in China since you moved to New Zealand?

Alicia: Yeah I can tell here is more like people more gender, I don’t know how to say it in English. It is like different gender has more equal rights. So I feel like more freedom compared to the working environment to China. And people won’t judge you.

Alicia’s decision to move to a new field provided her with the opportunity to study computer science with reduced exposure to negative gender stereotypes. Many participants made sacrifices and took risks in order to follow their aspirations, whether this was moving country, taking on increased student debt, or leaving a job.

Experiences prior to university entry often served to help participants in their current degree. Some participants felt that having time working normal jobs helped them mature, as Renee described: “I took two years off [after high school] and I was just working so I didn’t have to get a student loan, and then even just working and dealing with heaps of different people was helpful as well. So I came to uni and I could socialise a bit better.” Other participants felt that entering the job market before university increased their motivation for pursuing education. Aubrey realised that working an administrative job “really was not for me”, while Patrick realised he “hated” working manual labour jobs. Sean worked in a factory, which helped him see what life could look like without a university degree: “No they sent me to a factory job for a bit. It wasn’t that bad, but it wasn’t something I wanted to do for the rest of my life. That is what helped me as well.”
In some cases students had to step away from family, whanau, or significant partners who held opposing values to aid their educational journey. Renee identified the moment that she left a controlling partner as a key moment in their pursuit of education:

When I was halfway through Year 13 I got onto quite a bad relationship and it lasted for three years, that like gap year time, and I wanted to learn more things, like start a career or go study, but the person I was with was very much like: ‘no if you go study then you are sacrificing our relationship’ almost. So I was very limited. So when I left that person and then went to uni I was like: ‘I am so free, I can learn anything I want to. Like literally the world is my oyster’. So I don’t know, it was just so cool. It was powerful in a way to see that I can learn as much as I want. There are so many ways to learn whatever you want, so I may as well if I can. It is like when you hold a spring down and it has got so much potential, and then you let it go and it is like fuck yeah, do you know what I mean? Like that was me leaving that person and being like: ‘yeah’.

Leaving a relationship where values regarding education are not shared gave Renee a renewed sense of potential. Renee’s experience suggests that social relationships do not always carry with them a value that can be leveraged to gain advantage in a field. As highlighted by Adler and Kwon (2002), social capital may also carry risks, as relationships can be costly to maintain, and overembeddedness (i.e., a strong focus on in-group relationships) can result in an inertia that limits the flow of new ideas and development (Gargiulo and Benassi 1999). For Renee, the influence of her partner meant that she was unable to seize new opportunities, while leaving the “bad relationship” opened new opportunities up for Renee “I can learn anything I want to. Like literally the world is my oyster”.

7.4 Summary

The current chapter has detailed the manner in which participants interviewed in the current study interacted with the field of science education. It discussed how doxa, or common societal discourses, influenced participants’ educational trajectories through science. The influence of doxa was felt in terms of the value that is placed on different subject disciplines, and in the ways is which students view
themselves in relation to common stereotypes of who a scientist is. I also discussed how students may be motivated to progress in the field of science, and how actions may look different for students depending on their degree of affinity with the field. Through the recollections of participants, we can see how broad trends in participation reciprocate the common discourses that students are exposed to. We can also see how inequities located in each of the themes in theoretical model may relate to differences in how students interact with institutions and those with power in the field. The following section will discuss some potential directions that may be followed to address sources of inequity in science.
Part III: *How Can We Make the Field of Science Education More Equitable?*
Chapter 8

Opportunities For Interventions:
Making the Field More Equitable

Preamble

Previous chapters have focused on answering the question of what participation in science education looks like, and why it looks that way. I explored these questions through a range of data sources, from the large-scale administrative data sets discussed in Chapters 2 and 3, to the questionnaire analysed in Chapter 4, and to the interviews with undergraduate science students recollected in Chapters 6 and 7. After offering some answers to the questions of what and why in these previous chapters, the question I now to seek answers to is: how can we make the field of science education more equitable? While my response to this question is mainly informed by the content of previous chapters, in some cases I will introduce new quotes from participants who had first-hand experiences participating in interventions.

8.1 Introduction

A major goal of social sciences research is to combine theory and practice. For Bourdieu, this involved a full integration of theory with analysis. Following Bourdieu’s convictions, my thesis has sought to build a theoretical framework interwoven with the analysis of both quantitative and qualitative data. However, there is also a need for research to carry a commitment to social justice (Solorzano 1997, Yosso 2005). While the interpenetration of theory and practice may result in what
Bourdieu labelled a “total science of society” \cite{Bourdieu1992}, we must also endeavour to instigate changes that make society more equitable. As Karl Marx summarised: “The philosophers have only interpreted the world, in various ways. The point, however, is to change it.” \cite{Marx1888}. A commitment to social justice thus moves beyond theory and works toward “the elimination of racism, sexism and poverty, as well as the empowerment of People of Color and other subordinated groups” \cite{Yosso2005}. A commitment to social justice thus moves beyond theory and works toward “the elimination of racism, sexism and poverty, as well as the empowerment of People of Color and other subordinated groups” \cite{Yosso2005}. A commitment to social justice thus moves beyond theory and works toward “the elimination of racism, sexism and poverty, as well as the empowerment of People of Color and other subordinated groups” \cite{Yosso2005}.

The following, and penultimate, chapter of my thesis now looks at exploring answers to the question of how we can make changes to improve outcomes for students studying science. I will scrutinise each step of my theoretical model (Figure 8.1) to explore potential opportunities for intervention, within the context of both theory and practice. The opportunities will be heavily informed by the research undertaken in my thesis, but I will also draw upon previous research to add broader contextual details to points made.

![Figure 8.1: Complete Theoretical Model](image)

The following sections will now briefly discuss possible interventions that may improve students’ initial access to social capital in science, and efforts that can
be made to help enable students to leverage value from the connections they do have access to. It will also discuss some interventions that may improve students’ feelings of belonging in science, especially for students who represent groups that are marginalised in science. Each section will discuss possible interventions relevant prior to university entry, and interventions specifically tailored to the field of university.

8.2 Access to Social Capital

At the most fundamental level, students may find it more difficult to advance in the field of science if they do not have access to forms of social capital that carry value in science education. Chapters 5 and 6 highlighted how some students may grow up within a family that places little value in science and without bridging forms of social capital that can provide access to science-related resources and knowledge. In addition to limiting access to resources, my theoretical model also outlines the cascading impact that a scarcity of connections can have on students’ feelings of confidence within the field of science. For those students who do build sufficient capital to progress in science, those with fewer connections may find the transition to university more difficult. To address these issues, I discuss two key areas where interventions can take place. Firstly, we may seek to increase the availability of connections open to all students prior to university. Secondly, it is integral that universities seek to reduce feelings of isolation by bringing students together.

8.2.1 Prior to University: Increase Availability of Connections

As outlined in Chapter 5 and demonstrated in Chapter 6, the structure of scientific knowledge means that students from communities without a reservoir of scientific knowledge may find it harder to access science. Unlike other types of careers, science tends to be less visible in the community and students are less likely to be exposed to informal science experiences\(^1\) [Bolstad and Hipkins, 2008]. Scientific knowledge can take on a sticky quality, in that it sticks to communities where the foundations of science-related conversation are automatic, while individuals who do not hold prerequisite knowledge are less able to pass on the flow of information. Students who grow up in families where science is regularly discussed may carry advantages in studying science\(^1\) [Dou et al., 2019], while those who do not are required to ‘catch up’ when they are exposed to science formally at school. This
may be a particular issue for individuals from rural communities where bridging forms of social capital are potentially fewer (Sørensen, 2016) and there is a less diverse reservoir of community knowledge (Israel et al., 2001).

There are several directions that may be taken to reduce the stickiness of scientific knowledge. Firstly, we can seek to boost the value of science in everyday life. In Chapter 5, participants recalled how their family would “switch off” when science came up in conversation, but, as Chloe hypothesised, if people knew more about the relevance of science in their lives they may be more interested. Claussen and Osborne (2013) make a strong argument that more needs to be done to boost the appeal of science in everyday life. In addition to boosting interests, highlighting the value of scientific knowledge may also lead to increases in general scientific literacy. Increasing general levels of scientific literacy may enable students and their families to access more flows of scientific information.

The flow of scientific information may also be facilitated by changing the way that science is delivered to communities. In the context of Aotearoa New Zealand, research has found that interventions to deliver seminars about science to students at school can have a positive impact on students’ knowledge of careers in science (Bolstad and Hipkins, 2008), and these types of experiences were cited as beneficial by many interview participants. These initiatives can boost students’ knowledge of what science careers involve, and potential pathways forward. Blackman and Benson (2010) found that the delivery of scientific knowledge is more effective when the community is involved in the process of creating knowledge. Following this, Blackman and Benson (2010, p.286) argue that we should reconsider how science is delivered: “In metaphorical terms it moves away from being delivered as a parcel by scientists to interested parties to a more multifaceted, co-created approach.” Echoing the arguments of previous researchers, efforts need to be made to promote the relevance of science within local communities (Linda Barton-Redgrave, 2016a,b). Community-based science practices, such as those grounded in Mātāuranga Māori (Hikuroa, 2017), may also be especially productive. Hikuroa et al. (2011) provide an example of how a scientific project, inclusive of mātāuranga, can help a community access scientific knowledge by translating scientific terminology and integrating it with the local context.

Finally, we can support and encourage students from rural communities to study science at university. Scholarships targeting rural communities can provide

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1One example offered by the University of Auckland is the Rural Regional Admission Scheme (RRAS), which seeks to encourage people to train and then return to their rural area to work (University of Auckland, 2020b).
a valuable pathway to university study for students from rural areas (Curtis et al., 2017b), and doing so can increase the bridging social capital of rural communities. Renee, who would talk about her studies with her family and friends back home, described this process in action:

So me taking that knowledge back, it is cool to have them be influenced by it, and then change the outlook on life and get that different lens going, and that’s cool. And I like learning stuff because then it can be translated onto other people and help them learn.

Renee’s ability to act as a translator shows her important network position as a weak tie (Burt et al., 2013), someone who provides a unique link from one community to another, facilitating the flow of information.

### 8.2.2 For University: Bring Students Together

Universities can be daunting institutions, especially for students who enter into their first year with a limited network of support. Comments from interview participants suggested that the University of Auckland has a particular reputation for being a socially isolating institution. One way to improve the connections that students are able to make is by providing spaces for students to interact with one another. As touched on in Chapter 6, student accommodation at university provides one example of a place where students are brought together and provide the opportunity for students to access social capital. However, it is important to provide students with opportunities to make peer connections that do not require additional financial burdens (McClure and Ryder, 2018).

In the classroom environment, connections between students may be facilitated by providing opportunities for students to collaborate, as opposed to traditional, teacher-focused lectures. Lectures with large numbers of students can be intimidating, while group work provides an environment that students are more familiar with (McKinley and Madjar, 2014), and more comfortable interacting with others. However, forms of group work can have negative consequences if they are not designed in a way that provides a safe environment, or where the lecturer is unable to facilitate connections (McCabe and O’Connor, 2014). Examples of this were demonstrated by participants in Chapter 6. Hakeem was “terrified” of attending a specific tutorial where groups changed regularly, as he felt under increased pressure to perform in front of group members he did not have time to get to know.
Similarly, changing groups regularly exposed Stephen to increased risk of anxiety as he felt he had to repeatedly explain aspects of his gender identity.

Outside of classrooms, universities can also facilitate connections between students by providing access to extracurricular activities and physical spaces. Research has shown that hubs where students can connect can be highly beneficial for female students in science, and for students who represent ethnic minority groups (Birani and Lehmann 2013). In Aotearoa New Zealand, there have been growing efforts to provide support to Māori and Pasifika students in particular (Wilson et al. 2011). While the benefits of these support programmes are wide-ranging (as will be discussed in later sections), on a structural level they serve to connect students together. Spaces dedicated to Māori and Pasifika students can facilitate the development of personal networks and aid these students’ transition to university (McKinley and Madjar 2014). For example, Sean was able to connect with other students who also hung out at the MAPAS house, while Patrick met most of his friends at university through Tuākana. Many participants also pointed to the sense of community that these programmes were able to foster. Facilitating connections through these kinds of programmes opens students up to a range of advantages when it comes to leveraging value from social capital. However, as outlined in previous chapters, the value that students may leverage from social relationships can also be inequitable. The following section will discuss opportunities to address this issue.

8.3 Leveraging Value from Social Capital

The value of social capital is derived from the economic and cultural capital that can be mobilised through connections with others. These resources may provide students with advantages in supporting their learning and providing student access to information about the field. However, Chapter 2 provides evidence that high school decile plays a role in the pathways that students take though science education, and this was reflected in the range of experiences recalled by interview participants.

8.3.1 Prior to University: Level the Playing Field

Students are more likely to leverage the value of their social relationships with teachers if the teacher is supported in their classroom. Chapter 4 highlighted the
strong influence that teachers continue to have on science students after transitioning to university, while other research shows that school quality plays an important role in determining students’ university enrolment and completion (Deming et al., 2014). As with individual agents, the practices of a school institution are influenced by an institutionalised habitus, and the capital that the school holds. Some schools are under-resourced institutions serving under-resourced students, and these constraints may place limits on the pathways that are open to students. This may explain the finding in Chapter 2 that low decile schools tended to be less likely to have students taking the ‘academic’ focused science standards. As outlined by Thrupp (2015), low decile schools may have to address pastoral needs of its student base prior to focusing on learning needs, and as a result less time may be spent on curriculum matters. Without the push from schools, students must drive their own path forward to university, as Chloe described: “[university] wasn’t really a thing unless you wanted it to be a thing” (Chloe). For highly-resourced schools, serving highly-resourced students, the distance from necessity is greater and thus the school can afford to engage in meeting the specific demands of its student-base. These schools may be more geared towards “spoon-feeding” (Stephen) students to go to university.

In addition to differences in institutional habitus, disparities in resourcing introduce another inequity. After moving from a private school to a low decile rural school, Stephen, who had to share many of his lessons with students from other year groups, felt science lessons were less engaging: “we are quite a low decile school, so we didn’t have the resources I guess to make it fun”. Highly resourced schools may be more able to provide students with learning opportunities that cater to individual needs (Thrupp, 2007), and increase students enjoyment of science (Hampden-Thompson and Bennett, 2013). Susan, who went to a high decile private school, described how her school created a new advanced class for herself and two other students. As argued by Thrupp (2015), the contrasting high school science experiences of students attending lower decile and higher decile schools contests neo-liberal assumptions that all schools are able to provide equally demanding curriculums.

8.3.2 For University: Bridging Programmes

Students may wish to enter university despite having gaps in their knowledge, and this is a particular issue for students who are the least privileged in terms of the capital they hold. Students who are first-generation to university (Murtagh, 2010),
opportunities for interventions or represent a minority group in science (Birani and Lehmann, 2013; Roberts et al., 2002) may have more difficulty adapting to life at university, while students from low-decile schools (disproportionately Māori and Pasifika) may also be less well prepared in terms of the prerequisite knowledge obtained in high school (McKinley and Madjar, 2014). University bridging programmes (also known as foundational or preparatory courses) offer one direction that can widen participation at university by helping students fill in gaps in knowledge and adjust to life at university. Some participants had first hand experiences of bridging programmes. Lily took part in the Hikitia Te Ora course, which aimed to help her cover gaps in physics, chemistry, and biology coming into university (Curtis et al., 2017a). While Lily did not perceive that she had gaps in subject-knowledge, she recognised the benefits of Hikitia Te Ora in helping her adapt to a new lifestyle: “I didn’t have those gaps, but it was more of a transition in terms of confidence for me. Like coming into university I knew it would be a different lifestyle, a different format of studying and all that sort of thing.” Lily’s experience points to the benefits of bridging programmes outside of their role in widening participation. Beyond covering gaps in the fundamental science knowledge needed at university (Thalluri et al. 2016), bridging programmes can help students get more of a ‘feel for the game’ and adjust to life at university. Bridging programmes may help students adjust to more independent learning styles (Gordon and Nicholas, 2013), help students gain confidence within the field (Johnson and O’Keeffe, 2016), and reduce levels of attrition from first year courses (Thalluri et al., 2016).

Bridging programmes may be especially beneficial for Māori and Pasifika students, who face additional difficulties when adjusting to life at university (McKinley and Madjar, 2014). Students from these groups may be less likely to receive advice and guidance in navigating university pathways (McKinley, 2005), while they may also find it more difficult to adjust to university institutions where pedagogy is more grounded in an independent learning culture. Bridging programmes can offer students the opportunity to learn in a decolonised environment where the culture of a student is more valued (Curtis et al., 2017a). Research has found that bridging programmes targeting Māori and Pasifika students can boost student retention and outcomes (Curtis et al., 2017a). With that being said, Curtis et al. (2017a) point to the increased need for bridging programmes to adapt to the diverse realities of students lived experience, instead of just aiming to integrate students into the existing university culture.
8.4 Habitus

The capital that students accrue in university science not only provides access to resources, but it also influences the way that students see themselves in the field. Capital, which determines students’ position in the field, is internalised by students and considered within a system of dispositions, or habitus (Bourdieu and Waquant 1992). Students who hold high levels of valued capital may be more likely to feel an affinity with the field (a point highlighted in Chapter 4), and see progression to university as a path drawn out.

In order to encourage students to see science as a field where they belong, we need to provide an environment where they can see their habitus as congruent with the culture of the field in which they are participating (Horvat 2003). In this sense, we do not want students to change who they are to fit in with the field, but to enable students to carry out science being who they are.

8.4.1 Prior to University: Provide Recognition

Students may be more likely to internalise the idea that science is for them if they are able to recognise role models who they feel they can emulate. My research found that students who have academic family members may be more likely to see science as a domain where they can be successful, while having access to role models outside the family can also help students see the field as somewhere that they belong. As detailed in Chapter 4, students who recalled exposure to good high school science teachers are more likely to see the field of science as somewhere that they can be successful.

Chapter 6 highlighted how exposure to role models continues to have a positive influence on students, especially if a role model normalises aspects of an individual’s own identity. Research has found that students are most able to leverage advantages from educators who are more similar to them (Gehlbach et al. 2016), which means that students who have been historically underrepresented in science can face additional barriers due to lack of representation. Providing students from minority groups in science access to similar role models may be beneficial, especially if role models are present at different career stages, including tutors, lecturers, and professors. As outlined by (Roberts et al. 2002), this “stepping-stone model” can enable students to see a clear and structured path through the field. Other research suggests that “at-risk” students with mentors who represent the same ethnic group are more likely to meet regularly, feel more support, and adjust
opportunities to further education (Santos and Reigadas 2004). In Aotearoa New Zealand, access to role models have been cited as positive factors in the success of Māori and Pasifika students at university (Mayeda et al. 2014). However, there continues to be concerns related to the poor representation of Māori (McAlister et al. 2019) and Pasifika (Naepi 2019) in advanced academic positions, and this may reduce opportunities to provide a stepping-stone model for these groups.

While seeing role models may help students internalise the idea that the field is for them, the feeling of being seen by others as someone who is good at science is also important. This was demonstrated in Chapter 4, which found that students who perceived that their teachers felt they were good at science tended to have higher levels of self-concept in science. The implications of this research provide a simple direction that educators can take to help students feel more belonging in the field: recognise students. As summarised by Hazari and Cass (2018), meaningful forms of recognition include providing encouragement and setting high expectations, attending to students’ needs and providing opportunities for them to ask questions, directly conveying confidence in a students’ ability, and providing opportunities for students to work autonomously. These forms of recognition may foster the development of students’ identity within science fields (Wang and Hazari 2018), and improve the likelihood of students continuing to progress in the field (Hazari et al. 2017). As detailed in Chapter 6, even subtle forms of recognition (remembering a student’s name or face) can have powerful impacts on a student’s feeling of belonging.

8.4.2 For University: Improve Pedagogy

Chapter 4 highlighted the important role that educators play during high school, and Bolstad and Hipkins (2008) point to the need to improve the pedagogy of high school teachers in Aotearoa New Zealand to improve student engagement with science. My research, specifically Chapter 6, suggests that this recommendation also applies to educators in the context of university. According to Prosser and Trigwell (2014), forms of academic interaction may be less likely in traditional teacher-focused lectures and this can result in poorer student approaches to learning. This point was echoed by the experience of Patrick: “The teacher would just walk around in a class of about like 80 and we just didn’t really learn anything. So we kind of got a bad impression from that class.” When students are provided with opportunities to interact with their educators, poor interactions can result in students perceiving that the field is not somewhere they belong. In
Chapter 6, some participants recalled how some educators had a reputation for being difficult, and may respond to students in a demeaning manner. In order to address this issue, efforts must be made to ensure that university educators are well trained and supported to be effective teachers. Training university educators to improve their pedagogy can result in deeper levels of understanding, increased student satisfaction and improved student outcomes (Prosser and Trigwell 2014; Gibbs and Coffey 2004).

Training university educators can also serve to improve the content of courses so that it is engaging for a wider audience. Connor et al. (2015) argues that university educators often approach teaching in the same way that they were taught themselves. This maintains a learning environment that benefits students who share similarities to those who have historically benefited, while students who share fewer similarities to their educators are less likely to succeed (Gehlbach et al. 2016). Thus, students who enter into science embodying culture that differs from that which is dominant in the field may feel more distant. For example, Helemonga found his educators at university “very distant” and felt that was reflected in his assessments: “When you write your lab report it has to be kind of like not on your level, but on the marker’s level in order for that person to understand what you are writing. So you are not writing for yourself you are writing for them, for their perception.” In order to make the field more equitable, we must try to bridge the gap between the culture of the field and the different cultures that students embody. Bolstad and Hipkins (2008) advise that increasing the relevance of science to students of different backgrounds is a difficult task. Research suggests that reframing the student-teacher relationship so it is more student-focused can enable students to define their own educational journey (Connor et al. 2015) and doing so can improve student outcomes in higher education (Gibbs and Coffey 2004). This lends support for forms of content delivery other than lectures, which can be an intimidating and isolating experience for students (McKinley and Madjar 2014). In Aotearoa New Zealand, efforts to provide student-centred learning experiences in STEM are becoming more common. Connor et al. (2015) provide examples of how student-centred projects can expose engineering students to key concepts whilst enabling students to be more personally engaged in the work. While traditional forms of delivery may be more likely to reproduce existing structures in the field, student-centred experiences that are “flexible enough to accommodate different student interests” may be more likely to provide an environment in which all students can benefit (Connor et al. 2015, p.45). However, in order for student-centred approaches to be successful, efforts must be made to provide
a safe-learning environment that places value on the heterogeneity of students (McCabe and O’Connor 2014).

Efforts to teach university educators to be more culturally responsive may also reduce the distance felt by students (Ikiua 2019), with this being demonstrated in past research in primary school (Linda Barton-Redgrave 2016a,b) and high school contexts (Bishop et al. 2009). The experiences of participants in my research suggest that the Tu¯ akana and MAPAS programmes provided spaces and pedagogical practices in which participants felt that the rules were different and a sense of connection was more readily felt. Chloe felt that Tu¯ akana tutorials were not as “cliquey” and Lily recognised the benefits of being a member of the MA-PAS cohort: “...we always sit together as a group during lectures and that and we all support each other through our learning”. As described by participants, programmes such as Tu¯ akana and the MAPAS provide an academic culture that contrasts with the mainstream culture of competition and isolation. The sense of community generated through these programmes serves as a valuable form of bonding social capital, and as a result students may be less likely to question whether they belong in the field. The spaces provided by programmes such as Tu¯ akana and MAPAS also provided students with the opportunity to learn in an environment where the negative impacts of doxa were less prevalent, a point that will be discussed in the following section.

8.5 Doxa

Outside of the of the social relationships that students hold, general discourses in society (or doxa) influence the development of habitus. As identified in Chapter 7, participants recalled experiences of dealing with stereotypes operating in the fields of education, science, and university. Fields that project negative doxa will have a ‘chilly climate’ for students who do not fit (Blickenstaff 2005), and as a result, students may not see the field as a place that is for them even if they had the potential to succeed (Cheryan et al. 2017). As outlined by Bourdieu, doxa become embedded within society and influence the pathways that seem more or less thinkable for students. These doxa would contribute to the trends in enrolment that I previously outlined in Chapters 2 and 3. In order to address these pervasive societal discourses, we must continue to combat negative stereotypes and implicit bias. My research also found that counter spaces – environments where students have reduced exposure to negative doxa at university – can be highly beneficial.
8.5.1 Prior to University: Combat Negative Stereotypes

Societal stereotypes are pervasive. In my research, experiences of gender stereotypes and racist discourses were common experiences for many participants. These doxa exist through a widespread adherence to relations of order that are accepted as self-evident, because they structure the “real world” and “thought world” (Bourdieu, 1984, p.473). It follows that by changing the representation of science in the real world, we can begin to change the structures that are internalised within the thought world. This means increasing the representation of under-represented groups in science (including women, minority-ethnic groups, and working-class men). However, efforts to change the way that science are represented must be done with care, and in a way that legitimises the groups being represented and prevents the recycling of other stereotypes. These points were raised by female scientists who were interviewed in a study by Kitzinger et al. (2008), who suggested media representations of women in science should avoid portraying them as love interests, as entirely de-feminised, or overly-feminised. Instead, women should be presented as realistic, with diverse motivations, and involved in a range of science-related careers. Efforts to present scientists as “normal” people may also enable more students to view science as a field where they can progress. As detailed by some interview participants in Chapter 7, the notion that science is a domain only for “one-percentile” students, or the “hero-scientist” can be a major obstacle to participation. Explicitly teaching students about the failures of scientists may be one possible intervention for addressing this doxa and improving learning outcomes for students in science (Lin-Siegler et al., 2016).

8.5.2 For University: Offer an Inclusive Culture

In order to combat the negative impact of doxa in a university context, efforts need to be made by educators to provide safe learning environments where stereotypes and biases are not tolerated or perpetuated. While we can encourage educators to provide a safe learning environments on an individual level, it does not necessarily follow that all educators will buy in to these efforts (Nakhid, 2006), or have the capability to recognise where doxa is perpetuated. Given that doxa is by its very nature pervasive, efforts to address it will be more successful when directed from those who have power in the field.

Equity charters provide one such method of providing a top-down approach to addressing inequitable cultures within university settings, a point of discussion
opportunities for interventions raised in Chapter 3. Charters provide a recognition of best practice for departments and institutions that advance equality in science. For example, the Athena SWAN charter requires institutions to commit to addressing structural and cultural issues that contribute to gender disparities by ensuring equal pay, support, and employment opportunities (Equality Challenge Unit, 2018). Evidence suggests that these efforts have improved support for women in science, and increased efforts by intuitions to reduce discrimination and bias (Ovseiko et al., 2017). Significantly, Athena SWAN awards are now a prerequisite for institutions seeking to gain funding from governments (such as those in UK), which may be a key factor in determining the charter’s effectiveness (Ovseiko et al., 2017). However, it is important to consider aspects of marginalisation that are not made explicit or prioritised within a charter. As touched on throughout my thesis, and by previous critiques (Tsouroufi, 2019), inequities are embedded in areas not specifically considered by charters, such as the curriculum that universities employ, as well as intersecting aspects of an individual’s social location (such as ethnicity and social class). It is important that the employment of specific charters do not hide institutions’ wider responsibilities in addressing inequities (Nakhid, 2011).

Within the context of enacting structural changes to create a more inclusive culture, universities can seek to serve students who are marginalised in science by providing safe, culturally inclusive counter-spaces that protect against negative doxa. Tuūkana and MAPAS programmes provided participants with the opportunity to experience a new learning culture. Previous research suggests that counter-spaces can also reduce students’ exposure to “everyday racism and colonialism” (Mayeda et al., 2014), microaggressions and isolation (Ong et al., 2018). Mayeda et al. (2014) describe how these counter spaces can provide Māori and Pasifika students with the opportunity to learn in a culturally inclusive environment away from judgement from Pākehā/European peers and teachers, where students are not faced with assumptions regarding their competence or other racist discourses. Counter spaces thus give students the opportunity to learn in an environment where gendered, racial and classed aspects of habitus are “honoured and supported” (Horvat, 2003, p.14).

However, some participants suggested that these support programmes could be improved. In giving feedback to this section, Helemonga suggested that programmes such as Tuūkana and MAPAS may actually reinforce feelings of confinement for Pasifika due to the level of institutional support these programmes receive:
Does it really reduce exposure to racism? Or is it a segregation for Pacific students to feel confined within that category? Well that’s how I experienced it... Tuākana and MAPAS was established out of remorse and pity due to the fact that UoA is complicit with White Supremacy to portray an idea of diversity. Tuākana learning spaces are being shoved in the back of the Biology building and Old Choral Hall in a size of a shoebox. [To improve things] make the Tuākana space be the center of UoA... [It] may not reduce the feeling of being confined within a category, but at least it’s a start.

It is important to note that while Tuākana is now a centralised initiative within the University of Auckland, it was originally established independently by individuals passionate about increasing the sense of belonging for Māori and Pasifika students (University of Auckland, 2016a). Helemonga’s perception of Tuākana highlights the need for universities to support Māori and Pasifika students in a way that legitimises them and places them at the centre (metaphorically and physically). Hakeem also pointed to the need for these programmes to provide other forms of institutional support:

Tuākana was good but they had the angle of destroying the stereotype for Pacific Islanders, like people normally think you are lazy and all that... it didn't feel that there was much focus on actually living, just getting into uni and getting used to just the basic kind of things, getting used to uni.

Interventions may also seek to help students “get used to uni”, and help them progress through science at university. The following section will discuss some ways in which we may help students, especially those less familiar with university, generate capital.

### 8.6 Generating Social Capital

The future acquisition of social capital is informed by habitus. Given that this theme concerns students’ future generation of social capital at university, I focus on two directions where universities may help all students develop future relations within the field. The first relates to the manner in which some students may be explicitly/implicitly excluded from participating in formal channels that can help build capital, such as undergraduate research projects. The second direction
discusses ways in which we may break down a perceived power differential between students and educators that may hinder students’ engagement in informal channels of building capital. Both of these directions are informed by the experiences of participants building their capital at university, detailed in Chapter 7.

8.6.1 Rethink Admissions to Formal Programmes

Students can gain many benefits from participating in programmes that extend beyond the completion of a qualification. Undergraduate Research Experiences (UREs) are often cited as a potential way for students to participate in scientific procedures and get first-hand experiences of science (Linn et al., 2015). An example of UREs were demonstrated in my research, which drew upon interviews with students who were members of the Science Scholars programme. This programme, which students apply for out of high school, enables students to build social capital that is highly valuable in the field of science. It pairs students up with academic mentors, and it also provides students with membership to a highly science-orientated cohort of academic peers. Through programmes such as Science Scholars, students have more opportunities to access further cultural capital and develop a scientific habitus (Linn et al., 2015).

While the benefits of UREs are notable, access to UREs are often highly competitive due to the significant time, money, and personal investment they require (Linn et al., 2015). Many of these programmes require students to apply, and those selecting students for admissions often judge students according to traditional definitions of success such as GPA (Bangera and Brownell, 2014). The selection process may also be influenced by implicit biases that can exacerbate inequities further (Bangera and Brownell, 2014). The selection process for URES may also not be equitable when considering the resources that students have at their disposal. As highlighted in Chapter 6, some students may not have access to a flow of information that programmes exist, have covered the prerequisite courses for entry, have knowledge of how to apply, or know what is best to write in their application (Thompson et al., 2016).

Beyond factors related to institutionalised cultural capital, students may also exclude themselves from applying if a programme highlights factors that are incongruent with students’ habitus. For example, if a programme emphasises that admissions are highly competitive, a less confident (but sufficiently capable) student may not apply. While the culture of academia and science may favour outward expressions of confidence, competitiveness, “self-assertion and bravado” (Ong
et al., 2018; Traweek, 2009, p.75), many students hold values that differ from those typical of the field but carry their own strength. For example, some participants in the current research made comments relating to being humble in terms of their educational successes. They may feel the need to “lay low” or “not show-off” (Helemonga), or it may feel “cocky” (Hakeem) to identify as being good at science. Prestigious programmes often do not value these expressions of humility, but focus more on rewarding students who are able to articulate and project the capital they have already accumulated. Individuals who grow up within a family that is characterised by concerted cultivation may be more comfortable and able in meeting these requirements (Lareau, 2011). Course-based Undergraduate Research Experiences (CUREs) may be one intervention that can mitigate some of the barriers students face in generating social capital through undergraduate research. These types of intervention seek to provide all students enrolled in a course with academic mentors (with a fewer number of mentors shared between a greater number of students) and research experiences (Linn et al., 2015). By providing all students enrolled in a course with CUREs, students who would otherwise be unaware of the benefits of research experiences (or their existence) are able to access valuable sources of capital (Bangera and Brownell, 2014). CUREs also bypass admissions procedures that may exclude capable students from being accepted or from putting themselves forward. With that being said, the impacts of CURES can vary, and a significant time investment may be needed for students to become enculturated into lab practices (Linn et al., 2015). Through a Bourdieusian lens this makes sense, as it takes time for the resources that students are exposed to to become embodied. However, CUREs may open a gateway for all students to experience research, and in doing so, they remove a potential bottleneck to UREs (Bangera and Brownell, 2014).

8.6.2 Reduce the Perceived Power Imbalance

My research found that when students come to build their capital within the context of university, students who have been the subject of concerted cultivation or have experiences with academics growing up will feel more comfortable reaching out to their educators. Knowing the benefits that can be gained through seeking connections to educators at university is a highly advantageous form of cultural capital, as is the knowledge of who to approach and the conventions to follow. Students who are less familiar with the way that university institutions operate may find it more difficult to approach lecturers through informal channels. As
suggested by participants in Chapter 7, the process can be intimidating and uncomfortable. It falls to educators and educational institutions to ensure that all students feel able to build their capital in a way that is congruent with their socio-cultural background. As outlined by Zepke and Leach (2007, p.664): “Diversity is not only a powerful concept; it is a concept of power. It separates the ‘us’ from the ‘other’; privileging the ‘us’, in this case the teachers.”

Educators have the power to positively impact on students from diverse backgrounds by placing value on the culture that they embody, instead of requiring students to adapt to a university culture in which they may be unfamiliar. Participants’ experiences of support initiatives, such as Tuākana and the MAPAS provide an example of how the power differential between students and teachers can be diminished. In practice, this pedagogical approach makes it easier for students to approach those with power in the field. Patrick found Tuākana made it easier for him to receive one-on-one help from lecturers. Chloe’s recollection of Tuākana neatly summarises the manner in which Tuākana made it easier for students to build social capital:

Chloe: I’ve been really fortunate that through Tuākana as well we get a lot of one on one lecturer time anyway. So that kind of removes that barrier very early. I remember orientation week of year 1, like all the Tuākana different departments have their own lunch or whatever, and all the lecturers from that department came to that. So I think that took off like the: ‘you can’t talk to them’ kind of thing.

Me: Did they just seem like normal people?

Chloe: Yeah exactly, and they are at the end of the day. I think we put lecturers on such a high pedestal because at the end of the day they are the ones marking our grades and they are the ones who are like the holy grail of knowledge. So I think the whole way uni is taught as well — one person talking to like 500 people, can be a bit like at the end of the day you must respect them, but yeah they are there to help us succeed. So I will view that, but I know a lot of people won’t and that I think is just normal.

Chloe’s recollection points to the positive impact that Tuākana had in enabling students to see teachers as normal people, whilst highlighting how traditional, teacher-focused approaches to education heighten the power differential. Given that many students exist outside of the field of Tuākana, efforts must also be
made to ensure that mainstream pathways through university science education provide the same opportunities for all students. Specifically, educators may make concerted efforts to get to know the students in their class, and take steps to ensure that students feel valued as learners. This may be best achieved when educators value diversity in the classroom (Zepke and Leach 2007), and do not place the onus on students to adapt their culture to fit the field.

8.7 Conclusion

This chapter has sought to answer the question of how we can provide equitable outcomes for students. Institutions have the power to offer interventions that may help provide more equitable outcomes for students. Following our theoretical model, these interventions can target different points in the cycle. Interventions may seek to boost the availability of connections for students both prior to and at university, facilitate students’ development of academic identity by engaging in good pedagogical practices, and provide opportunities for students who are marginalised to learn in environments free from negative doxa. The directions outlined are by no means exhaustive, but they offer some ideas which may help students feel more congruence with the domain of science, and aid them in seeking out and forming future relationships in the field.
Chapter 9

Reflections and Directions

My thesis has sought to answer three key research questions: What does science participation look like in Aotearoa New Zealand, why do we see differential trends in student participation in science, and how can we make the field of science more equitable. The following section will provide my final reflections on these questions, summarising what my research has revealed, and some future directions that may be pursued to further explore this area of research.

9.1 What Does Science Participation in Aotearoa New Zealand Look Like?

My first two chapters provide a clear idea of what science participation looks like in Aotearoa New Zealand. By the end of high school, various trends in student enrolments are observable. While on its surface, science tends to have relatively even levels of participation for female and male students, within its component fields there are clear gender disparities. Physics, computer science, and practical technology subjects are dominated by male students, while female students make up the majority of students in other science sub-fields, especially the life sciences. Māori and Pasifika students, as well as students attending schools in less affluent areas, are relatively less likely to be enrolled in science standards in general. Chapter 2 provides a demonstration of the utility of treating high school assessment systems as a complex system. With that being said, future work should look to expand on this analysis by including the enrolment data of private schools, or schools using alternative forms of assessment. While this would add a great deal of complexity to a source of data that is already very complex, it would offer greater
insights on the levels of disparities between state schools and those that serve the elite.

With the transition to university, Chapter 3 begins to draw attention to the dynamic nature of the field of science. The field can be characterised in terms of the vertical movements students make upwards and downwards in their objective rankings in a field of study, and also in terms of the horizontal movements they make between different fields of study. Building our description of what the field of science looks like, Chapter 3 further highlights the importance of fine-grained analysis.

Reflecting on these two chapters, I believe that my work offers a detailed description of what the field of science looks like in Aotearoa New Zealand. In summary, the first part of my thesis points to the field of science as being one that is stratified across gender, ethnicity, and socio-economic status (SES) by the end of high school, with gender disparities continuing with the transition to university study. Further research should continue to answer this question, and expand on the limitations of my work. In particular, more work needs to be done to understand the pathways students make through different levels of high school and transitioning to science at university. Network analysis provides one form of analysis that can consider the complexity of these pathways, and may be a fruitful area of further exploration. The Bourdiseusian framework used to interpret the analysis of Chapter 3 pointed to potential reasons for why we see uneven levels of participation across science domains, a second avenue that I will now reflect on.

9.2 Why Do We See These Trends in Science Participation?

After outlining the trends in science participation, my research turned to understand why we see these patterns. Considering the overall work of the second part of my thesis, I point to the important relationship shared between students’ social capital and their internalised dispositions, or habitus. Students who are most able to access and leverage value from social capital that is valuable in science may be more likely to see science as somewhere that they can be successful, and consequently progress in the field.

Chapter 4 highlighted how positive recollections of science teachers in high school relates to a student’s belief that they can be successful in science at university. The important role that educators play was summarised by interview partici-
Why Do We See These Trends in Science Participation?

Educators can spark interests in a subject, ensure that students acquire the prerequisite knowledge needed for university, and get students engaged with what science looks like outside of the curriculum. On the other hand, poor relationships with high school teachers may result in students feeling that education and science is not somewhere that they belong — this can ‘ruin’ subjects, or lead to students dropping out of school altogether. Schools that are less well resourced are less able to mobilise resources for students to expose them to scientific knowledge in an engaging way. In addition to providing increased access to resources, high decile schools may also be more likely to engage in the process of “spoon-feeding” students so that they can enter into academic pathways more easily. More research is needed to further substantiate these findings, but my work suggests that, while schools have the potential to make science equally accessible to students across Aotearoa New Zealand, it is clear that the education system is stratified in a way that enables students in high decile schools to access high status science subjects, while students in low decile schools have to settle for less.

My work corroborates previous research that suggests that students who come from academic families are more likely to make a smooth transition to university. I explain this in terms of the families capabilities to pass on cultural capital that is high valued in the field of university. As recalled by some undergraduate science students who were interviewed, high parental expectations regarding further study may lead to students feeling that the path to university was already drawn out for them, that it was inevitable. Students who are the subject of concerted cultivation may be more able to navigate university institutions successfully, while those who are exposed to science early may also be most able to develop a habitus that aligns with the field of science. These students can enter into university study like a fish in water, and feel comfortable generating social capital in the field.

Beyond the influence of social capital, the general discourses in society can also help us understand why we see the trends in science participation outlined in Part I of the thesis. Using Bourdieu’s concept of doxa, we can see how common perceptions around who belongs in which subjects echo real life trends. Through interviews with students, my attention was drawn to common discourses on what subjects have value. Subjects such as engineering, medicine, and law are typically viewed as the high subjects, and this may explain why Chapter 3 found that most of the high-achieving students, and especially high-achieving female students, were more likely to pursue medicine as opposed to physics. At the same time, doxa also serve to exclude students from marginalised groups, such as Māori and Pasifika
students, from these high-status domains. While the students I interviewed were able to demonstrate resistance to these discourses, my overall thesis points to how objective structures are manifest in societal discourses and in individuals’ subjective experiences.

In summary, I explain why we see uneven levels of participation in science in terms of three key factors. Students will be more likely to progress in science if they are born into a family that acculturates them to the field, go to a school that further enables them to make the progression to further study, and live in a society where discourses favour them. This explanation for why is both broad and complex. However, my attempts to answer this question can facilitate the generation of interventions to address inequities in the field of science. I will now reflect on some key directions that may provide answers to the question of how we can make the field of science more equitable.

9.3 How Can We Make the Field of Science More Equitable?

My thesis offers some potential directions for how we can make the field of science more equitable. Without repeating my recommendations word for word, I think this question can be answered on two main levels. Firstly, some students will be born into contexts where their exposure to science is limited until they enter school. It is also likely that these students are overly represented in rural areas or less affluent areas, among Māori and Pasifika groups, and where high schools are under-resourced. If we want to aim towards becoming an egalitarian society where all students are enabled to reach their potential, students need to be given the same opportunities to succeed if they wish to.

Secondly, the struggle to determine whose capital has value has clear implications for the field of science. The “culture of no culture” that is typical of science favours individuals who fit in with the established power — i.e., white, male, western modern science. While there has clearly been progress in addressing the negative impacts of this culture on those who do not fit in with the common narratives of who a scientist is, we must ensure that it is done in a way that legitimises the cultural capital that marginalised groups embody. This means ensuring that non-western perspectives of science are integrated into the school curriculum in a way that is not tokenistic, and ensuring that students of all groups are given the opportunity to learn in contexts where their culture is valued. This points to the
highly valuable role that programmes such as Tuākana and the MAPAS can offer students at university.

9.4 Limitations

Throughout the thesis there were several topics that were touched on, but not explored in depth. The following sections will discuss some areas that warrant further research.

Although issues of gender were a strong focus of this thesis, my theoretical analysis of how gender and sexuality are considered within a Bourdeusian framework are limited. My analysis situates gender differences as the result of classed habitus (or a gendered habitus), where similar exposures lead to similar internalisations, and thus similar practices. The discourses surrounding gender offer one such experience, and following Bourdieu’s description of doxa, this discourse reproduces itself and becomes self-evident due to the impact it has on shaping students’ educational trajectories. For example, female students are more likely to be stereotyped as being bad at mathematics, and this may then dissuade female students from the domain, which reinforces the original negative stereotype. Other theorists, such as Skeggs (2004), offer considerable critiques of Bourdieu by situating his theory in the context of feminist theory. Incorporating feminist critiques of Bourdieu into my theoretical model may have yielded valuable insights, as I may have been able to offer a more considered discussion of femininity and masculinity (both of which are complex topics) and the relationships between gender, sexuality, and power. In a related note, the position of gender diverse students in science was touched upon, with the experiences of one student who identified as trans male. This topic was not explored beyond the student’s experience of having to identify as a member of a minority group within science. Further explorations of LGBTQ+ students’ experiences in science and academia are warranted. Research in this area is scarce, although findings from Breck Lorenz et al. (2020) suggest that students in STEM may hold more opposition to discussion of LGBTQ+ issues in curriculum. Kersey (2018) provide one example that has investigated the experiences of transgender students in post-secondary STEM Education specifically.

My analysis of race and ethnicity is also limited as it focuses on comparing ‘others’ to the dominating culture in science. In doing so, my analysis may potentially homogenise the experiences of Māori, Pasifika, and Asian students in science. Further research is needed to expand on how Māori and the various Pasifika cultures in particular relate to university science. Further discussion of which
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forms of knowledge have value in the field of science is warranted, as well as students’ perceptions of science curriculum at university. For further discussion of this topic, I point to the works of McKinley (2005), Stewart (2017), and Hikuroa (2017). While my research touches on some of the experiences of Asian students in science, this analysis is very limited and also only briefly touches on the role of immigration in students’ educational journeys. For further research into the experiences of minority-ethnic (including Asian) students in science, I recommend the work of Vong (2016).

The current research focused mainly on successful stories of participants in education – this was a deliberate choice to focus on the assets of students instead of deficits. With that being said, it is still important to listen to voices of those who have been excluded as well as those who made it in the face of exclusion. In adopting an assets-based approach, the current research neglects the “dark side” of social capital (Gargiulo and Benassi 1999), the manner in which relationships can result in ‘social liability’ as opposed to social capital. The impact of overembeddedness, for example, was touched on briefly in Chapter 8 in the discussion of how Renee found renewed purpose after leaving a controlling relationship. Another participant recalled the strong demands placed on their time by their family-orientated Pasifika family, and how these demands made it difficult for them to focus on their education. There is much to unpack in this discussion, and this lies outside of the scope of the current research and my capabilities as a Pākehā/Palagi researcher.

The complexity of this experience is touched on in previous research. Zepke et al. (2011) found that family responsibilities can place more demands on Pasifika and Māori students, while Theodore et al. (2018) found that family is commonly cited as both a potential hindrance and strong source of support in the completion of post-graduate qualifications for Pasifika students.

One final topic that has not been discussed in the current work is the impact of the internet and computers on students’ experiences in science. The internet can serve as a powerful and equitable source of social capital in science, especially as access to the internet has increasingly become more equal. Many participants touched on how they looked to the internet for advice, information, and role models. Students may also be exposed to computer science through gaming (Lakanen and Kärkkäinen 2019), as was the case for a couple of participants in my research. While the role of computers and the internet on students’ interests in science was a minor theme in my interviews, past research suggests that early exposure to computers can spark interests in computer science for a diverse range of students.
Future work should explore this research area in the context of Aotearoa New Zealand.

9.5 Going Forward

I opened up my thesis with an introduction that touched upon my own personal experience in science education. I was able to progress through university and into a PhD, despite my experience of disillusionment with high school science education, but many students who experience the same disillusion with science are not so lucky. Ultimately, my thesis emerged from an effort to understand why tertiary science education is a path drawn out for some students, but not all. By answering the questions of what science participation looks like, why it looks that way, and how we can make science education more equitable, my thesis offers an in depth exploration of students’ experiences in science in Aotearoa New Zealand. Despite the limitations outlined in previously in this chapter, I believe that my thesis has contributed to answering these key research questions, and opened up a window to how these questions can be approached using novel methods that can provide new insights. It is my hope that this work can contribute to ideal goal of making tertiary science education a field where students from all backgrounds feel that they belong.
Bibliography


Bibliography


Appendices
Science Scholars Interviews:
Human Ethics Approval
Participant Information Sheet

Project Title: Science Capital in New Zealand Science Scholars  
Name of Principle Investigator/Supervisor: Dr Kirsten Locke, Dr Dion O’Neale  
Name of Student Researcher: Steven Turnbull

Researcher introduction
Kia ora! My name is Steven Turnbull and I am a PhD student in Education. I am based in the school of Critical Studies in Education and my supervisors are Dr Kirsten Locke and Dr Dion O’Neale. My thesis will explore how a person’s life experiences impact on their choices to study science in higher education.

Research Purpose and an Invitation
Broadly speaking, my research looks at why people choose to study science. This question alone is quite important, with governments across the world concerned with the number of students who are dropping out of science subjects at school. I want to take a positive approach to answering this question, by understanding the factors in a person’s life that positively impact on aspirations to study science.

My research is based on a sociological theory set out by Pierre Bourdieu, who argued that access to resources affects not only the accessibility of a career path, but also our desires to pursue that path. An obvious resource is money, while things such as knowing someone in that career, or even watching a particular TV program about that career are also important. My goal is to understand what resources are important for students who ended up wanting to study science.

As a part of my research, I would be very interested in interviewing you. You have been identified because you have been enrolled in the Science Scholars programme. If you choose to participate, you will be one of around 30 students who will be interviewed. My aim is to explore how your life experiences (e.g., family, friends, events etc.) may have led to your enrolment in science at university. Your participation in this study is totally voluntary – you can refuse to participate and withdraw at any time during the interview. This study will not offer any advantages or disadvantages to you.

Project Procedures
We will take part in one reasonably short semi-structured interview. This basically means I have a set of questions I wish to ask you, but I am more interested in having a conversation with you and understanding what you think is important. This interview is likely to take less than an hour, and will be located in a private space at the University of Auckland (if you are not happy with the location, you can offer a more suitable location). I will be looking to ask you about various topics. For example:

- Your experiences growing up – what did you find interesting back then?
- Your experiences in school – what subjects did you choose and why?
- Your transition to university, and where you see yourself going in the future.

I will also ask you about the role that your family, friends and teachers have played during your life so far. The interview will be audio recorded, transcribed, and then analysed. If you volunteer your contact information, I will share the interview transcript with you, firstly to ensure that you are still comfortable with the information you shared, and secondly to ensure that I have transcribed everything correctly (you will have 2 weeks to make any changes). The only cost to you will be the time given to the interview and potentially the travel to the interview. Your grades or experiences at the university will not be affected by anything you say (as guaranteed by Dr Nicolette Rattenbury, the administrator of the Science Scholars programme and Professor John Hosking, Dean of Science).
What are the benefits for you when participating in this research?
Although I cannot promise any benefits from participating in the study, your interview may offer a unique insight into the factors that benefit students in science. I hope that what you say will lead to a positive impact on other students in science.

Data storage/retention/destruction/future use
I will audio record our interview so that I can transcribe it verbatim (i.e., word-for-word), and analyse it. It is possible that a 3rd party that has signed a confidentiality agreement will be used to transcribe interviews. You will be able to volunteer your contact information to receive a copy of the interview transcript so that you can review what has been said, and check that it has been transcribed correctly. You will have 2 weeks to make any changes. All electronic data will be stored on a password protected computer on a secure University of Auckland server for 6 years. All physical data, including consent forms, will be kept in a locked file cabinet in my supervisor’s office for 6 years. After a 6 year period, any electronic data will be permanently erased, and any physical data will be destroyed and put in a bin at the University of Auckland designated for confidential information.

Anonymity and Confidentiality
To protect your confidentiality, you will choose a pseudonym at the beginning of our interview. This pseudonym will be used in transcriptions, and in any future reporting or publications. I will not seek to find out other identifiable information (e.g., when you were born, or addresses). We will ensure privacy during the interview by conducting it a secure location on campus at the University of Auckland. Due to the number of students in the Science Scholars programme, there is a small possibility that you may be identifiable from the interview. The research team will sign a confidentiality agreement, along with any 3rd party transcribers. My supervisor Dr Dion O’Neale is a lecturer in physics and may have taught you, or may teach you in the future. To avoid any conflict of interest, Dion has not been involved in the selection of participants and will not be involved with the interview process. If you are a student of the researchers we give our assurance that your participation or non-participation in this study will have no effect on your grades or relationship with the University and that you may contact your Head of Department should you feel that this assurance has not been met.

Right to Withdraw from Participation
Although I do not expect that the topics we talk about will cause any discomfort, you may be uncomfortable divulging personal experiences that you have been through. I want to make it explicitly clear that you do not have to talk to me about anything you are uncomfortable with. You may withdraw from the interview at any time without giving reason, and can withdraw your consent for me to use your information within a 2 week timeframe after our interview.
If for any reason you significantly uncomfortable with the interview, you can be put in contact with the university counselling centre (923 7681; Kate Edger Information Commons, Level 3).

Contact Details and Approval Wording
If you do agree to participate in this study, your contact information can be volunteered so that I can contact you. I will only contact you to share interview transcripts and a summary of the findings. However, I will never identify you as one of the research participants.
You can contact me (Steven Turnbull; s.turnbull@auckland.ac.nz), my supervisors Dr Kirsten Locke (k.locke@auckland.ac.nz) and Dr Dion O’Neale (d.oneal@auckland.ac.nz) or my head of school Assoc. Prof Carol Mutch (c.mutch@auckland.ac.nz) if you have any concerns about the research. The Head of Department for Physics, Professor Richard Easther, can be contacted at r.easter@auckland.ac.nz.

Approved by the University of Auckland Human Participants Ethics Committee on 08-Dec-2017 for three years. Reference number 020532
Science Scholars Interviews:
Participant Information Sheet
Participant Information Sheet

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Name of Principle Investigator/Supervisor: Dr Kirsten Locke, Dr Dion O’Neale
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Contact Details and Approval Wording
If you do agree to participate in this study, your contact information can be volunteered so that I can contact you. I will only contact you to share interview transcripts and a summary of the findings. However, I will never identify you as one of the research participants.

For any concerns regarding ethical issues you may contact the Chair, the University of Auckland Human Participants Ethics Committee, at the University of Auckland Research Office, Private Bag 92019, Auckland 1142. Telephone 09 373-7599 ext. 83711. Email: ro-ethics@auckland.ac.nz

Approved by the University of Auckland Human Participants Ethics Committee on 08-Dec-2017 for three years. Reference number 020532
Questionnaire and Interviews: Human Ethics Approval
10-Dec-2018

MEMORANDUM TO:

Dr Dion O’Neale
Physics

Re: Application for Ethics Approval (Our Ref. 022339): Approved with comment

The Committee considered your application for ethics approval for your study entitled Capital in STEM Students.

Ethics approval was given for a period of three years with the following comment(s):

Approved with comment:
Ethics approval was given for a period of three years with the following comments and required minor changes:
1. The committee would like to thank the applicants for a well-written application.

2. Survey PIS:
a. Under the heading ‘How did you get my contact details?’ insert ‘on’ before ‘a departmental emailing list’.
b. Please also include the name and contact information for the HoD (of the PI), and a space to separate these details from the statement about ethical concerns.

3. You may wish to review the formatting of the public documents to improve readability.

The expiry date for this approval is 10-Dec-2021.

If the project changes significantly you are required to resubmit a new application to UAHPEC for further consideration.

If you have obtained funding other than from UniServices, send a copy of this approval letter to the Activations team in the Research Office, at ro-awards@auckland.ac.nz. For UniServices contracts, send a copy of the approval letter to the Contract Manager, UniServices.

The Chair and the members of UAHPEC would be happy to discuss general matters relating to ethics approvals if you wish to do so. Contact should be made through the UAHPEC Ethics Administrators at ro-ethics@auckland.ac.nz in the first instance.
Please quote Protocol number **022339** on all communication with the UAHPEC regarding this application.

(This is a computer generated letter. No signature required.)

UAHPEC Administrators
University of Auckland Human Participants Ethics Committee
c.c. Head of Department / School, Physics  
Dr Dion O'Neale

**Additional information:**

1. Do not forget to fill in the 'approval wording' on the Participant Information Sheets, Consent Forms and/or advertisements, giving the dates of approval and the reference number. This needs to be completed, before you use them or send them out to your participants.

2. At the end of three years, or if the study is completed before the expiry, you are requested to advise the Committee of its completion.

3. Should you require an extension or need to make any changes to the project, please complete the online Amendment Request form associated with this approval number giving full details along with revised documentation. If requested before the current approval expires, an extension may be granted for a further three years, after which time you must submit a new application.
Questionnaire and Interviews: Questionnaire Example with Participant Information Sheet
Kia ora! My name is Steven Turnbull and I am a PhD student in Education. I am based in the school of Critical Studies in Education and my supervisors are Dr Kirsten Locke and Dr Dion O’Neale. I am inviting you to participate in a short online survey, which is a part of a larger research project that will explore how a person’s life experiences impact on their choices to study science in higher education.

What does the research cover?
Phase 1: A short online survey administered to all students studying in departments based in the Faculty of Science. The main purpose of the survey is to obtain preliminary information regarding demographic background, science experiences, family and peer views of science. Phase 2: Interviews will be conducted with 20 participants who completed the survey and gave consent to be interviewed. The interviews will select students on a first to reply basis, with a focus on students who are typically less well represented in science. Interviews will focus on survey responses, but will be semi-structured. This interview will take less than an hour, and will be located in a private space at the University of Auckland (if participants are not happy with the location, they can offer a more suitable location).

Why is my participation important?
By participating you will be contributing to our understanding of why people choose to study science. To be able to represent everyone reliably, we need as diverse and broad a range of participants as possible. Every single person in the study is incredibly important to us, as every single response can help to increase the reliability and accuracy of our conclusions. As a token of appreciation, everyone who completes the questionnaire will be entered into five prize draws for $100 grocery vouchers (total prize pool $500). Prizes will be drawn in October 2019. All participants who participate in the follow up interviews will be given a guaranteed $30 of grocery vouchers (students who do take part in the interviews have the right to withdraw at any time during the interview, and will still be given the voucher).

How did you get my contact details?
You were contacted as you are a departmental emailing list in the Faculty of Science. The questionnaire is completely anonymous, and you will only be asked to submit your contact email if you want to be kept up to date with the findings, or give consent to be interviewed.

Can you tell me more about how I can participate? If you choose to take part in the study, then please complete this online questionnaire. Most people can complete the questionnaire in less
than 15 minutes. The questions are not designed to be sensitive nature, but you are free to leave any questions blank that you do not feel comfortable answering.

Where can I learn more about recent findings from the study? You may volunteer your contact details to be kept up to date with the results of the survey.

How do you ensure my confidentiality? We take our participants’ confidentiality very seriously. All questionnaire responses are completely anonymous, unless you choose to give contact details to be informed of study results, or consent to be interviewed. We will never give out your name or contact details. Your results will only be viewed and analysed by members of the research team. Your questionnaire responses will be stored for 6 years on a secure computer server at The University of Auckland for research purposes, and contact details will be removed from the responses once interviews have been completed.

How is the study funded? This study is funded by a University of Auckland research account belonging to Dr Dion O’Neale.

Do you have any other questions? For questions regarding this project, please contact Steven Turnbull (s.turnbull@auckland.ac.nz), or supervisors Dr Dion O’Neale (d.oneale@auckland.ac.nz, ) and Dr Kirsten Locke (k.locke@auckland.ac.nz; ext 48359). For ethical concerns contact: The Chair, The University of Auckland Human Participants Ethics Committee, The University of Auckland, Private Bag 92019, Auckland. Phone 09-373-7599, extn. 83711, email: ro-ethics@auckland.ac.nz

APPROVED BY THE UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE
ON 10-Dec-2018 FOR 3 YEARS. REFERENCE NUMBER: 022339
Q2 Submission of the questionnaire constitutes consent to participating in the research. Do you agree to participate?

- Yes, I agree to participate and am ready to start (1)
- No, I don’t want to participate (2)

Skip To: End of Survey If Submission of the questionnaire constitutes consent to participating in the research. Do you agree... = No, I don’t want to participate

End of Block: Consent

Start of Block: Demographics

Q3 The following questions will ask you to give some more information about yourself.

Q4 What is your gender identity? (e.g., Female, Male, Gender diverse, Transgender etc.)
Q5 What is your ethnicity? (You may select more than one)

- New Zealand European/Pākehā (47)
- Other European (67)
- Māori (49)
- Samoan (51)
- Cook Islands Māori (52)
- Tongan (53)
- Niuean (54)
- Tokelauan (55)
- Fijian (56)
- Other Pacific Peoples (57)
- Southeast Asian (59)
- Chinese (60)
- Indian (61)
- Other Asian (62)
- Middle Eastern (63)
- Latin American (64)
- African (65)
☐ Other (please specify) (66)

Q109 What is your date of birth? (DD/MM/YYYY)

Page Break
Q6 Did you attend high school in New Zealand?
- Yes (1)
- No (2)

Q7 Did you attend a single-sex high school?
- Yes (1)
- No (2)

Q8 Did you attend a private school?
- Yes (1)
- No (2)
- Don’t know (3)
Q9 What stage of university are you in?

- First Year Undergraduate (1)
- Second Year Undergraduate (2)
- Third Year Undergraduate (3)
- Fourth Year Undergraduate (4)
- Post-graduate (5)
- Other (Please specify) (6) __________________________________________

Q10 Do you know your rank score from high school? (*Rank Score is used to determine eligibility to specific programmes of study, and is based on your high school results.*)

- Yes (1)
- No (2)

Display This Question:

*If Do you know your rank score from high school? (Rank Score is used to determine eligibility to specific programmes of study, and is based on your high school results.*) = Yes*

Q11 You said you know your rank score from high school, what was it?

<table>
<thead>
<tr>
<th>0</th>
<th>40</th>
<th>80</th>
<th>120</th>
<th>160</th>
<th>200</th>
<th>240</th>
<th>280</th>
<th>320</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rank Score ()</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

End of Block: Demographics
Start of Block: Which of these subjects is your main field of study?
Q12 Which subject do you consider your main field of study?

▼ Accounting (1) ... Other (please specify) (31)

Q13 When did you decide on what you wanted to study at university?

- Before high school (1)
- During high school (2)
- After high school but before university (3)
- Whilst at university (4)
- I’m still undecided (5)
Q14 Which of the following best describes the reason(s) you chose to study this subject?

- I am good at it/got good high school grades (1)
- My high school teacher encouraged me to continue with the subject (2)
- My parents/family motivated me to continue with the subject (4)
- I am interested in the subject (5)
- The subject will help me get the job I want to pursue (6)
- This subject is really easy (7)
- This subject is really difficult, and I like a challenge (8)
- I do not feel that I had a choice (9)
- Other - please specify (10)

- Don't know (11)
Q15 Which of the following science courses are you currently taking? (you may select more than one)

☐ Biology (1)
☐ Chemistry (2)
☐ Computer science (7)
☐ Maths (8)
☐ Physics (3)
☐ Psychology (10)
☐ Statistics (4)
☐ None of the above (9)
Q16 Please rate how much you agree or disagree with the following statements. (0 being strongly disagree, 100 being strongly agree)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Disagree</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>I understand everything in my science courses ()</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I find science difficult ()</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>I get good marks in science tests ()</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>If I study hard, I will do well in my science courses ()</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>I am just not good at science ()</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning about science is exciting ()</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Q17 The following section will ask you about your high school teachers.

Q18 Please rate how much you agree or disagree with the following statements. (0 being strongly disagree, 100 being strongly agree)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Disagree</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>My high school teachers recognised that I was good at science ()</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>My high school teachers cared whether I understood science ()</td>
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<tr>
<td>My high school teachers explained to me that science is useful for my future ()</td>
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<tr>
<td>My high school science teachers were enthusiastic about science ()</td>
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<tr>
<td>My teachers have specifically encouraged me to continue with science after high school ()</td>
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</tbody>
</table>
Q19 The following section will ask for your opinions on different scientific disciplines, including:

- The **Physical Sciences** (Physics, Chemistry, Geophysics)
- The **Life Sciences** (Biology, Medicine, Health)
- **Information Technology** (Computer Science, Information Systems)
- **Maths and Stats**
- **Engineering**
- **Social Science** (Psychology, Sociology).
Q20 In general, how do people value the following subjects? 
0 being not very valuable, 100 being very valuable.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Not valuable</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Sciences ()</td>
<td></td>
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<tr>
<td>Life Sciences ()</td>
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<tr>
<td>Information Technology ()</td>
<td></td>
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<tr>
<td>Maths and Stats ()</td>
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<td>Engineering ()</td>
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<tr>
<td>Social Sciences ()</td>
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</table>
Q21 The following section will ask you about your family background.

Q22 Think about your FATHER (or male carer) and his job. Which of these phrases BEST describes the MAIN job that he does currently?

- Professional job (e.g. manager, doctor, architect, teacher, lawyer, dentist, accountant, director, nurse) (1)
- Senior government or public sector worker (e.g. inspector, prison governor, customs officer, surveyor) (4)
- Store worker (e.g. sales representative, shop sales person) (5)
- Hands-on job requiring specialist training (e.g. plumber, electrician, fitter, mechanic, foreman, bus driver or conductor, police officer, fire fighter agricultural worker, chef/cook) (6)
- Job needing a small amount of training or experience to start (e.g. hairdresser, beautician, mini-cab driver, caretaker, teaching or school assistant, childcare worker, nursery nurse) (7)
- Job needing no special training (e.g. general labourer, casual worker, lorry driver, window cleaner, domestic cleaner, caterer, hotel or bar staff) (8)
- Homemaker/unpaid carer (househusband) (9)
- Unemployed (10)
- Prefer not to say (13)
- Don’t know (11)
- Other (please specify) (12) ________________________________________________
Q23 Think about your MOTHER (or female carer) and her job. Which of these phrases BEST describes the MAIN job that she currently does?

- Professional job (e.g. manager, doctor, architect, teacher, lawyer, dentist, accountant, director, nurse) (1)
- Senior government or public sector worker (e.g. inspector, prison governor, customs officer, surveyor) (4)
- Store worker (e.g. sales representative, shop sales person) (5)
- Hands-on job requiring specialist training (e.g. plumber, electrician, fitter, mechanic, foreman, bus driver or conductor, police officer, fire fighter agricultural worker, chef/cook) (6)
- Job needing a small amount of training or experience to start (e.g. hairdresser, beautician, mini-cab driver, caretaker, teaching or school assistant, childcare worker, nursery nurse) (7)
- Job needing no special training (e.g. general labourer, casual worker, lorry driver, window cleaner, domestic cleaner, caterer, hotel or bar staff) (8)
- Homemaker/unpaid carer (housewife) (9)
- Unemployed (10)
- Prefer not to say (13)
- Don’t know (11)
- Other (please specify) (12) ________________________________________________
Q24 I am the first in my family to go to university

- Yes (1)
- No (2)
- Don't know (3)

Display This Question:
If I am the first in my family to go to university = No

Q25 You said you were not the first in your family to go to university. Who in your family has gone to university?

- Mother (1)
- Father (2)
- Sibling (3)
- Grandparents (8)
- Extended family members (aunts, uncles, cousins) (4)
- Other (please specify) (7)

- Don't know (6)
Q26 One of my family members works as a scientist or in a job that uses science

- Yes (1)
- No (2)
- Don’t know (3)

Display This Question:
If One of my family members works as a scientist or in a job that uses science = Yes

Q27 You said someone in your family works as a scientist or in a job using science. Can you tell us who they are? (you may select multiple)

- Mother (2)
- Father (6)
- Sibling (7)
- Grandparents (5)
- Extended family members/whānau (aunts, uncles, cousins) (3)
- Other (please specify) (4)

________________________________________________
Q28 The following section will ask you about your relationships with family, friends, and others important figures in your life.

---

Q29 Who do you talk to about science?

- [ ] Friends (1)
- [ ] Classroom peers (2)
- [ ] Siblings (3)
- [ ] Mother (4)
- [ ] Father (12)
- [ ] Extended family members/whānau (grandparents, aunts, uncles, cousins) (5)
- [ ] Scientists (6)
- [ ] University assistance (e.g. Tuākana, UniBound, physics help room etc.) (10)
- [ ] Teachers/lecturers (7)
- [ ] Tutors (11)
- [ ] No one (8)
- [ ] Other (please specify) (9)

---
Q30 I can ask the following groups for help with school/university work

☐ Friends (1)
☐ Classroom peers (2)
☐ Siblings (3)
☐ Mother (4)
☐ Father (12)
☐ Extended family members/whānau (grandparents, aunts, uncles, cousins) (5)
☐ Scientists (10)
☐ University assistance (e.g. Tuākana, UniBound, physics help room etc.) (9)
☐ Teachers/lecturers (6)
☐ Tutors (11)
☐ No one (7)
☐ Other (please specify) (8)

________________________________________________
Q31 I can ask the following groups for advice on careers in science-related fields

☐ Friends (1)
☐ Classroom peers (2)
☐ Siblings (3)
☐ Mother (4)
☐ Father (13)
☐ Extended family members/whānau (grandparents, aunts, uncles, cousins) (5)
☐ Scientists (11)
☐ University assistance (e.g. Tuākana, UniBound, physics help room etc.) (10)
☐ Teachers/lecturers (6)
☐ Tutors (12)
☐ Careers advisers (7)
☐ No one (8)
☐ Other (please specify) (9)

________________________________________________
Q32 The following section will ask you about your parents/carers.

Q33
Please rate how much you agree or disagree with the following statements.
(0 being strongly disagree, 100 being strongly agree)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Disagree</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>My parents/carers expected me to go to university ()</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My parents/carers know how well I am doing at university ()</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My parents/carers think science is interesting ()</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My parents/carers think it is important for me to learn science ()</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My parents/carers would like it if I worked in science ()</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>My parents/carers have explained to me that science is useful for my future ()</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Q34 The following section will ask you about your friends.

Q35
Please rate how much you agree or disagree with the following statements. (0 being strongly disagree, 100 being strongly agree)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>My friends went to university ()</td>
<td></td>
</tr>
<tr>
<td>My friends see me as a &quot;science&quot; person ()</td>
<td></td>
</tr>
<tr>
<td>My friends think that science is important ()</td>
<td></td>
</tr>
<tr>
<td>My friends think science is cool ()</td>
<td></td>
</tr>
<tr>
<td>My friends care about their university grades ()</td>
<td></td>
</tr>
</tbody>
</table>

Page Break
Q36 The following section will ask about the resources you had growing up.

Q37 Growing up, how many books were there in your home?

- None (1)
- Very few (less than 50 books) (2)
- One shelf filled with books (50 books) (3)
- One bookcase filled with books (200 books) (4)
- More than one bookcase filled with books (more than 200 books) (5)
- Don’t know (6)

Q38 Growing up, did you have access to a computer or laptop outside of school time?

- Yes (1)
- No (2)
- Don’t know (3)
Q39 Growing up, did you go to museums or galleries?

- At least once a week (4)
- At least once a month (11)
- At least once a year (12)
- Never (13)
- Don't know (14)
Q40 Growing up, did you do science activities (e.g., science kits, nature walks, do experiments)?

- At least once a week (1)
- At least once a month (8)
- At least once a year (9)
- Never (10)
- Don’t know (14)

Q41 Growing up, did you read books or magazines about science?

- At least once a week (1)
- At least once a month (8)
- At least once a year (9)
- Never (10)
- Don’t know (12)

Q42 Growing up, did you look up things online about science or nature?

- At least once a week (1)
- At least once a month (4)
- At least once a year (5)
- Never (6)
- Don’t know (8)
Q43 Growing up, did you visit the zoo or aquarium?

- At least once a week (1)
- At least once a month (8)
- At least once a year (9)
- Never (10)
- Don’t know (12)

Q44 Growing up, did you watch TV programmes about science or nature?

- At least once a week (1)
- At least once a month (8)
- At least once a year (9)
- Never (10)
- Don’t know (12)

Q45 Growing up, did you go to a lunchtime or after-school science club?

- At least once a week (1)
- At least once a month (8)
- At least once a year (9)
- Never (10)
- Don’t know (12)
Q46 Please leave your contact email if you would like to be kept updated with the results of the survey, and be entered into a prize draw of one of five $100 grocery vouchers.

Q47 Would you be happy to be interviewed (and receive a guaranteed $30 worth of grocery vouchers if interviewed)?

- Yes (please leave your contact email) (1)
- No (2)
Questionnaire and Interviews:
Participant Information Sheet
Project Title: Capital in STEM Students
Name of Principle Investigator/Supervisor: Dr Kirsten Locke, Dr Dion O’Neale
Name of Student Researcher: Steven Turnbull

Participant Information Sheet - Interviews

Researcher introduction
Kia ora! My name is Steven Turnbull and I am a PhD student in Education. I am based in the school of Critical Studies in Education and my supervisors are Dr Kirsten Locke and Dr Dion O’Neale. My thesis will explore how a person’s life experiences impact on their choices to study science in higher education.

Research Purpose and an Invitation
Broadly speaking, my research looks at why people choose to study science. This question alone is quite important, with governments across the world concerned with the number of students who are dropping out of science subjects at school. I want to take a positive approach to answering this question, by understanding the factors in a person’s life that positively impact on aspirations to study science. I am interested in the perspectives of all students, regardless of whether they study science or not.

My research is based on a sociological theory set out by Pierre Bourdieu, who argued that access to resources affects not only the accessibility of a career path, but also our desires to pursue that path. An obvious resource is money, while things such as knowing someone in that career, or even watching a particular TV program about that career are also important. My goal is to understand what resources are important for students who ended up wanting to study science.

As a part of my research, I would be very interested in interviewing you. You have been identified because you have signalled that you would be interesting in being interviewed on a questionnaire administered to students at the University of Auckland. If you choose to participate, you will be one of around 20 students who will be interviewed. My aim is to understand your science background, levels of interest in science, and what your plans for the future are. Your participation in this study is totally voluntary – you can refuse to participate and withdraw at any time during the interview. You will be given a $30 voucher as a thank you for participating.

Project Procedures
Phase 1: A short online questionnaire administered to all students studying in a department based in the Faculty of Science. The main purpose of the questionnaire is to obtain preliminary information regarding demographic background, science experiences, family and peer views of science.
Phase 2: You are one of 20 participants who has been selected to be interviewed after completing the questionnaire and giving consent to be interviewed. You have been selected on a first to reply basis, with a focus on students who are typically less well represented in science. Our interviews will focus on your questionnaire responses but will be semi-structured. This means that I am more interested in having a conversation with you and understanding what you think is important. This interview will take less than an hour and will be located in a private space at the University of Auckland (if you are not happy with the location, you may offer a more suitable location).

The interview will be audio recorded, transcribed, and then analysed. If you volunteer contact information, I will share the interview transcript with you, firstly to ensure that you are still comfortable with the information shared, and secondly to ensure that everything has been transcribed correctly (you will have 2 weeks to make any changes). The only cost to you will be the time given to the questionnaire and interview, and potentially the travel to the interview. Your grades or experiences at the university will not be affected by anything you say (as guaranteed by Professor John Hosking, Dean of Science).

What are the benefits for you when participating in this research?
You will be given a $30 grocery voucher.

Data storage/retention/destruction/future use
I will audio record our interview so that it can be transcribed verbatim (i.e., word-for-word) either by myself (Steven Turnbull) or by a third-party transcriber who has signed a confidentiality agreement. The transcription will then be analysed. You will be able to volunteer your contact information to receive a copy of the interview transcript so that you can review what has been said, and check that it has been transcribed correctly. You will have 2 weeks to make any changes. All electronic data will be stored on a password protected computer on a secure University of Auckland server for 6 years. All physical data, including consent forms, will be kept in a locked file cabinet in my supervisor’s office for 6 years. After a 6 year period, any electronic data will be permanently erased, and any physical data will be destroyed and put in a bin at the University of Auckland designated for confidential information. Previous questionnaire responses will also be kept on a secure server at the University of Auckland for 6 years, but contact emails will be removed once the interview phase is complete to help preserve your confidentiality.

**Anonymity and Confidentiality**
To protect your confidentiality, questionnaire responses will be anonymous (except if you have volunteered your contact details to receive a copy of results, or consent to be interviewed). You will choose a pseudonym at the beginning of our interview. This pseudonym will be used in transcriptions, and in any future reporting or publications. I will not seek to find out other identifiable information (e.g., addresses). We will ensure privacy during the interview by conducting it a secure location on campus at the University of Auckland. The research team will sign a confidentiality agreement, along with any 3rd party transcribers. My supervisor Dr Dion O’Neale is a lecturer in physics and may have taught you, or may teach you in the future. To avoid any conflict of interest, Dion has not been involved in the selection of participants and will not be involved with the interview process. If you are a student of the researchers, we give our assurance that participation or non-participation in this study will have no effect on your grades or relationships with the University of Auckland. You may contact your Head of Department should you feel that this assurance has not been met.

**Right to Withdraw from Participation**
Although I do not expect that the topics we talk about will cause any discomfort, you may be uncomfortable divulging personal experiences that you have been through. I want to make it explicitly clear that you do not have to talk about anything you are uncomfortable with. Your participation in this study is totally voluntary. You can choose not to answer any particular questions – or ask for the audio recorder to be turned off at any time, without needing to provide a reason. You can choose to withdraw your participation up to 2 weeks after the interview has been conducted. If for any reason you are significantly uncomfortable with the interview, you can be put in contact with the university counselling centre (923 7681; Kate Edger Information Commons, Level 3).

**Contact Details and Approval Wording**
If you do agree to participate in this study, your contact information can be volunteered so that I can contact you. I will only contact you to share interview transcripts and a summary of the findings. I will never identify you as a research participant.

You can contact me (Steven Turnbull; s.turnbull@auckland.ac.nz), my supervisors Dr Kirsten Locke (k.locke@auckland.ac.nz; extn. 48359) and Dr Dion O’Neale (d.oneal@auckland.ac.nz) or my head of school Assoc. Prof Carol Mutch (c.mutch@auckland.ac.nz) if you have any concerns about the research. The Head of Department for Physics, Professor Richard Easther, can be contacted at r.easther@auckland.ac.nz For any concerns regarding ethical issues you may contact the Chair, the University of Auckland Human Participants Ethics Committee, at the University of Auckland Research Office, Private Bag 92019, Auckland 1142. Telephone 09 373-7599 ext. 83711. Email: ro-ethics@auckland.ac.nz

Approved by the University of Auckland Human Participants Ethics Committee on 10-Dec-2018 for three years. Reference number 022339
Transcriber Confidentiality Agreement
Project Title:
Capital in STEM Students

Name of Principle Investigator/Supervisor:
Dr Kirsten Locke, Dr Dion O’Neale

Name of Student Researcher:
Steven Turnbull

TRANSCRIBER CONFIDENTIALITY AGREEMENT

Transcriber: ____________________________

I agree to transcribe the audio-recordings for the above research project. I understand that the information contained within them is confidential and that I must not disclose or discuss it with anyone other than the researcher and his/her supervisor(s). I shall delete any copies that I may have made as part of the transcription process.

Name: ____________________________

Signature: __________________________

Date: ____________________________

Approved by the University of Auckland Human Participants Ethics Committee on 10-Dec-2018 for three years. Reference number 022339