Rere Āwhio

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CONTENTS

Bruno Balducci, Bing Dai, Barry Dowdeswell and Lorraine Skelton

Kia ora koutou katoa, nau mai haere mai, and welcome to Issue Four of Rere Āwhio.

In this issue, we explore a range of topics that address the growing intersections of sustainability, technological advancement, and social equity. Our contributors have engaged with current challenges in education, technology, and environmental stewardship, offering thought-provoking insights that we hope will resonate with both scholars and practitioners.

Sustainability in Education and Beyond

Priscy Dissanayake and Indrapriya Kularatne delve into the awareness of sustainability among international students in Auckland. Their work highlights how educational institutions play a crucial role in shaping the environmental consciousness of future leaders. Similarly, Nenie Petrisia and Indrapriya Kularatne follow this with their exploration of data-driven and machine learning approaches to perishable food waste optimization in New Zealand's retail sector, presenting innovative strategies for waste reduction in an industry often marked by excess. Following on from here Andrey Lykov and Yury Zhukov's research into vape and e-cigarette waste management underscores the importance of public responsibility and environmental care in tackling new waste streams.

Equity and Wellbeing in the Modern Workforce

Liman Wu and Waruni Hewage turn our attention to equity in remote work settings, particularly in the data science field. Their analysis highlights discrepancies in remote salaries and points to the need for fairer compensation structures. The theme of worker wellbeing is further explored by Jayani Dissanayake, Olufemi Omisakin, and Indrapriya Kularatne in their literature review on how remote work affects the psychological health of IT workers. Together, these pieces paint a picture of the challenges and opportunities of modern work environments.

Education, Innovation, and the Future of Work

The exploration of education and innovation is continued by the work of Rehan Masood, Nick Wilson, Nayani Landage, and Omer Altaf, who discuss learners' perceptions of Building Information Modelling (BIM) in collaborative educational settings. Meanwhile, Leijun Shi and Srividya Krishnamoorthy offer a critical look at the role of site meetings in New Zealand construction projects, emphasizing their contribution to successful project outcomes.

Barry Dowdeswell, Tariq Khan, Asanthika Imbulpitiya, Waruni Hewage, Kathiravelu Ganeshan, and Farhad Mehdipour tackle the complexities of concept acquisition in undergraduate software engineering courses, focusing on the timing of object-first versus object-late learning approaches. Lorraine Skelton contributes a timely piece on speech recognition software in tertiary education, a tool increasingly essential for both students and academic staff in today's digital age.

Diversity and Transformation in Industry

Finally, Hetaswi Patel and Firas Almughrabi examine the barriers faced by women in New Zealand's construction industry, offering critical insights into the enablers of wellbeing and professional success. In a spotlight on industry leaders, Lorraine Skelton profiles Veronique Manti, an immigrant turned influential business transformation and innovation consultant, whose career reflects the broader theme of resilience and adaptability.

Andrew Widjaja and Edwin Rajah bring the issue to a close by discussing the importance of developing critical thinking skills among international postgraduate learners, a crucial competency in our increasingly interconnected world. Bruno Balducci rounds off this exploration with an editorial on the implications of artificial intelligence for vocational education, a topic that is as complex as it is timely.

As we navigate an era of unprecedented change, this set of works offers a clear message: the future of work, education, and environmental responsibility is interconnected and increasingly reliant on innovative solutions. We hope that the insights and research shared within these pages inspire meaningful discussions and further exploration in these vital areas.

SUSTAINABILITY AWARENESS AMONG UNDERGRADUATE AND POSTGRADUATE INTERNATIONAL STUDENTS IN AUCKLAND

Priscy Dissanayake and Indrapriya Kularatne

OTAGO POLYTECHNIC AUCKLAND INTERNATIONAL CAMPUS

ABSTRACT

This study investigates the application of sustainable practices by international students in the tertiary sector in Auckland, New Zealand and their knowledge of sustainability principles, with a specific focus on undergraduate and postgraduate level students. The hypothesis tested in this investigation is that there is a difference in the level of understanding of sustainability between undergraduates and postgraduates. A considerable number of international students arrived in New Zealand in the year 2023 and will be joining the workforce shortly. Auckland, as a multicultural city, offers a unique setting for observing the intersection of diverse cultural influences on sustainable behaviour. Although research has been conducted regarding sustainability and education, it has been observed that research based on the levels of education and its implications for understanding of sustainability is lacking. This creates a research gap in the area of study.

As a primary research instrument, a questionnaire was used to gather information on both the awareness of sustainability and the ability to apply it of international students in Auckland. A quantitative data analysis including Pearson's Chi-square and Fisher's Correlation Coefficient tests was conducted to identify the differences between the undergraduate and postgraduate levels. The findings reveal key factors influencing the differential application of sustainability knowledge, including cultural backgrounds, academic levels, and the practicality of sustainability practices in Auckland. No significant difference in knowledge and application of sustainability between the two levels of study was identified. This indicates the need for disciplined specific approaches to enhance sustainability practices in Auckland.

Keywords: Circular economy, Food-energy-environment trilemma, Subjective norm, Sustainability and inner transformation, Triple bottom line.

INTRODUCTION

This study aims to determine whether there is a difference between the level of education of students in relation to the application of sustainability in New Zealand among international students in the tertiary education sector. Despite facing competition from other countries, New Zealand's education industry remains robust, contributing significantly to the GDP. Therefore, international students can be seen as crucial for New Zealand's sustainable development goals, aligning with the government's commitment to the Triple Bottom Line (TBL) approach—which emphasises planet, people, and profit.

There is a noted gap in sustainability education among tertiary institutions for international students in New Zealand, highlighting the need for a stronger pedagogical emphasis on sustainability in curriculum and teaching methods. Therefore, it is important to define how a transformational change could be introduced to reduce this gap in the tertiary education sector in New Zealand.

The concept of sustainable development is based on an ongoing learning process rather than a static implementation of predetermined values and behaviours. This approach emphasises that educators in New Zealand must possess the capabilities needed for advancing sustainability, such as critical reflection and problem-solving, in order to teach and engage learners in constructing sustainable practices rather than just learning about them. Recently, there has been growing attention to the concept of 'inner transformation' in sustainability education, highlighting the importance of personal and mindfulness-based approaches in fostering a reflective and sustainable society. In 2009, a survey was conducted by the New Zealand National Environment Education (NZNEE) consisting of 1,300 industry professionals and eight case studies from leading firms. The results of this survey showed that 75% of organisations are required to share knowledge about the corporate environment and sustainability goals, and 65% would prefer a job candidate who is

sensitive to environmental issues and sustainability (Jim Wu et al., 2010). DV investment (2003) identified that 56% of investors are planning to increase their allocations to Environmental, Social, and Governance (ESG) investments by 2024. Further, by 2030, 24 million new "jobs" will be created, by shifting to a greener economy (UNO, n.d.). Hence adequate emphasis must be given to guiding international tertiary students in order to inculcate better sustainable circular economic practices (Sustainable Development Goals, n.d.).

In December 2020, a climate emergency was declared in New Zealand after it experienced extreme catastrophic weather events that directly impacted its primary industries and the socio-cultural and economic wellbeing of the country. In response, the government of New Zealand has mapped out a path to net zero emissions by 2050 with a climate emergency plan developing and adopting, Te Tāruke-ā-Tāwhiri: Auckland's Climate Plan (Climate Connect Aotearoa, 2023). With the impact of Cyclone Gabrielle in January 2023, climate change impacts were felt very strongly in Tamaki Makaurau, Auckland, and across New Zealand (Climate Connect Aotearoa, 2023). This resulted in the Auckland region's insurance losses, which are estimated at $1.66 billion, nearly six times the total loss of climate damage in 2022 (Climate Connect Aotearoa, 2023).

Tangata whenua, the Māori community in New Zealand, have a strong focus on sustaining the flora and fauna of the country. Based on the Māori paradigm, there is an intricate, holistic and interconnected cosmological explanation about the natural world (Mika et al., 2022). Accordingly, it is the responsibility of atua (departmental gods) to sustain the wellbeing of flora and fauna; and the relationships between humans and ecosystems as a reciprocal relationship comprising manaaki whenua (caring for the land) and manaaki tangata (caring for people) (Mika et al., 2022). With such an emphasis on caring for the land and its people by Māori, all immigrant students in the tertiary sector must be made aware of the importance of sustainability in New Zealand.

As previously discussed, there are two primary areas of focus regarding sustainability in New Zealand. Firstly, the impact of recent natural disasters has highlighted the need for resilience and environmental stewardship. Secondly, the Māori community places significant emphasis on the interconnectedness of people (tangata), flora, and fauna in New Zealand. These considerations underscore the importance of raising awareness among international tertiary students about the necessity of protecting and promoting sustainability initiatives in the country. Given that Auckland is the commercial capital of New Zealand and more susceptible to contributing to environmental hazards, it is crucial to consider the impact of international tertiary students on sustainable initiatives in the country.

The research objectives of this study are to identify the application and knowledge of sustainability amongst international tertiary students at the undergraduate and postgraduate levels, and thereafter to propose recommendations if a gap is identified between the knowledge and application between the two groups. In addition to the cognitive understanding of sustainability, this article identifies the importance of effective engagement and action-oriented learning that leads to meaningful change. It also discusses how Integrating sustainability into education requires a shift towards transformative pedagogies that extend beyond imparting knowledge to fostering deeper understanding, empathy, and actionable insights among learners. This approach is crucial for addressing local challenges and nurturing a sustainable future for international tertiary students in New Zealand. It is also important to address the practical significance of the education and curriculum for tertiary-level students in New Zealand.

LITERATURE REVIEW

International student education in the tertiary sector in New Zealand faces strong competition from countries like the US, the UK, Canada, and Australia. The education and training industry is amongst the 10 best industries in New Zealand (Stats NZ, 2020). The actions, attitudes, and behaviour of these students are expected to have a considerable influence on the sustainable future of New Zealand. The contribution of this stakeholder group to a greener New Zealand cannot be ignored. The government of New Zealand remains committed to international education, and it wants to support sustainable, resilient providers who are committed to understanding the Triple Bottom Line (TBL) which is based on the impact on the 3 P's (planet, people, and profit). To protect the TBL, it is important that high sustainability values are developed in these students in New Zealand (Think New, n. d).

The most recent catastrophic climate disaster in the country was Cyclone Gabrielle in January 2023. The overall economic impact of this cyclone was substantial, with a multi-billion-dollar loss to the economy of the country, maybe as much as $13 billion (Stevenson, 2023). This kind of impact on the TBL cannot be ignored. Therefore, necessary measures that should be initiated to encourage tertiary international students to address sustainability should be adopted.

The business community has demanded the integration of sustainability-related issues into business management curricula, and the academic community has also endeavoured to facilitate such a shift into the system. Within the last few decades, business schools that offer business and society-related courses increased from 34% in 2001 to 63% in 2007 (Jim Wu et al., 2010). This is due to the paramount need that exists for business organisations to focus not only on profitability but also on sustainability. In this context, it is interesting to analyse whether the educational level of tertiary international students in New Zealand would adequately impact their application and commitment to sustaining the environment.

As one of such measures to enhance sustainability, circular economic and sustainable practices in the day-to-day lives of students should be emphasised through education. Simple measures initiated by adopting circular economic practices such as reducing waste in industries by reusing and recycling, can contribute significantly to reducing global warming. There are many lesser-known contributors to reduction of climate change. Reducing food waste and material waste in the fashion industry are two of them. It is believed that if global food waste were a country, it would be the third largest greenhouse gas emitter, behind China and the U.S. The carbon footprint of this wasted food is about 3.3 billion tons of Carbon Dioxide (CO2) (USAD U.S. Department of Agriculture, 2022).

According to Ronen and Kerret (2020), students should be an integral part of generating effective solutions for sustainability. As an example, students can be encouraged to think of practical solutions by answering the question of how and where they can buy sustainable products. How can such sustainable product usage be implemented? Further to providing role modelling and conducting brainstorming, students can present best practices such as "cradle to cradle", where at the end of a product's life, it can be truly recycled following nature's cycle with each item being recycled before it returns to the earth. This could become, directly or indirectly, a completely safe non-toxic and biodegradable nutrient. Furthermore, students could adopt pro-environmental solutions such as going to stores that lend clothes or to thrift stores rather than buying items new and discarding them. In addition to these sustainable initiatives by students, working with a common goal towards sustainability in finding solutions is also identified as a way of promoting students' creativity, raising their curiosity and motivating them practically.

Although most tertiary educational establishments include sustainability in their curricula as a pivotal step, the quality of the curriculum and learning and teaching experiences are more important for ensuring that sustainability in education is a worthwhile endeavour. Therefore, sustainability in education is a part of learning about problems, complexities, and critical thinking that ought to be integrated into all degree programmes in New Zealand. In such instances, it is imperative to dig into the existing 'pedagogical' gaps in the existing sustainability education literature in New Zealand. A 2011 survey of academics across 20 universities in Australia (including 2,458 continuing staff, 1,818 limited-term contract staff, and 622 sessional staff) found that 37.3% of academic staff (Sandri, 2022) had not undertaken any specific teacher training. Those that had, may not have received adequate learning pedagogy in their teacher training. This could have resulted in not emphasising sustainability in the tertiary educational pedagogy. This indicates that a considerable proportion of tertiary academic teaching staff have not received adequate teacher training specific to sustainability (Sandri, 2022).

In view of this situation, some suggested improvement to reduce the gaps in the education models in New Zealand, the Pedagogy on Educational Practices, Iceberg Metaphor and the Conceptual Model on Scaffolding to Sustainability can be used. Figure 1 illustrates how important it is to inculcate sustainability into the value systems of education in New Zealand. The pedagogy of building sustainability as a value for the tertiary sector of education is the corner stone of a society consisting of individuals who will respect and conserve the environment and sustain it for future generations. If the pedagogy is strong with the values of sustainability, the educational approach will be built on the same values.

Figure 1:Illustrating Pedagogy on Educational Practices (Iceberg Metaphor)
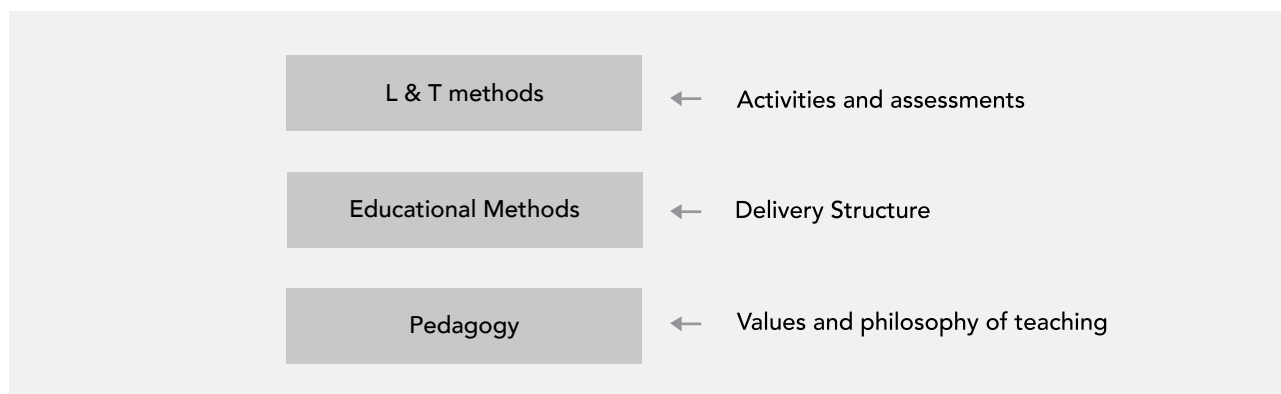
Note: Adapted from Sandri (2022)

Development of sustainable practices in education is a 'learning process', rather than a 'rolling out' act. Figure 1 illustrates how a set of pre-determined behaviours, values, assumptions, and a philosophy of teaching placed at the very bottom of the iceberg can flow to the top to influence the Learning and Teaching (L&T) methods. This emphasises the need for the staff to be geared with capabilities for sustainability teaching, such as critical reflection, praxis, and problem-solving, where learners are actively constructing rather than merely learning about sustainability. Based on this Pedagogy on Educational Practices, the Iceberg Metaphor is an educator's context-specific pedagogy to address problems on sustainability in which education should aim to address climate change, social inequality, and the food-energy-environment trilemma which are complex social issues.

Wamsler (2019) stated that more holistic pedagogical practices are the need of the day, as illustrated in Figure 1. Challenges to sustainability in education are one of the strongest initiators of approaches for sustainable development. Achieving Sustainable Development Goals (SDGs) will need the implementation of the pedagogies and approaches to catalyse the necessary changes rather than carrying out 'business as usual'. To minimise the current gaps, the concept of the inner or 'personal transformation' has been a recently highlighted term for receiving growth and attention in sustainability, science, and education.

Based on the concept of personal transformation, mindfulness-based contemplative teaching approaches have begun to be a new way of addressing socio-ecological challenges and creating a more reflective, compassionate, just, and sustainable society. Therefore, although mindfulness-based, contemplative teaching approaches are increasingly gaining mainstream acceptance in education, they have received only limited attention from researchers (Wamsler, 2019). The inner transformation of the educator and the learner is yet to be connected to education for sustainability. This connection will enable the pedagogy, which is inclusive of values, assumptions and the philosophy of teaching, to achieve the required sustainability and inner transformation of the learners and the educators.

According to Sammalisto et al. (2016), learning about sustainability and global concerns and acting on them is not solely a cognitive matter but must involve an affective understanding. It has been identified that knowledge by itself will not result in changes in awareness and actions concerning sustainability. Therefore, educational institutions must aim to develop deeper circular learning patterns with a pedagogy, where the knowledge is reflected upon and leads to action. Consequently, sustainability knowledge can be defined as knowledge required for understanding and awareness of the need for sustainability as a basis for action.

Sammalisto et al. (2016) further identified that action on sustainability takes time, and it progresses through certain stages as illustrated in Figure 2. Hence, action on sustainability will not take place immediately. However, it was found that the "knowledge gap" is not proportionate to the "commitment gap" in sustainability. It is further evident that the wider concept of sustainability in discipline-specific courses is better than generic "awareness" courses. The former can make a difference in the attitudes scaffolding to actions of the students. Integrating sustainability themes and providing adequate authority to act upon the requirements can be more effective in learning and teaching sustainability.

Figure 2: Conceptual Model on Scaffolding to Sustainability
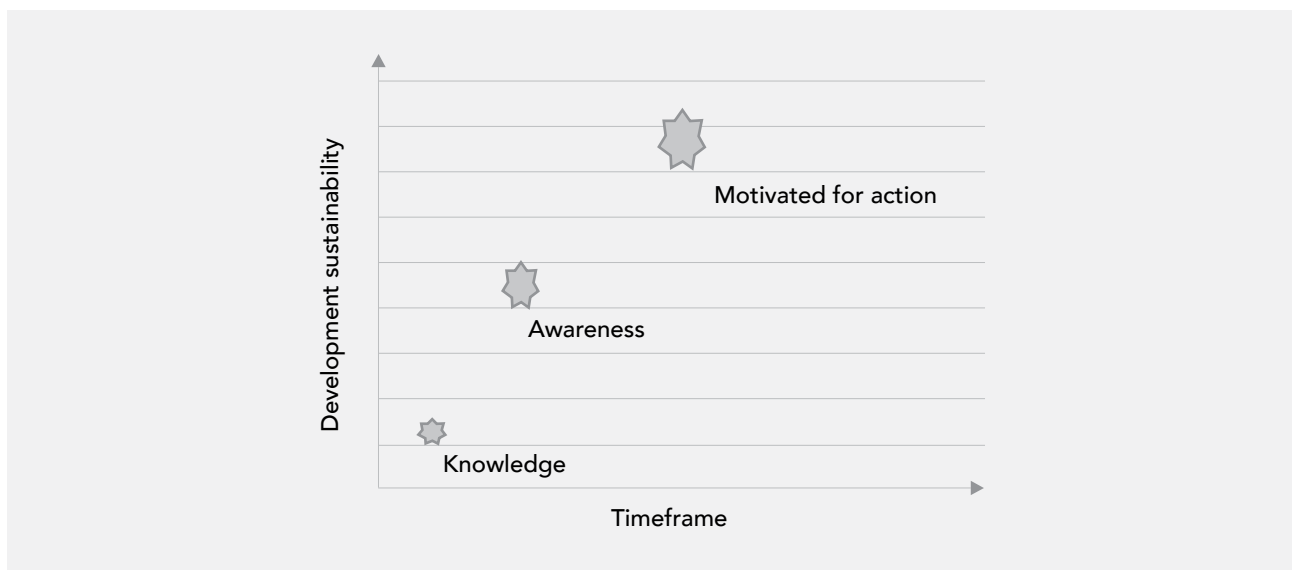
Note: Adapted from Sammalisto et al. (2016)

According to Felgendreher and Lofgren (2018), since 1990 many global universities have considered international initiatives such as the UN Decade of Education for Sustainable Development (ESD), 2005–2014 (UNESCO 2015), and the Declaration of University Leaders for a Sustainable Future (ULSF, 2015). These initiatives focus on planned behaviour on sustainability. Many of these initiatives have been translated into normal strategies and day-to-day activities for lecturing on environmental or sustainable development issues in courses and curricula. Most sustainable initiatives at universities are being undertaken as day-to-day lessons based on the curriculum with limited emphasis on relating explicitly to the concept of ESD. A useful framework for defining the ESD outcome that this study set out to measure is the theory of planned behaviour. The theory of planned behaviour has three factors that influence one actual behaviour: attitudes to a behaviour, perceived behaviour, and the control and actual behaviour of subjective norms. Behavioural attitudes are specific behaviours that can be either positive or negative. Perceived behaviour is how easy or difficult it is to perform the behaviour. Subjective norms are

perceived social pressures. It has been identified that individuals believe in the most approved actions in society, based on subjective norms. Hence, a subjective norm will have a better influence on individuals' perceptions of social norms in society, and this can guide them as to how to behave in a specific situation. A social norm can be addressed as a collective perception of the expected action. As social norms have an influence on subjective norms, these in turn influence the decision on how to behave in relation to sustainability. Empirical studies have identified that subjective norms are correlated with the way individuals intend to behave in many situations. This could be the way that education should be focused in order to involve tertiary students to be active in sustainability programmes and initiatives in New Zealand.

Considering all the above facts, leadership also has a key role in initiating radical innovation, resulting in fast-track initiatives on sustainability from students and staff. Innovative and transformational leadership values and philosophy also need to be enriched with new tools and approaches such as networking and management systems for integrating sustainability into education (Kilkis & Kilkis, 2017). Learners who absorb the sustainability culture can become sustainability leaders in the future. They need to develop systems thinking competencies with the ability to think outside the box to be geared to overcome sustainability challenges, in order to overcome goal conflicts between social, economic and environmental aspects (Filho et al., 2020).

The intent of this study was to determine whether there is a difference between undergraduate and postgraduate students, in their knowledge and application on sustainability in New Zealand. It has been found that little research has been undertaken in this specific area, which indicates that there is a research gap.

RESEARCH METHODOLOGY

This section outlines the research design that was adopted in this research project to gather primary data from international tertiary learners in New Zealand. The research design consists of descriptive and experimental research methods. According to Chetty (2020), descriptive research is very popular in areas such as education, nutrition and epidemiology. Two sample groups were set up to collect data from two different tertiary education providers for international students in Auckland. Group 1 (G1) consisted of undergraduate learners, and group 2 (G2), consisted of postgraduate learners.

The convenience sampling method was used to collect data. This sampling method is appropriate when obtaining people's perceptions and attitudes (Qualtrics, n.d.). G1 and G2 samples were mutually exclusive and collectively exhaustive, which enabled a better comparison to ensure that important aspects or factors associated with the problem were addressed appropriately (HR World, 2021). All members of the sample were studying for a business management qualification in New Zealand as an international student in one of the tertiary education institutes in Auckland. The potential participants were invited to participate in this research through emails and posters.

These two groups were provided with a questionnaire consisting of 13 questions. These questions addressed four main areas. Section one of the questionnaire had two questions to screen the interviewees to be specifically international students enrolled in either undergraduate or postgraduate studies in New Zealand. The questions in section two included Likert and dichotomous questions focused on identifying how familiar the term sustainability was amongst the two groups. Section three of the questionnaire was focused on identifying if the learners had already been involved in sustainability initiatives in New Zealand based on their cognitive dissonance. Section four of the questionnaire was based on identifying if the learner's behaviour in relation to sustainability was influenced by subjective norms.

The questions in the questionnaire were constructed to obtain the required information from the participants. A pilot test was conducted on the questionnaire to identify if the questionnaire contained potentially confusing questions for the interviewees, i.e. double-barrelled questions (asking about two different issues, while only allowing a single answer), or loaded questions (that inherently contains an assumption). Biased and confusing long questions were removed from the questionnaire. This process was helpful in obtaining a reliable and valid data set. The questionnaire did not consist of open-ended probing questions, allowing the participants to be more comfortable with questions which involved less time to answer. A statistical test such as a C-test, Chi- square and Fisher test was conducted to detect the significant differences between the two groups at 0.05 level of significance.

RESULTS, ANALYSIS AND DISCUSSION

Participant Demographics

The undergraduate group (G1) comprised 15% female and 85% male participants. This group consisted of learners from India, Nepal, Indonesia, Qatar and China. The average age for this group was 21, consisting of learners ranging from 19 to 25 years of age. The postgraduate group (G2) comprised 41% males, 44% females and 14% who did not state their gender. This group consisted of learners from China, Sri Lanka, India, Philippines, Vietnam, Argentina, Thailand and Fiji. The average age for this group was 30, and learners ranged from 21 to 52 years of age.

The outcome of the four areas of the questionnaire is discussed in the following section.

Screening Questions

The purpose of the first screening question was to eliminate any participants from the two samples who were not undertaking a course in the tertiary education sector in New Zealand. The second screening question focused on identifying whether the participants were following an undergraduate or a postgraduate course in New Zealand. After screening, G1 and G2 comprised 34 and 36 learners respectively.

Familiarity with Sustainability

A third ranking question included in the questionnaire aimed to obtain information on participants' familiarity with the words innovation, supply chain, sustainability, and investment. For this question the mean, standard deviation (SD), and sample error (SE) were calculated to obtain the P value at 0.05 significance level to identify whether there was a significant difference between G1 and G2. The P value obtained for familiarity with the word sustainability between G1 and G2 was 3.69. This indicates that familiarity with the word sustainability differs considerably between the two groups. The undergraduates were more familiar with the other three words in the question than the word sustainability. The postgraduate students were more familiar with the word sustainability than the other three words. This indicates that there is a clear difference between the two groups in familiarity with the word sustainability. The P values obtained for the familiarity with the words innovation, investment and supply chain, are significantly less compared with the P values obtained for sustainability, i.e. 0.94, 2.3 and 0.0001 respectively. This indicates that the difference in familiarity with these three words was not significantly different within in the two groups G1 and G2, unlike the word sustainability.

The fourth question aimed to determine whether the two tertiary education providers had communicated about sustainability practices in New Zealand to the participants of the two groups. In G1, 32 students answered yes, and in G2, only four students answered 'yes', as Illustrated in Figure 3. The tertiary institute where the undergraduates were studying had communicated the importance of sustainability to their students far more than had the postgraduate tertiary institute (P= 6.94). This indicates the high discrepancy in awareness of sustainability between the two groups in tertiary education. This suggests that there is no consistency in communicating the importance of sustainability to learners in tertiary education in Auckland, New Zealand. However, the New Zealand education strategy for international tertiary students emphasises the importance of sustainability. As stated in the New Zealand 2022-2030 International Education Strategy, the government wants to create a new future for international education that is sustainable, resilient, and diversified (Think New, n.d.). Further, the Māori paradigm emphasises caring for the land and caring for people (Mika et al., 2022).

Figure 3: Sustainability Awareness of Learners at Tertiary Institutes

PERCENTAGE OF AWARENESS OF LEARNERS

	G1	G2
No	2	32
Yes	32	4
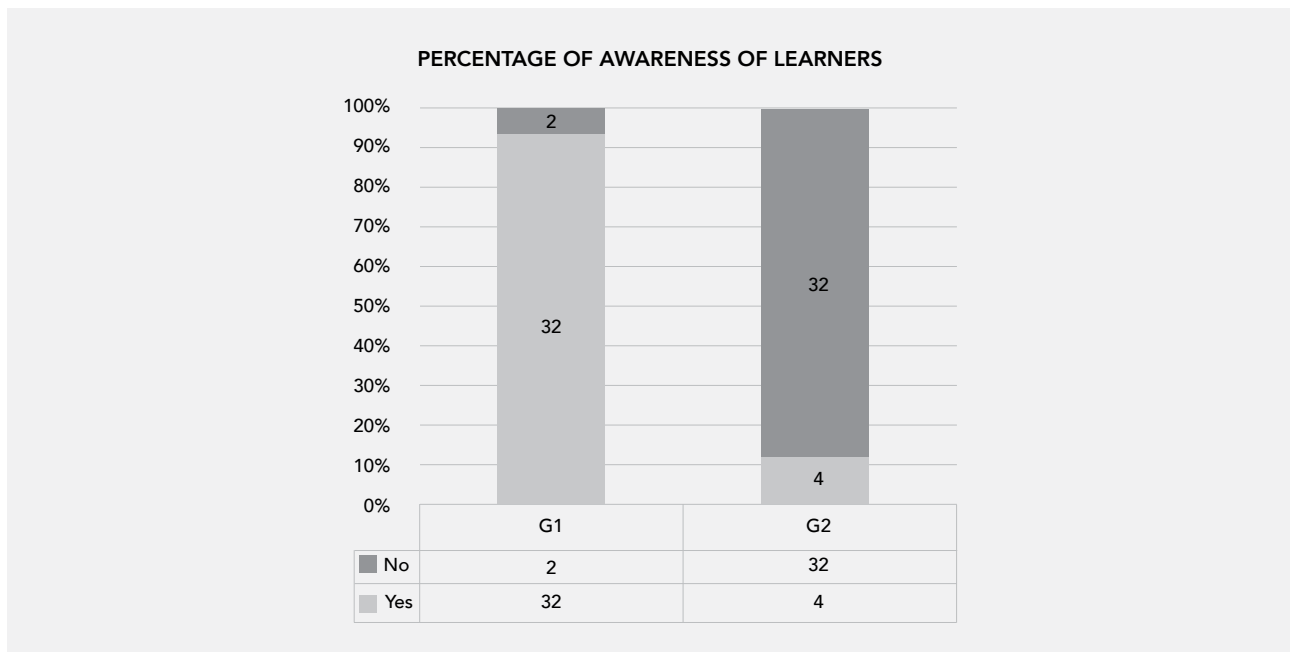
Impact on Cognitive Dissonance Behaviour on Sustainability.

The responses to the fifth question were based on whether the participants had been involved in environmental or community work during their stay in New Zealand. In G1, two students answered 'yes', and in G2, three students answered 'yes' for this question, as illustrated in Figure 4. This indicates that learners of both G1 and G2 are not very committed to being involved in sustainability projects based on their cognitive dissonance (P= 0.003793). The next two questions, the

sixth and seventh, were relevant only to the interviewees who answered 'yes' to this question because the probing questions were relevant only to the six interviewees who answered 'yes'. These two questions were based on identifying how they came to know about the sustainability initiatives that they were involved in, and whether it was from the tertiary institute they studied at. There were no responses to these two questions by the 6 relevant interviewees.

Figure 4: Involvement in Sustainability Initiatives in New Zealand

	G1	G2
Yes	2	3
No	32	33
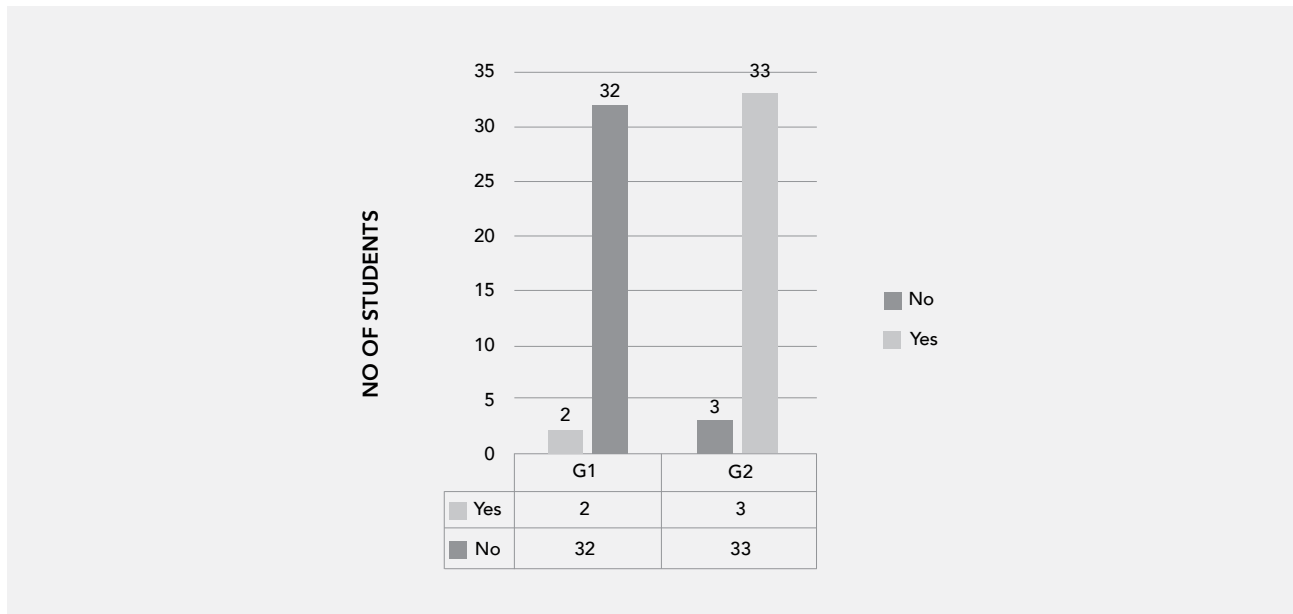
The eighth question aimed to identify the willingness of the participants to be involved if they were given the opportunity to participate in a project to make the environment and the community a better place in Auckland, New Zealand. Both groups responded in a similar manner. There were only three students from G1 and five from G2 answering 'yes' for this question. (P= 0.003793.) This indicates that there is no significant difference between the two groups on the willingness to participate in a project on sustainability as illustrated in Figure 5.

Figure 5: Willingness to Get Involved in Sustainability Initiatives in New Zealand

	G1	G2
No	2	32
Yes	32	4
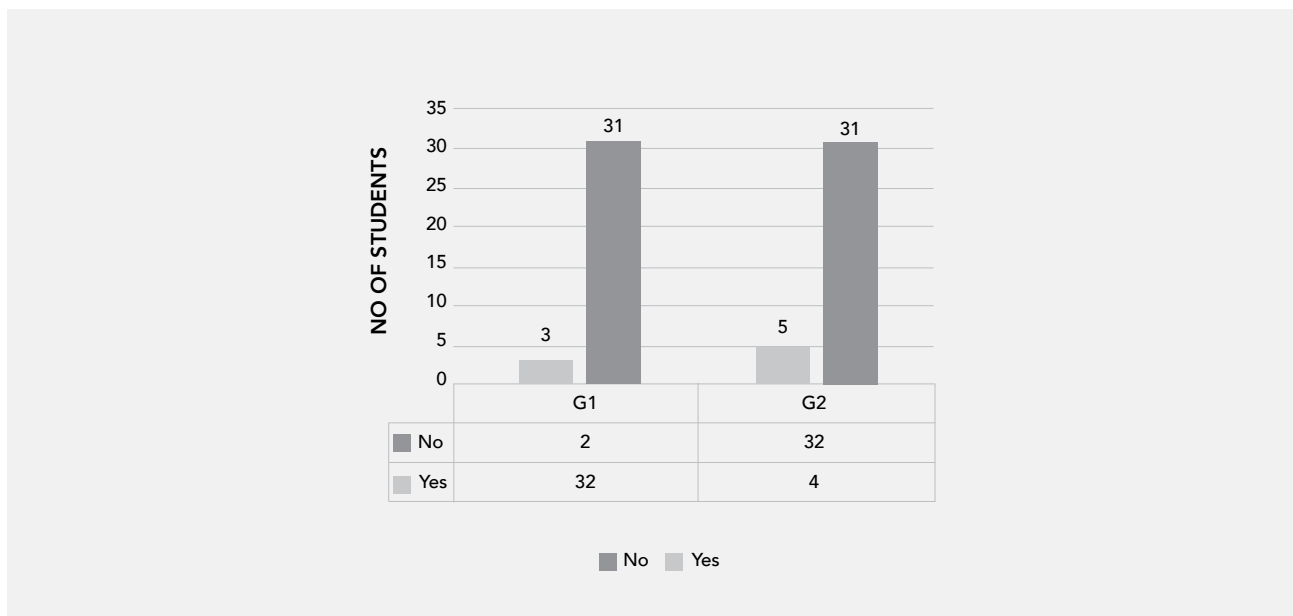
The ninth question was on how many hours students thought they could allocate, once in three months, if they were to get involved in a sustainability initiative. The total number of hours on average for the participants of G1 was 10.5, and for G2 it was 11.6 hours. P= 0.8269 value indicates that there is not a significant difference between the two groups in willingness to allocate time to sustainability initiatives.

Impact on the Subjective Norm

The tenth question was based on inquiring how important the students think it is to act today, to sustain the environment in New Zealand. There was little difference between the two groups where 82% of G1 and 72% of G2 answered that it was very important, which indicates that the two sample groups do understand the importance of engaging in activities and initiatives on sustainability in New Zealand. According to Sammalisto et al. (2016), and based on Figure 2, it is important that action be taken to transform this understanding and knowledge on the subjective norm into action.

The eleventh question asked to what extent the participants thought they had to get involved in making the community and the environment a better place in New Zealand. In G1 73%, and in G2 70% answered to a great extent. This indicates that 27% of G1 and 30% of G2 do not feel that it is every individual's duty and commitment to contribute to the betterment of the community and environment in New Zealand. Both groups G1 and G2 had an almost similar outcome. This indicates that different levels in education do not result in a different approach to commitment to sustainability.

According to information gained from questions about the willingness of the learners to participate in sustainable activities (how many hours they can allow for activities, how important they think it is to act today on sustainable activities, and to what extent the learners think they have to get involved), it appears that there is no significant difference between the two groups G1 and G2. However, with the question relating to the awareness of the term sustainability, there was a difference between G1 and G2. This suggests that awareness of sustainability may not be an indicator for the tertiary students to apply themselves to sustainability activities based on the cognitive dissonance theory. This confirms that the pedagogy of teaching should consist of a strong base including sustainability as a value and a philosophy of teaching for the tertiary sector of education (Sandri, 2022). This concept can be included in the learning outcomes of the assessments that are designed for the learners so that the learners and the educators are exposed to sustainability and inner transformation. Then sustainability can become a subjective norm amongst international tertiary level students. This approach can lead to best practices in learners such as "cradle to cradle" and recycling initiatives. These initiatives will contribute to New Zealand's goal of reducing 2017's biogenic methane emissions by 10 per cent by 2030 (Climate Change Response (Zero Carbon) Amendment Act, 2019).

The twelfth question was based on the accuracy of putting rubbish in the appropriate waste bins at their residences. Eighty-five per cent of G1 and 80% of G2 indicated that they always put rubbish into the appropriate waste bins accurately. However, 15% in G1 and 20% in G2 indicated that they put their rubbish in the appropriate waste bins sometimes accurately or not at all accurately. It is important that these 15% and 20% of learners be directed to act in the always accurately group to obtain a 100% success rate. Both groups G1 and G2 have an almost similar outcome indicating that different levels in education do not result in a different approach to commitment to sustainability based on subjective norms.

The thirteenth question asked participants to state whether they carried a reusable shopping bag to do their shopping. Only 62% of G1 and 86% of G2 did always carry a reusable bag for their shopping. Based on the results of these two questions, it seems that subjective norm can provide better results in achieving a national goal of emitting zero greenhouse gases (except biogenic methane) by 2050 in New Zealand (Ministry of Environment, 2021).

Statistical analysis

To statistically analyse the above figures in questions ten, eleven, twelve and thirteen, we conducted a Pearson's Chi-square test and obtained P values for the four questions. Based on these values Table 1 indicates that there is no difference in the commitment and application of sustainability practices between the two groups, i.e. undergraduate (G1) and postgraduate students (G2).

Table 1: Pearson Chi-square Test Results

DESCRIPTION	X	DF	P VALUE
How important it is to act today	1.544	2	0.462
To what extent they have to get involved	0.343	2	0.842
Accuracy of rubbish disposal	5.537	2	0.062
Carrying a reusable shopping bag	3.281	2	0.194

Note: DF = Degree of Freedom

Due to the small sample sizes associated with this research, with 34 and 36 participants for G1 and G2 respectively, Fisher's Exact Test was also conducted to reconfirm the P values in Table 1. As indicated in Table 2, all four P values were less than 1.96 which indicates that there is no significant difference between the two groups in their commitment to sustainability based on their level of education.

Table 2: Fisher's Exact Test Results

DESCRIPTION	X	DF	P VALUE
How important it is to act today	1.544	2	0.564
To what extent they have to get involved	0.343	2	0.865
Accuracy of rubbish disposal	5.537	2	0.069
Carrying a reusable shopping bag	3.281	2	0.224

Note: DF = Degree of Freedom

With the above P values calculated, it was found that there is no significant difference between the learners' behaviour on sustainability based on cognitive dissonance and subjective norms. Hence, as explained by the Pedagogy on Educational Practices (Iceberg Metaphor), it is important to develop sustainable practices in education as a learning process rather than a rolling out act. Therefore the very bottom of the iceberg can flow to the top to the Learning and Teaching (L&T) methods which can develop more dedicated learners of sustainability (Sandri, 2022). Also, the conceptual model of scaffolding to sustainability indicates that these sustainability initiatives take time to deliver results (Sammalisto et al., 2016). Therefore, it is important that initiatives be taken to implement the Pedagogy on Educational Practices without further delay.

It was also found that there has been very limited research carried out to analyse the difference between the undergraduate and postgraduate learners' cognitive dissonance behaviour and the subjective norm behaviour in relation to sustainability. Hence this area of study can be further explored in wider geographical locations.

Delimitations

The sample sizes should have been larger to represent better the population of tertiary learners in Auckland New Zealand. The geographical areas to represent the population should have been from different areas of the country to obtain a more accurate inference. The research instrument, i.e. the questionnaire, should have had some open-ended questions to probe more fully into the participants' commitment to sustainability.

CONCLUSION

This research indicates that while there is a difference in the awareness of sustainability between undergraduate and postgraduate international students in Auckland, New Zealand, their level of involvement in sustainability initiatives remains relatively consistent. This suggests that the application of sustainability is not inherently tied to the level of education but may be influenced by other factors.

The analysis underscores a conspicuous void in scholarly investigations within this area of study, delineating a pronounced research gap awaiting exploration. By integrating sustainability principles into pedagogy, fostering contemplative teaching practices, embracing circular economic principles, conducting further research, offering discipline-specific courses, and advocating for a human-centred curriculum, international tertiary educational institutions in New Zealand can play a pivotal role in cultivating a generation of socially and environmentally responsible Kiwi citizens.

RECOMMENDATIONS

a) **Deeper Integration of Sustainability in Pedagogy with Strategic Leadership for Sustainability:** Tertiary educational institutions in New Zealand should prioritise the development of circular learning patterns centred around the values and philosophy of sustainability. Learning outcomes should be structured to facilitate the translation of sustainability knowledge into actionable practices. A generation of environmentally conscious tertiary international students and innovative and transformational leaders in sustainability should be developed in New Zealand.

b) **Promotion of Contemplative Teaching:** Implementing contemplative teaching methodologies can facilitate a shift in the collective perception and behaviour of tertiary students towards sustainability. By encouraging inner transformation, students are more likely to adopt sustainable practices in their daily lives.

c) **Embrace Cradle to Cradle Principles:** Tertiary educational institutions in New Zealand should actively promote sustainable best practices, such as the "cradle to cradle" approach and circular economic principles. These initiatives not only reduce environmental impact but also instil a mindset of resource conservation and regeneration among tertiary level international students.

d) **Further Research and Education Strategy:** The New Zealand education strategy for international tertiary students and

the Māori paradigm underscore the importance of sustainability. Therefore, additional research is warranted to explore the nuances of sustainability knowledge and application among international undergraduate and postgraduate students. This will help identify specific areas for improvement and inform targeted educational interventions.

e) **Introduction of Discipline-Specific Courses:** Addressing the observed gap between knowledge and commitment to sustainability requires a shift towards discipline-specific courses rather than generic awareness programmes. Tailoring education to the unique needs and interests of students within their respective fields of study can foster deeper engagement and tangible action in relation to sustainability.

f) **Advocacy for a Human-Centred Curriculum:** Academic communities should advocate for a paradigm shift in business curricula, moving away from an organisation-centred worldview towards a human-centred approach. By aligning educational content with the values and priorities of individuals, subjective norms on sustainability can be transformed into actionable behaviours, ultimately leading to a more sustainable future for New Zealand.

g) **Incorporating appropriate models** - The Pedagogy on Educational Practices, Iceberg Metaphor, and the Conceptual Model on Scaffolding to Sustainability should be incorporated into teaching.

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VAPE/E-CIGARETTE WASTE MANAGEMENT IN AUCKLAND: NAVIGATING THE PATH TO ENVIRONMENTAL RESPONSIBILITY

Andrey Lykov and Yury Zhukov

OTAGO POLYTECHNIC AUCKLAND INTERNATIONAL CAMPUS

ABSTRACT

In recent years, the popularity of vaping has surged, with a growing number of individuals turning to electronic cigarettes as an alternative to traditional smoking. However, this rise in vaping has brought forth a pressing issue: the management of electronic cigarette waste. There is a lack of established guidelines for the proper disposal of electronic cigarettes worldwide despite the presence of rare metals, harmful chemicals, and intricate components in both the devices and the batteries. Addressing the issue of e-cigarette waste management is imperative for the wellbeing of our ecosystem and communities.

This study explores the existing practices and barriers to vape waste management in Auckland, New Zealand. The analysis explored existing recycling policies and guidelines of the Ministry for the Environment and Auckland Council, discusses the challenges faced by recycling companies, and presents the perspective of the vape stores and the place they see for themselves in the recycling process. This information is compared with best international practices to present practical recommendations which could improve the current recycling practices for electronic-cigarette products.

Keywords: Waste Management; E-waste; Vape Recycling; Environmental Policy

INTRODUCTION

Electronic waste (e-waste) is a significant source of pollution and a challenge to recycle. It includes a wide range of complex electronic products, such as old computers, tablets, mobile cell phones, computer screens, household appliances, and vapes, which all contain metals, polymers, and potentially dangerous compounds like lead, mercury, and cadmium (Amer et al., 2019; Canavati et al., 2022; Goswami, 2019; Paranjape & Yadav, 2023). The improper disposal of e-waste can result in electronic waste pollution, contributing to environmental degradation and potential harm to ecosystems, not to mention the loss of valuable production resources (Leclerc & Badami, 2023; Minashkina & Happonen, 2022; Shaikh et al., 2020; Tukiman et al., 2021). A vape or electronic cigarette (e-cigarette) is a gadget that mimics smoking by giving users nicotine or other chemicals in the form of vapour or an aerosol that may be inhaled (Edwards et al., 2023). Most vaping devices are imported from China (Gravely et al., 2019). Shenzhen is a recognised global hub for e-cigarette manufacturing (Gravely et al., 2019). Vapes consist of a heating element, microprocessor, a cartridge or pod that carries a liquid solution known as vape juice or electronic-liquid (e-liquid), and a battery, typical components of e-waste (Aaron, 2021; Buttler, 2023). Electronic cigarettes are hazardous waste and require immediate attention lest they cause severe pollution to soil and groundwater (Awasthi et al., 2018; Belot, 2023; Turaga et al., 2019; Mor et al., 2021; Van Yken et al., 2021).

Euromonitor International highlights the magnitude of the issue, with a record 55 million people using e-cigarettes globally in 2021, compared to seven million in 2011 (Van Reenen, 2022). The escalating number of users directly correlates with the growing environmental impact caused by the accumulation of e-cigarette waste (Mock & Hendlin, 2019). In March 2023, Auckland Council commissioned an audit of kerbside refuse bins (Personal Communications, Auckland Council, 2024). In the 575 kerbside refuse bins sampled, 132 vapes were found. This was similar to the number of household loose batteries (145 items) that were found (Personal Communications, Auckland Council, 2024). Vapes have effectively doubled the number of small batteries disposed of in domestic kerbside refuse bins (Personal Communications, Auckland Council, 2024).

In response to this challenge, some initiatives have emerged within the vaping industry to tackle the issue. Companies like Gaiaca, Terracycle, DotMod, Shanlaan, Dovpo, and Vinn have introduced recycling programmes, disassembling and repurposing vaping devices into raw materials for new products (Buttler, 2023). However, disposing of vapes remains a complex problem due to the lack of comprehensive and complete national or municipal-level solutions, with efforts primarily consisting of private, disparate initiatives. The disposal of e-liquid containing nicotine poses a significant risk to children, pets, wildlife, and water sources. Therefore, raising awareness about proper disposal methods is crucial, discouraging the discarding of these substances in kerbside refuse bins or sewers (Beutel et al., 2021).

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Not all countries have the necessary resources to recycle vapes and other e-waste, so international cooperation and national policies play a crucial role in managing and effective recycling (Shaikh et al., 2020; Tian et al., 2024). By mandating responsible practices and enforcement mechanisms, such legislation ensures accountability among stakeholders, fostering a sustainable approach to e-waste management. Stakeholders, in this case, are those who are potentially concerned with the sale, purchase, use, control of turnover or disposal of vapes, such as consumers, vaping stores, waste collectors and preprocessors, recyclers and government officials (Chygryn et al., 2020;).

In Auckland, New Zealand vape waste management is directly or indirectly regulated by four pieces of legislation: the Basel Convention, the Resource Management Act 1991, the Waste Minimisation Act 2008, and the Smokefree Environments and Regulated Products (Vaping) Amendment Act 2020 (Ministry of Health New Zealand, 2023). The 2023 amendment to vaping regulations introduced restrictions on the sale of vapes with non-removable batteries from December 21, 2023, and obliges vape stores to sell only reusable vapes from March 21, 2024 (Ministry of Health New Zealand, 2023). Finally, in accordance with the Waste Management and Minimisation By-law 2019, Auckland Council's waste collection service strictly prohibits the disposal of vape waste, including lead-acid or lithium batteries, in refuse bins collected from kerbsides (Auckland Council, 2023).

New Zealand has started a few initiatives in response to the rising issue of vape waste (Egan, 2022). Together with TerraCycle, a global leader in recycling, vape companies Vapo and Alt New Zealand have developed a programme for recycling vaping gadgets (Egan, 2022). With this programme, participants in Auckland, New Zealand may deposit their collected e-cigarettes at Vapo stores or send them in by courier (Auckland Council, 2024). Recycling involves breaking down vaping equipment into its component parts, which are subsequently recycled into new goods, like patio furniture (Schyns & Shaver, 2021). The collaboration between vape stores and TerraCycle in Auckland, New Zealand is a prime example of transitioning from a linear waste system to a circular economy model (Fogarassy & Finger, 2020).

Although these recycling programmes are a step in the right direction, we are still a long way to effective vape recycling either in Auckland, New Zealand or abroad (Buttler, 2023; Canavati et al., 2022; Gillingham & Stock, 2018). However, within the new framework regulating the turnover of e-cigarettes, some steps have been taken to reduce the harm of e-cigarette waste to the environment. Once a fully removable battery is required for all single-use and reusable vapes which should make it more manageable for the users to follow Auckland Council battery disposal bylaws (Ministry of Health New Zealand, 2023).

To advance Auckland, New Zealand's sustainability goals, it is vital to study the complex characteristics of e-cigarette waste and develop strategies supported by evidence and tailored to regional needs (Amer et al., 2019). Key problems include the lack of clear legislation and enforcement; lack of a clear and simple roadmap for the collection, preprocessing, processing, recycling and disposal of vapes or their components; and lack of public awareness of the recycling procedures and collection points (Ali & Akalu, 2022; Attia et al., 2021; Chioatto & Sospiro, 2022; Kamateros & Abdoli, 2023; Lopes dos Santos & Jacobi, 2022). A singular focus on carbon dioxide (CO_2) emissions could detract from equally pressing environmental concerns, such as e-waste management and plastic pollution (Tombe & Winter, 2015). While initiatives like the Cities Climate Leadership Group (C-40) strive to minimise CO_2 emissions through innovative urban planning and policies, the e-waste problem remains relatively unaddressed within these frameworks (Hsu et al., 2017).

METHODOLOGY

This study adopted an exploratory design (Nakash et al., 2022). It synthesised publicly available information from the Auckland Council, and other relevant government agencies on the relatively novel problem of managing vape waste in Auckland, New Zealand. This included databases, official guidelines, practice recommendations, policy papers, and statistical data to create a comprehensive picture of the current regulatory and policy framework. Data from public sources and inquiries to the Auckland Council and the Ministry for the Environment were used in accordance with the Official Information Act (OIA) 1982 (Laugesen, 2020). Additionally, the study included semi-structured interviews with three recycling companies and seven vape shops.

The study utilised thematic analysis to interrogate the collected data, employing an inductive methodology to scrutinise official documents and communications and the semi-structured interview data (Ahmed, 2021; Braun, 2023). The semi structured interview data were categorised into five key themes (refer to Figure 1).

Figure 1: Semi-structured Interview themes and findings.

RESPONDENT	COLLECT AND/OR RECYCLE	DO NOT COLLECT OR RECYCLE	MAIN CHALLENGIES				
			LACK OF AWARENESS	LACK OF MOTIVATION	LACK OF FACILITIES	INSUFFICIENT LEGISLATION	LACK OF ROADMAP
Vape store #1	X		X	X		X	
Vape store #2		X	X				
Vape store #3	X		X			X	X
Vape store #4		X		X		X	
Vape store #5		X					
Vape store #6		X	X				
Vape store #7	X			X		X	X
Recycler #8		X	X	X	X		X
Recycler #9		X		X	X		X
Recycler #10		X	X	X	X	X	X

This analytical approach helped address the core research questions regarding Auckland, New Zealand's current struggle in managing e-cigarette and potential methods for improving these practices to lessen environmental impacts. Thematic analysis was also used to explore publications, publicly available data and responses from authorities and companies.

Ultimately, the analysis revealed four main themes contributing to the challenges of e-cigarette management: regulatory hurdles, public awareness and participation, technological and logistical challenges in recycling, and financial and economic considerations.

FINDINGS

The study showed that there is a serious problem with e-cigarette waste management in Auckland, New Zealand the main causes of which are a lack of awareness and motivation of stakeholders (refer to Figure 1), indicating either a lack of understanding of the recycling mechanics (Attia et al., 2021) or a lack of interest in it. Motivation can be boosted by financial incentives or fines and a communal sense of responsibility (Xiang & Mangmeechai, 2024).

Four of the seven vape stores surveyed did not collect vapes from customers and did not inform them about the consequences of incorrect vape disposal. Respondents of three vape stores claimed that they were participating in the collection programme, but only one of these vape stores had a collection box for spent vapes. The respondent of vape store 6 explicitly said that their main goal was to sell vapes and make a profit and not to pay attention to issues of recycling and environmental impact.

There were also significant problems among waste recyclers. Recyclers 8 and 9 pointed out the lack of financial interest in collecting and processing vapes due to the complexity of the process of disassembly and low content of valuable materials. Recycler 10 noted the difficulties in sorting vapes from the main waste stream and the lack of consumer interest in the proper disposal of e-cigarettes.

The lack of a clear roadmap or guidance on e-cigarette waste management is another significant problem in Auckland, as evidenced by data obtained during the semi-structured interviews with respondents of both the recycling companies and vaping stores. A respondent from Recycler 9 expressed concern about the lack of clear instructions and procedures for collecting, sorting and processing vapes. They noted that "without a clearly defined action plan, their company faces difficulties in determining how to properly handle vaping waste, which makes it much more difficult to dispose of it" (Personal Communication, Respondent 9, 2024). Recycler 10 stated: "We do not have recycling capacities for vape waste. We could collect them, but what is the next step? (Personal Communication, Respondent 10, 2024)"

The same problem was reflected in the responses of vaping store 7, who stressed that their main task is to sell products, and they face uncertainty about what to do with vapes after collecting them. The respondent said, "We just don't know what to do with vapes if we start collecting them. There are no instructions, there is no set path by which we could send

this waste for recycling or disposal (Personal Communication, Respondent 7, 2024)." Responses to inquiries sent to the authorities confirmed the respondent's claim that an effective vaping disposal scheme has not yet been developed. The authorities propose to return them back to stores or find special reception points for electronic hazardous waste, which indicates a lack of integration and specialised solutions for the problem of waste management from vaping.

The lack of specialised legislation regulating the management of e-cigarette waste as part of e-waste is one of the main obstacles to effectively solving the problem in Auckland. In Aotearoa/New Zealand the management of e-waste is primarily regulated by the Waste Minimisation Act 2008 and the Litter Act 1979. These Acts provide the legal framework for reducing waste, including e-waste, and improving resource efficiency throughout the country. It enables measures such as product stewardship schemes, where manufacturers, importers, and retailers take responsibility for the entire lifecycle of products, including disposal and recycling. Nevertheless, these laws do not give a clear idea of the problem of e-cigarette waste management as part of e-waste and possible solutions in this area (Ministry for the Environment, 2023). This aspect was specified in the responses of recyclers and vape stores, highlighting the deep uncertainty and legal vacuum in this area. The respondent of recycler 10 pointed out the difficulty of working in the absence of clear regulatory acts concerning the specifics of collecting, transporting, storing, and processing waste from e-cigarettes. They expressed the opinion that "without a legislative framework defining the responsibilities and procedures of all participants in the process, their recycling activities remain unregulated and risky (Personal Communication, Respondent 10, 2024)." Similar problems were identified in the responses of the respondent of vape store 7, where the lack of legal responsibility of all parties led to passivity and unwillingness to get involved in recycling processes. "We do not know what obligations we have under the law and how to properly dispose of these products (Personal Communication, Respondent 7, 2024)," the respondent noted, emphasising the need for legal clarity.

DISCUSSION

The effective management of e-cigarette waste in Auckland faces significant hurdles due to a lack of awareness and motivation among key stakeholders, reflecting a wider global challenge. Addressing these issues is crucial for fostering sustainable waste management practices and promoting environmental responsibility (Attia et al., 2021).

Awareness is foundational in catalysing change. Despite the substantial environmental risks posed by improperly disposed of e-cigarette products, such as contamination from hazardous liquids and challenges in recycling electronic components, there remains a notable gap in stakeholder awareness. Literature highlights the importance of informed consumers in adopting sustainable behaviours, pointing out that awareness can lead to more environmentally friendly practices (Shahabuddin et al., 2023). This underscores the need for targeted educational campaigns to enhance understanding of the environmental impacts of e-cigarette waste and the benefits of proper disposal methods.

Motivation, however, is equally crucial. For consumers of e-cigarette products, motivation can stem from financial incentives or from the recognition that their actions contribute to a greater communal virtue, protecting the environment. This dual approach to motivation—combining tangible rewards with the satisfaction of contributing to environmental sustainability—can significantly enhance participation in e-cigarette- waste management initiatives. The literature on recycling behaviours supports this, indicating that personal commitment and the presence of incentives are key drivers for recycling actions (Attia et al., 2021).

For commercial entities such as vape stores and recyclers, the primary motivation is profit. Ensuring that e-waste collection and recycling processes are financially viable is essential for engaging these stakeholders in sustainable e-waste management practices. Without a clear financial benefit, participation from commercial stakeholders may be limited. This is confirmed by the experience of Shanghai, which continues to increase the pace of e-waste recycling, thanks to the recycling subsidy programme. A special programme introduced in Shanghai, the 'Old for New' scheme (OfN), tries to make the formal collection system more attractive in two ways. On the one hand, electronics retailers and other formal take-back entities were given subsidies to offer incentives to consumers to return their e-waste to formal channels. Recyclers also received comparatively high subsidies, enabling them to compete successfully with informal collection systems and cover part of their expenditures connected with the recycling process. The level of electronic waste collection at special collection points and at retailers of electronic equipment reached 2.1 kg/cap/year and keeps growing (Qu et al., 2019).

There are special e-waste collection centres in Vancouver which could help with further insight in e-waste collection. Electronic waste is sent to special recycling centres and the e-cigarettes that Canada cannot recycle are sent offshore according to the extended producer responsibility (EPR) principle. EPR requires manufacturers, brand owners, and initial importers to be accountable for the financing and operation of e-waste management programmes. These obligations are established through legislative or regulatory means (Compagnoni, 2022). At the same time, fines are provided for releasing electronics, including e-cigarettes, into containers for other types of waste. However, statistics on the quantitative collection of electronic waste in Vancouver are not provided by official sources (Tutton et al., 2022).As the Vancouver experience shows, legislation can play a critical role in increasing motivation by creating a framework where compliance with e-waste management and recycling practices is not only environmentally responsible but also legally required, thus avoiding potential penalties.

The data obtained during the study, including feedback from respondents of vape stores and recycling organisations, confirm that the current legislation does not impose clear obligations on any of the parties involved in the process of e-cigarette waste management. This means that there are no legal requirements for vape stores, recyclers and consumers to take a responsible approach to the disposal and processing of e-cigarette products. In addition, the legislation does not provide for extended responsibility of manufacturers for the final fate of their e-cigarette products after their use (Lopes dos Santos & Jacobi, 2022).

The respondents emphasised that the lack of such regulation leads to insufficient motivation for the development and implementation of effective programmes for the collection and recycling of e-cigarette waste. As a result, a significant portion of this e-cigarette waste ends up in landfills, where it can harm the environment by polluting soil and reservoirs with chemicals contained in batteries and cartridges (Kamateros & Abdoli, 2023).

An additional problem is the lack of mechanisms to effectively track e-cigarette waste flows, which makes it difficult to assess the extent of the problem and plan measures to address it. This creates obstacles not only for the organisation of collection and recycling processes but also for the development of policies aimed at reducing the volume of this waste and minimising its impact on the environment. Moreover, current legislation does not provide for extended manufacturer responsibility when a manufacturer obligated by law would be forced to take e-cigarettes back for recycling. Such an approach would be the fundamental for the development of a roadmap based on such a possibility provided for by law (Ministry for the Environment, 2023).

Based on these findings, it became obvious that there is a need to adopt new or modify existing legislation, which will include clear provisions on all aspects of e-cigarette waste management. Such legislation should ensure the expanded responsibility of manufacturers for the disposal and recycling of their products, establish requirements for the collection and recycling of e-cigarette waste, and provide mechanisms for monitoring and tracking the flow of this waste.

The lack of a roadmap and capacities for the collection and disposal of e-cigarette introduces significant obstacles to the effective management of this type of waste, which in turn leads to a number of negative consequences for the environment, public health and economic sustainability. This problem stems from insufficient regulation and coordination of actions between manufacturers, consumers and waste disposal authorities, which makes the process of collecting and recycling e-cigarettes unstructured and inefficient (Shahabuddin et al., 2023).

Without a well-defined roadmap, the process of disposing of e-cigarettes remains chaotic, which leads to their improper handling and disposal. Electronic cigarettes and their components often end up in landfills, where they can decompose for a long time, releasing toxic substances such as heavy metals and nicotine into the environment. These substances pollute the soil and water resources, posing a threat to ecosystems and human health.

In addition, the lack of a roadmap makes it difficult for public awareness and participation in the recycling process. Without accessible and understandable information on how and where to recycle used e-cigarettes, many consumers simply throw them into the kerbside refuse, which exacerbates the pollution problem (Hsu et al., 2017).

The economic consequences are also significant (Tombe & Winter, 2015). Electronic cigarettes contain a number of valuable materials that could be extracted and reused if an effective collection and recycling system existed. The lack of such a system leads to a loss of potential income and opportunities for the development of the processing industry (Tombe & Winter, 2015).

Scientific research confirms that the development and implementation of a roadmap for the collection and disposal of e-cigarettes can significantly improve the situation (Xavier et al., 2021). Such measures not only contribute to reducing environmental damage but also stimulate the development of recycling technologies, create new jobs and contribute to the formation of a more responsible attitude towards the environment among the population (Xavier et al., 2021).

In the context of proper and reasonable legislation, the creation of a roadmap for e-cigarette waste management stands as a critically important next step. This will make it possible to systematise the collection and disposal process, determine the responsibility of the consumers, and ensure proper control and monitoring of the implementation of established procedures. Only an integrated and coordinated approach will make it possible to achieve significant progress in solving this problem, minimise its negative consequences and ensure the sustainable development of society.

RECOMMENDATIONS

Based on the findings and discoveries, several steps should be proposed to improve e-cigarette waste management in Auckland, New Zealand. First of all, the Government should develop relevant legislation in the field of e-waste management. It is necessary to provide for a section of e- waste (which includes e-cigarettes) and identify all stakeholders and their responsibilities. The experiences of Vancouver and Shenzhen demonstrate the positive effect of introducing a system of extended producer responsibility (EPR) into legislation. This does not allow cities such as Auckland, where recycling is

poorly developed, to sidestep the issue of incomplete recycling of e-cigarette waste. It is also proposed in the future legislation to provide for a system for monitoring e-cigarette waste as part of e-waste management. This will allow Auckland to obtain statistical data on the import, consumption, and disposal of e-cigarette, understand the data, and take steps to improve the management of e-cigarette waste further.

In accordance with contemporary legislation, a roadmap can be developed that will allow defining goals, objectives and guidance for all stakeholders. Despite the fact that no examples of a well-developed roadmap for e-cigarette waste management could be found in the literature due to the novelty of the problem, the data obtained from the study allowed us to conclude that such a detailed plan is extremely necessary for Auckland and the rest of New Zealand.

The next step is to increase awareness of the problem and develop methods of solution. It is proposed that a large-scale advertising programme be deployed for the proper disposal of e-cigarettes. This programme should not only include disposal methods but also provide knowledge about the harm caused by e-cigarette waste and its component parts. Knowing not only how but also why it is necessary to dispose of e-cigarettes correctly will increase motivation for this action. Awareness-raising activities can be selected based on the popularity of such communication channels with society, such as television, the Internet, billboards, booklets, and social media.

Motivation is an integral part of the process of bringing the used e-cigarette to be recycled. As already noted, motivation is important for all stakeholders. In the case of manufacturers, this may be their extended responsibility. In addition to realising the importance of the processing process, it is proposed to financially incentivise the consumer. For example, the introduction of an additional duty of $2 per e-cigarette will require vape stores to return this money to consumers who bring their used e-cigarettes for recycling. The experience of countries that have implemented a system of refunds for packaging of goods or used goods suggests that there will be organisations who collect discarded e-cigarettes and take them to collection points to receive a refund. This will increase the collection and recycling of e-cigarettes, but it will also help clean up the environment and prevent further discarding of e-cigarettes in kerbside refuse or discarded inappropriately.

In addition, one of the recommendations is the introduction of additional containers for e-waste such as small household appliances and e-cigarettes in large cities like Auckland. Stockholm showed the greatest efficiency, where electronic waste is collected in the amount of 17.5 kg/cap/year, which is almost 80% of the total amount of electronic waste. This was achieved by installing special containers for electronic waste in private households. Kerbside collection at multifamily dwellings is a convenient option for residents of densely populated areas. A collection trial at a multifamily dwelling in Vienna (Austria) showed collection rates of 9 kg/cap/year, and kerbside collection with containers in Copenhagen (Denmark) reached 13 kg/cap/year (Salhofer, 2018). The problem of collecting e-waste like e-cigarettes is reduced due to the direct dependence on the convenience of receiving e-waste from the consumer. The introduction of small containers, as was done for organic produce, will allow the collection of not only e-cigarettes but also cables, computer mouse, phones and other e-waste.

Given the fact that Auckland is one of the world's leaders in the production of e-waste per capita, including waste from vaping, it is recommended to increase the number of collection points for receiving e-cigarettes and other e-waste and improve the infrastructure for its processing; recycling. However, e-cigarettes, as part of e- waste management, often do not contain enough valuable elements to be extracted during the recycling process to cover its costs. Therefore, the experience of Shanghai, where refiners began to be subsidised, is a positive example. In addition, this approach correlates with an increasing percentage of e-waste recycling.

CONCLUSION

In conclusion, the study on Vape/E-cigarette Waste Management in Auckland, New Zealand has shed light on the challenges and opportunities in effectively managing e-waste from vaping products. Through a thorough data analysis process employing thematic analysis, key themes influencing e-cigarette waste management have been identified, including regulatory hurdles, public awareness, technological challenges, and financial considerations. The inductive approach allowed for a nuanced exploration of the data, providing valuable insights into the current state of e-cigarette waste management in Auckland.

By addressing the research questions concerning the current challenges faced by Auckland Council in managing e-cigarette waste and potential strategies for improvement, this study has contributed to a deeper understanding of the complexities involved in e-cigarette waste management within the vaping industry. The thematic analysis served as a foundational tool for developing recommendations grounded in empirical insights from diverse stakeholders, paving the way for more sustainable e-waste management practices in Auckland.

In addition, it is important to recognise that this issue is holistic in nature and may be interconnected with further research, including studies on the health impacts of vaping. As the most effective approach to mitigating the issue of e-cigarette waste is by reducing vaping prevalence, there is a need for continued investigation into the broader implications of vaping. This could involve exploring strategies for the cessation of traditional smoking and e-cigarette smoking alongside e-waste management initiatives, thus addressing both the environmental and public health aspects of the vaping phenomenon.

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A WASTE REDUCTION JOURNEY: DATA-DRIVEN AND MACHINE LEARNING ON PERISHABLE FOOD WASTE OPTIMISATION IN NEW ZEALAND RETAIL SUPERMARKETS

Nenie Tamarisca Petrisia and Indrapriya Kularatne

OTAGO POLYTECHNIC AUCKLAND INTERNATIONAL CAMPUS

ABSTRACT

The issue of fresh food waste in retail supermarkets globally has become increasingly problematic, with New Zealand reporting alarming levels of waste primarily in vegetable, bakery, meat, fish, and fruit products. The retail supermarkets in NZ contribute more to food waste than any other sector, with an estimated 60,500 tonnes of food wasted annually due to customers' increasing expectations for fresh food, which is highly perishable. Despite numerous advanced technologies aimed at mitigating food waste, including deep learning techniques for fruit waste reduction and machine learning for food donation optimisation, perishable food waste remains a persistent challenge. This study employed a systematic literature review from scholarly journals to explore the potential of data-driven approaches combined with machine learning in preventing perishable food waste in retail supermarkets. The scholarly articles were extracted from online research databases. Drawing upon the principles of Sustainable Consumption and Production which aims to halve global food waste at the retail level and reduce waste through prevention strategies. This review focused on analysing existing research studies that investigated the application of machine learning for demand forecasting based on sales data and influencing parameters. Through a thematic analysis of the literature, this review identified key insights, challenges, and opportunities associated with implementing data-driven and machine learning strategies to mitigate perishable food waste in New Zealand retail supermarkets. By synthesising findings from the literature this study highlighted the urgency of the food waste prevention stage by utilising data-driven approach and machine learning for predicting accurate demand benefiting managers on fresh food purchase order decisions. Therefore, it helps improving operational outcomes, profitability, and customer satisfaction, specifically in lowering discarded unsold fresh food products.

Keywords: Data-driven, Machine Learning, Sustainability, Fresh food, Perishable food, Food waste reduction, Retail supermarkets.

INTRODUCTION

In retail supermarkets, providing fresh food is important due to the consumers' consideration to shop in supermarkets which have the best quality of fresh food products (Broekmeulen & Donselaar, 2019). The United Nations mentioned that an estimated 17% of food production is wasted in households, food service, and retail which has raised an issue about food systems sustainability and food insecurity (United Nations, 2024a). Furthermore, food waste production is closely connected to the increase of greenhouse gas emissions which leads to the contribution to the climate change problem (United Nations, 2024a). Research from University of Otago in New Zealand reported that retail supermarkets produced around 60,500 tonnes of food waste per annum (Goodman-Smith et al., 2020). It consisted of vegetable (27%) and bakery products (23%) as the highest amount of food wastage (Goodman-Smith et al., 2020; lovefoodhatewaste, 2020).

The Food and Agriculture Organisation of the United Nations (FAO) describes food waste as an appropriate food for human consumption being disposed of (either before or after the expiration date) (Food and Agriculture Organisation of the United Nations (FAO), 2013). Furthermore, food waste in retail supermarkets is caused by the shelf life, and supermarket standards for colour, shape and size, and variability (United Nations, 2020). According to Buisman, et al., (2019, p. 274), shelf life is defined as "the time between production and the use-by date". Short shelf-life products or fresh food, such as bakery products, fruit and vegetables, dairy products, poultry and fish, are part of the perishable food supplies which only have a maximum shelf life less than two weeks (Buisman, et al., 2019). These products need extra careful handling at the supply

chain level where they often get damaged due to temperature changes, packaging, and delivery time (Haji et al., 2020). Therefore, perishable products contribute to the highest food waste production compared to preserved food (Riesenegger & Hübner, 2022). Advanced technologies have been used in solving the food waste problem in retail supermarkets. For instance, a product's expiration-date tracking through the implementation of Artificial Intelligence (AI) helps supermarkets to update the inventories (Li & Sun, 2022). Machine learning (ML) as part of AI has also supported the improvement of food waste prevention solutions. By integrating sales data with external factors such as store campaign, weather, events, and public holidays, ML can create accurate demand forecasts. This helps managers predict bakery production needs and perishable food orders for suppliers. (Glatzel et al., 2016). Therefore, technology makes it possible for retail supermarkets to achieve the goal of halving global food waste at retail level and reducing food waste at a prevention level as stated in Sustainable Development Goal, SDG 12, Responsible Consumption and Production, indicators (United Nations, 2024b).

Based on the above, this research aimed to explore the usage of a data-driven approach and ML to reduce food waste in retail supermarkets through current literature. The information from this research will be valuable for retail supermarkets in New Zealand, to increase the business revenue while achieving environmental, social, and governance (ESG) goals. Therefore, this research was driven by two research questions: (RQ 1) What are the challenges faced by retail supermarkets on perishable food wastage production? (RQ 2) What is the impact of the usage of a data-driven approach and ML on perishable food waste optimisation?

LITERATURE REVIEW

Perishable Food Waste Problem in Retail Supermarkets

Perishable food products are characterised by a short shelf-life which requires careful handling at supply chain level and warehouse management systems to prevent damage and spoilage, preserve availability and ensure revenue for the business (Haji et al., 2020; Maheshwari et al., 2021). These include bakery products, fruits and vegetables, dairy products, poultry and fish which require short delivery times, high-speed transportation, and streamlined handling processes to maintain the retail supermarket's quality standards of colour, shape and size (Dreyer et al., 2016; United Nations, 2020). In the New Zealand retail supermarket context, the research from University of Otago reported that vegetables are the highest number of products being discarded, which amounted to 27% annually. This is followed by bakery products (23%), poultry and fish (19%), and fruits (17%) (Goodman-Smith et al., 2020). This research collected the data from the main retail supermarket chains in New Zealand such as Pak'n'Save, New World, and Woolworths in Auckland, Wellington, Christchurch, and Dunedin using a mixed-methods approach which resulted in approximately 60,500 tonnes of food waste annually or 13 kg per capita (Goodman-Smith et al., 2020). A previous study conducted by Reynolds et al. (2016) in 2011 reported that fruit and vegetables with the total amount of 17,188 tonnes were being wasted from commercial and industrial. This is followed by other grocery categories; bakery products (6,305 tonnes), poultry and fish (30,373 tonnes), and dairy products (23,231 tonnes). The Input-Output Life-Cycle Assessment (IO-LCA) model estimated 70kg/year food waste generated per capita (Reynolds et al., 2016). Estimated food waste generated in the New Zealand supply chain were also calculated in FAO the report (FAO, 2013). Around 180 kg/year of food waste per capita was indicated in production to the retailing stage in North America and Oceania in which New Zealand is included in that country category (FAO, 2013). The report summarised that the cause of food waste in developed countries occurs at retail and consumer levels (FAO, 2011).

The contribution to food waste is caused by the interdependency between consumer demand and supermarkets (Teller et al., 2018). It is a challenge for retail supermarkets due to uncertain demand, and product quality standards for customers (Teller et al., 2018). This is also related to the strong competition which forces the supermarkets to meet the customers' expectations on product freshness, large product choice, and availability (Teller et al., 2018). Especially for the main retail supermarket chains, such as Pak'n'Save, Foodstuffs and Woolworths, producing more food waste happens when they need to meet the high quality standards of fruit, vegetables, and poultry based on colour, size, shape; and the standard of freshness by providing fresh bakery products every day (Goodman-Smith et al., 2020). However, one major challenge that arises around managing perishable food products is preventing spoilage and loss (Riesenegger & Hübner, 2022). Careful inventory management and logistical coordination are needed to ensure sales before the expiration date (Kazancoglu et al., 2022).

Despite changing and uncertain customer demand challenges, limited understanding of advanced technology becomes a barrier for each retail supermarket buyer to use predictive analysis and demand forecasting to reorder the goods (Teller et al., 2018). Lack of knowledge and training among retail supermarket buyers and staff regarding these advanced technologies can contribute to the increase of food waste. Without the proper usage of predictive analysis and forecasting tools, the main retail supermarket retailers might struggle to accurately anticipate demand patterns, leading to overstocking of products, mainly fresh food which ends up being discarded (Riesenegger & Hübner, 2022). These challenges can be overcome with the adoption and effective usage of advanced technology such as ML algorithms for demand forecasting in order to prevent food waste in which utilising data provides insight for retail supermarket buyers (Teller et al., 2018).

Data-Driven Approach and Machine Learning

Machine Learning has been widely implemented and used in the waste management field as waste prediction analysis of household waste, construction waste, post-disaster waste, biomass waste, and others (Li et al., 2023; Nagalli, 2022; Yazdani et al., 2024; Zaman, 2022). There has been previous research focusing on waste measurement and optimisation on perishable food in retail supermarkets. The findings revealed the suggested dynamic shelf life and dynamic pricing strategies to solve the perishable food waste problem (Buisman, et al., 2019; Kayikci et al., 2022; Ping et al., 2024). Several studies underline the importance of leveraging technology to address food waste challenges in retail supermarkets. Neural networks are highlighted as potential ML algorithms to deal with large-scale forecasting problems for perishable food (Ziegler, 2020). Similarly, a study conducted by Maheshwari et al., (2021) emphasised the usage of Internet of Things (IoT) to reduce the inventory cost for improved perishability performance leading to significant reduction in food waste. Therefore, this technological advance has evolved retail supermarket operations by using information systems to plan and reduce food waste. However, advanced data containing additional parameters such as promotions, special effects, and future events have not been yet available or used for food waste prevention systems (Riesenegger & Hübner, 2022).

According to Provost and Fawcett (2013), a data-driven approach emphasises the decision-making based on empirical evidence and insights derived from data analysis. Meanwhile, ML, as part of AI, also relies heavily on data to train the models and make predictions (Bishop, 2006). With the ML algorithm, it can learn from the data and complex patterns without relying on rule-based programming with 85% accuracy (Dangeti, 2017). Therefore, both the data-driven approach and ML leverage data in extracting meaningful patterns which drive the decision-making benefits for the retail supermarkets.

For ML algorithms to effectively find patterns and relationships, large volumes of data are required (Murphy, 2012). The data is typically split 50%, 25%, and 25% respectively for training, validation, and testing sets (Dangeti, 2017). The ML algorithms frequently need to be trained on both training and validation datasets in order to ensure validity (Dangeti, 2017). According to Hastie et al., (2009), ML algorithms use statistical approaches to analyse and make predictions autonomously. Consequently, the quantity and quality of available data have a significant impact on the model's performance (Goodfellow et al., 2016).

The first step in creating and implementing an ML model is gathering data, which is then prepared to fit the chosen ML algorithm (Dangeti, 2017). Data analysis reveals hidden links and patterns among variables (Dangeti, 2017). Three sets of data are separated out: test, validation, and training (Dangeti, 2017). The training data is subjected to ML algorithms, and in order to avoid overfitting, hyperparameters are adjusted using the validation set (Dangeti, 2017). In the final step, deployment is needed to classify outcomes in real-time streaming data (Dangeti, 2017). The ML capacity to find associations and hidden insights in massive datasets enables data-driven decision-making easier (Sarker, 2021). Retail supermarkets can identify trends, patterns, and irregularities in data analysis using ML algorithms that they might miss using the conventional methods (Goecks, 2020; Murphy, 2012). This facilitates the decision-making, streamlines workflow, and drives creativity within retail supermarkets (Goecks, 2020; Murphy, 2012). Furthermore, the mutually beneficial relationship between ML and data-driven approaches is strengthened by their iterative nature (Barber, 2012; Goodfellow et al., 2016). The ML functions as a feedback loop in which data is used to train models, predictions are made, and feedback is then used to enhance and optimise model performance (Goecks, 2020). This iterative method helps retail supermarkets to continuously adjust and improve their models depending on evolving data patterns and business requirements (Goecks, 2020). Thus, data-driven techniques and ML are related as ML functions as a strong tool to extract information from data, thereby enabling data-driven decision-making processes that will impact on the reduction of perishable food waste.

METHODOLOGY

A systematic literature review is defined as "a method for identifying, evaluating, and interpreting compatible research results related to research questions and specific topics or phenomena of concern" (Ibda et al., 2023, p. 288). In this article, the researchers have discussed the field of information systems in which combining computer science, business, and social science. Therefore, a systematic literature review was essential for this research to ensure reliable and reproducible findings derived from the analysis of primary studies (Ibda et al.,2023). A thorough literature review of information systems improves the quality and dependability of research outputs, contributing to the advancement of the field (Okoli & Schabram, 2010).

Search Strategy

A systematic search was performed to identify relevant articles published in databases from 2015 to 2024. The articles were extracted from Google and ProQuest databases. A detailed search strategy with keywords was used to ensure reproducibility and transparency (Ibda et al.,2023). Search terms, keywords, related to "perishable food waste", "fresh food", "food waste", "demand forecasting", "predictive analysis", "retail supermarkets", "data-driven", and "machine learning" to explore the potential of data-driven approaches combined with ML in preventing perishable food waste in retail supermarkets. There were 432 and 466 articles found in Google Scholar and ProQuest, respectively, using the keywords mentioned.

Inclusion and Exclusion Criteria for Selection

The research was limited to the criteria which is taken from Google Scholar and ProQuest database to determine whether all included articles were appropriate to answer RQ1: "What are the challenges faced by retail supermarkets on perishable food wastage production?" and RQ2: "What is the impact of the usage of a data-driven approach and ML on perishable food waste optimisation?". This research implemented the following inclusion criteria: (1) published between 2015-2024. The selection of this date range is based on contemporary academic articles and reflects the most up-to-date research findings in the field; (2) focused on perishable food waste in retail supermarkets and utilised data-driven and machine learning as a solution for food waste optimisation; and (3) peer-reviewed.

Screening and Eligibility Assessment for Data Analysis

Following each search in above mentioned databases, the initial articles were exported into Zotero. After removing the duplicates, all titles and abstracts were screened to select the relevant articles based on the inclusion criteria and to ensure relevance according to research questions. The selection of articles was checked and categorised into included and excluded studies after the initial screening. The full text of the included category was then assessed against the inclusion criteria. A flow chart of the research selection procedure is presented in Figure 1.

Figure 1: Flow Chart Depicting the Process of Article Selection for the Systematic Literature Review
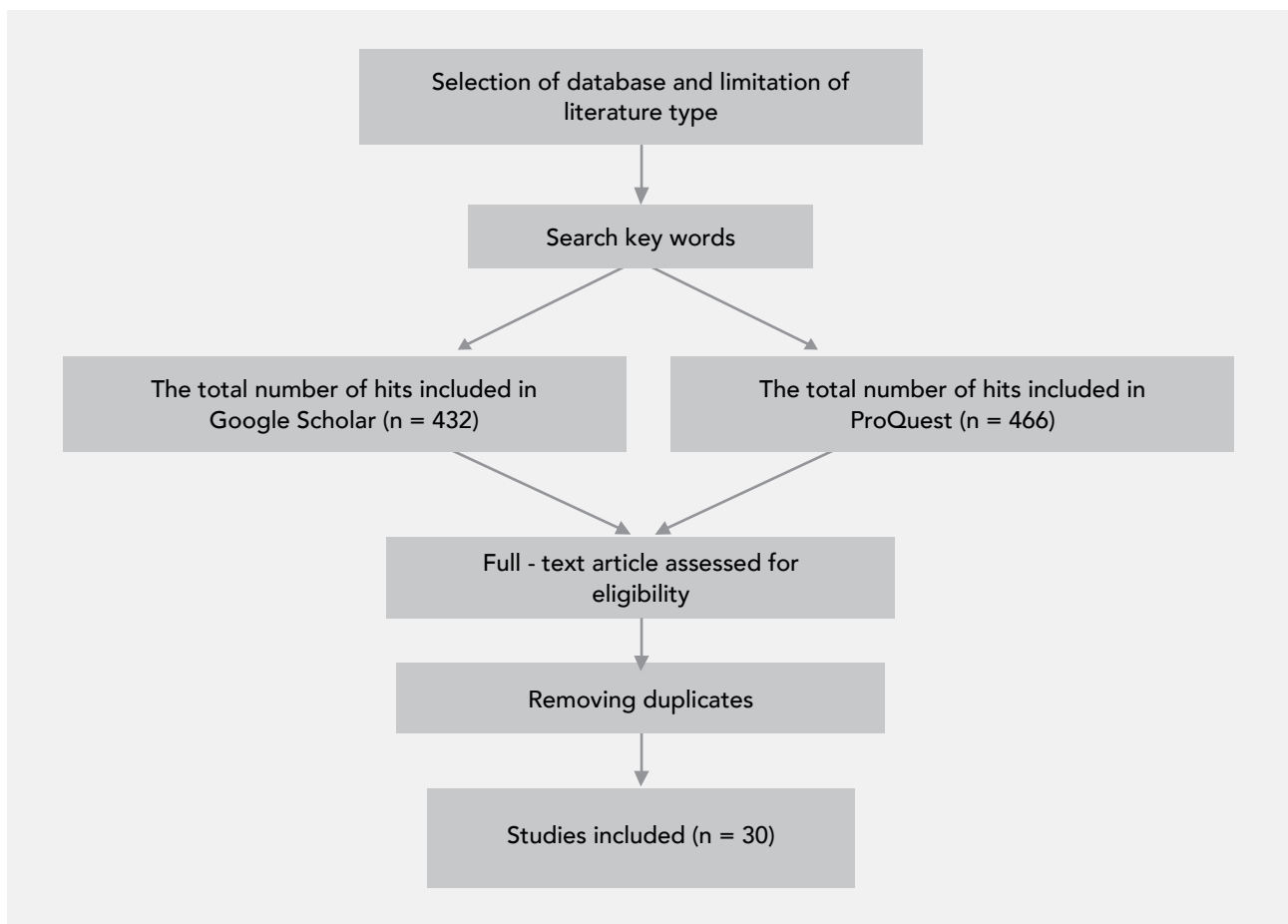
Note: Search Key words were (food waste prevention) AND (food waste reduction) AND (grocery retail sector) OR supermarket AND (machine learning) AND data-driven AND (demand forecast model) AND (predictive analysis) AND (decision-making for managers).

RESULTS AND DISCUSSION

The description of the results provides the findings of a synthesised evaluation of the 45 selected articles to answer the research questions. Detailed information of these studies is presented in Table 1. Based on the initial results, the articles are mapped according (RQ 1) What are the challenges faced by retail supermarket on perishable food wastage production? and (RQ 2) What is impact of the usage of data-driven approach and ML on perishable food waste optimisation? Articles that did not examine these two RQs were excluded, resulting in 30 articles being selected from 898 results on Google Scholar and ProQuest.

Table 1: Mapping results of the 40 Selected Articles Based on Links to the Research Questions

NUMBER	AUTHORS	RELEVANCE TO THE RQ
1.	Achamu et al., (2021)	RQ 2
2.	Alawadh & Barnawi (2024)	RQ 2
3.	Alfian et al., (2023)	RQ 2
4.	Andaur et al., (2021)	RQ 2
5.	Birkmaier et al., (2024)	RQ 2
6.	Bojer et al., (2019)	RQ 2
7.	Cicatiello et al., (2020)	RQ 1
8.	Dibsi & Cho (2023)	RQ 2
9.	Fredes et al,. (2023)	RQ 1
10.	Goodman-Smith et al., (2020)	RQ 1
11.	Haselbeck et al., (2022)	RQ 2
12.	Horoś & Ruppenthal (2021)	RQ 1
13.	Joensuu et al., (2022)	RQ 1
14.	Kayikci et al., (2022)	RQ 1 and 2
15.	Kerzel (2022)	RQ 2
16.	Kirci et al., (2022)	RQ 1
17.	Luo et al., (2021)	RQ 1
18.	Marques et al., (2021)	RQ 1
19.	Mattsson & Williams (2022)	RQ 1
20.	Miguéis et al., (2022)	RQ 2
21.	Mitra et al., (2022)	RQ 2
22.	Nasseri et al., (2023)	RQ 2
23.	Nasteski (2017)	RQ 2
24.	Ping et al., (2024)	RQ 2
25.	Riesenegger & Hübner (2022)	RQ 2
26.	Rodrigues et al., (2024)	RQ 2
27.	Sakoda et al., (2019)	RQ 1 and 2
28.	Sarker (2021)	RQ 2
29.	Scholz & Kulko (2022)	RQ 2
30.	Zhang & Yan (2024)	RQ 2

The Challenges of Perishable Food Waste in Retail Supermarkets

Retail supermarkets are reported as one of the sectors that contributed to the production of food waste (Joensuu et al., 2022). In dealing with food waste reduction, it is important to look at the solution according to the hierarchy in which preventing food waste is considered as a desirable solution (Joensuu et al., 2022). From all the types of food waste from retail supermarkets, research reported that fresh vegetables and fruit are mostly being discarded due to their apparent imperfections and oversupply (Fredes et al., 2023; Goodman-Smith et al., 2020; Joensuu et al., 2022; Smith et al., 2020). Unfortunately, retail supermarkets mostly use food donations in addition to sending their food waste to the landfill (Goodman-Smith et al., 2020). According to Goodman-Smith et al., (2020), not all retail supermarkets have the option to donate food to food rescue organisations, and they will not accept all available donations due to capacity reasons.

This limitation highlights the need to focus on food waste prevention at its source. By minimising food waste, the demand of food redistribution would decrease, in addition, reducing food waste at the source being more effective than relying on food donations (Goodman-Smith et al., 2020).

Prevention ought to be considered first when it comes to preventing food waste. Understanding the root causes of in-retail supermarket food waste is essential before implementing food waste prevention strategies (Cicatiello et al., 2020). One of the causes highlighted is overstocking due to inaccurate prediction of fresh food demand (Cicatiello et al., 2020). Based on a survey conducted by Fredes et al. (2023), overstocking is associated with retail supermarket planning, over buying, and purchasing without a sales plan, all of which will contribute to unavoidable food waste. It is reported that citrus, banana, inflorescence (broccoli, cauliflower, artichoke), and root and tubers (carrot, beet, turnip, parsnip) food waste are caused by poor retail supermarket planning and purchasing (Fredes et al., 2023). Poor retail supermarket planning correlates with the difficulties to provide accurate demand prediction and forecasting due to seasonal demand, promotion, and weather which lead to surplus food and food waste especially for the fresh food category (Horoś & Ruppenthal, 2021; Kirci et al., 2022). Meanwhile, research identified that some of the retail supermarkets were over-buying by more than 7% to ensure that the shelves were full, which is a driver of customer satisfaction (Goodman-Smith et al., 2020). Horoś and Ruppenthal (2021) discovered through interview with retail supermarket owners that overstocking levels are approximately 30%, largely attributed to customer expectation of constant product availability. These customer behaviours have forced the retail supermarkets to overstock to increase the retail supermarket image and brand loyalty even though it has an impact to the production of food waste (Marques et al., 2021).

Planning systems are important as a food waste prevention strategy of fresh food products in retail supermarkets. By looking at the inventory stocks and sales, retail supermarkets can estimate future orders and find ways to avoid overstocking while meeting customer expectations of product quality and availability (Horoś & Ruppenthal, 2021; Sakoda et al., 2019). This also enables the retail supermarkets to prepare for food loss and waste (FLW) which involves demand management where inaccurate forecasting is one of the causes of food waste (Luo et al., 2021). It is important for the retail supermarket managers to place accurate orders for fresh food which will help to control the amount of food waste generated. They also need to consider the inventory stock balance both in the inventory system and the warehouse. In addition, paying attention to campaigns, weather forecasts, public holidays, and events have a significant effect in predicting customer demand to reduce the amount of perishable food waste (Mattsson & Williams, 2022).

Data-Driven and Machine Learning for Perishable Food Waste Optimisation

For retail supermarkets, monitoring sales, orders, and inventory levels is essential for demand forecasting and predictive analysis, particularly when dealing with short-shelf-life products that risk being discarded if unsold (Haselbeck et al., 2022). This also aims to avoid overstocking and out-of-stock circumstances (Haselbeck et al., 2022). Sustaining retail supermarket operations through sufficient stock levels is the goal of an efficient inventory management system (Praveen et al., 2020). Algorithms powered by ML can be used to optimise perishable items (Achamu et al., 2021). Simply explained, ML is the capacity of a machine to process large amounts of data and is a computing system that gets better with practice. Less errors and greater accuracy are the results of ML in predictive modelling (Achamu et al., 2021). To reduce food waste and boost operational effectiveness, research by Kumar et al., (2021) emphasised the significance of effective inventory management in warehouses by utilising ML for predictive analysis of customers' demand. The ML and data-driven approaches also enable the retail supermarkets to detect out-of-stock (OOS) items automatically using the Point-of-Sale (POS) data and learning algorithms such as Random Forest and Ensemble Classifier to improve the predictive analysis (Kumar et al., 2021). With accuracy of 72%, this algorithm helps the retail supermarkets to control the inventory of perishable products (Andaur et al., 2021).

According to Riesenegger and Hübner (2022), demand forecasting for perishable food products in retail supermarkets is essential because of frequent reordering and fluctuating customer perceptions of products' freshness. When using a data-driven approach for ML-based forecasting, information on inventory levels, demand trends, and other relevant variables must be gathered and analysed (Dibsi & Cho, 2023). Data-driven models can produce precise demand forecasts for perishable food products by utilising relevant data such as previous POS data, trends, and external factors, i.e., weather and public holiday information resulted in increasing profit, improving product freshness and eliminating perishable food waste (Dibsi & Cho, 2023; Haselbeck et al., 2022; Kumar et al., 2021; Riesenegger & Hübner, 2022). Temperature variations influence customer behaviour and product demand, therefore integrating weather data improves forecasting accuracy (Riesenegger & Hübner, 2022). Additionally, in the retail supermarket stage of the perishable food supply chain, a data-driven approach supports the dynamic pricing strategy to determining pricing at various points during a sales season (Kayikci et al., 2022). Dynamic pricing strategy has resulted in 27% of deli and prepared food categories and 53.6% of produce category food waste reduction with a 10% increase in revenue (Sakoda et al., 2019; Scholz & Kulko, 2022). As a result, retail supermarket managers can effectively make quick decisions about the inventory whereby the dynamic pricing is updated based on real-time data of the perishable food shelf-life (Kayikci et al., 2022; Ping et al., 2024). Moreover, it is anticipated that the forecasting tool will include supply synchronisation with perishable food producers in order to lower supply chain aging and raise the in-retail supermarket's product quality (Birkmaier et al., 2024).

Meanwhile, according to Makridakis and Hyndman (1997), and Arunraj et al, (2016), it was stated that there are two types of factors that affect demand prediction: internal factors such as marketing campaigns, price variations and promotions; and external factors, such as weather, festivals, and events in which both factors are uncontrollable. Moreover, customer's behavioural data is also important as an influencing variable in developing the prediction models ML using neural networks (Alawadh & Barnawi, 2024). As an example, according to Kerzel's (2022) analysis, it was found that deli and prepared food categories had the most frequent and short 'days between visits' which means customers tend to buy the food for immediate consumption compared to the milk product category. Therefore, POS data plays an important role in gaining insight of customer purchasing behaviour.

A data-driven approach will be more effective if it is combined with ML algorithm. With a major focus on fruit and vegetables, ML is mostly used in demand forecasting for perishable food products in retail supermarkets. Studies conducted by Priyadarshi et al. (2019) and Arunraj et al. (2016) reported that the ML trend is used in forecasting the daily demand of tomatoes, onions, potatoes, and bananas using ML models such as Long Short-Term Memory (LSTM) networks, Support Vector Regression (SVR), Random Forest Regressions (RF), etc. These models are designed to estimate consumer demand for fresh products with enough accuracy to optimise inventory management and minimise waste (Priyadarshi et al., 2019 & Arunraj et al., 2016). On the other hand, the fish production model makes use of neural network approaches (Miguéis et al., 2022). Therefore, once ML-based predictive analysis has gone through data-driven modelling and training using a well-suited learning algorithm, the model is tested to check it can generate accurate predictions (Sarker, 2021). Further research mentioned that a supervised ML model using Logistic Regression, K-Nearest Neighbour, Decision Tree, Random Forest, etc enable the evaluation of customer purchasing behaviour (Alfian et al., 2023; Bojer et al., 2019; Nasteski, 2017). Mitra et al., (2022) stated that the XGBoost model of learning algorithm provides precise demand forecasting and reduces errors by training the decision trees, therefore, it overcomes the overfitting problem on ML learning algorithm. XGBoost is known for its efficiency and high performance in purchase probabilities prediction in which it is suitable to reduce overstocking of perishable food and optimise its waste production (Nasseri et al., 2023). Integrating Autoregressive Integrated Moving Average (ARIMA), Long Short-Term Memory (LSTM), and Frequent Pattern (FP)-Growth algorithms have also enabled the retail supermarkets to obtain accurate sales forecasting, restocking optimisation, and pricing adjustment leading to waste reduction and operation efficiency (Ping et al., 2024). According to Rodrigues et al. (2024), Random Forest and LSTM neural network algorithms forecasting model achieve the most effective results in reducing food waste, with reductions ranging between 14-52%. Meanwhile, individual item data processing using ARIMA model analyses which fresh food product has the largest purchase amount, catchweight quantity, and sales volume, making it the most profitable item in its category (Zhang & Yan, 2024). As a result, retail supermarket managers and buyers will be better equipped to navigate the challenges of managing perishable food waste, which will improve operational outcomes, keep high profit, and increase customer satisfaction. They will also gain insight into product popularity, product level promotion demand, and customer interest (Alfian et al., 2023; Bojer et al., 2019; Ping et al., 2024; Sakoda et al., 2019).

Combining the first and second research question, this research emphasises that fresh food items are important for retail supermarkets, accounting for up to 40% of their revenue (Felix, 2018). Reducing perishable food waste is therefore essential to improve profitability (Felix, 2018). Tesco, a large retail supermarket in the United Kingdom, is a success story in this regard (Kolev et al., 2023). Tesco has started to implement ML algorithms to optimise their food waste (Kolev et al., 2023). Tesco faces the challenge of managing the food stock leading to revenue loss and increase in food waste (Kolev et al., 2023). In addressing this issue, the supermarket uses ML models with domain expertise that helps in selecting relevant features, interpreting results accurately, and related to the business objective which is increasing revenue while reducing perishable food waste. This algorithm has had the biggest impact on fresh food items. Tesco has cut the number of expiring fresh foods going to waste by 5%, saving millions of fresh products each year (Kolev et al., 2023). Moreover, implementing an advanced demand forecasting system saved Tesco up to £100 million annually (Felix, 2018). In addition, Tesco utilises ML algorithms to reduce food waste by improving forecasting and stock management (Tesco, 2024). Using the supermarket's data, Tesco matches the right product ranges and sizes to their supermarket store size (Tesco, 2024).

CONCLUSION

In achieving SDG 12, Responsible Consumption and Production, this article identified the challenges of perishable food waste reduction in retail supermarkets and examined the usage of data-driven and machine learning approaches as food waste optimisation in the prevention stage. Through a systematic literature review conducted from 30 articles, the findings revealed that retail supermarkets have complex problems with perishable food waste that call for comprehensive solutions. The main causes of the problem are overstocking, imprecise demand prediction, and customer buying behaviour wanting perfect product appearance (Cicatiello et al., 2020; Kayikci et al., 2022; Riesenegger & Hübner, 2022). Despite recognising prevention as the best solution, retail supermarkets frequently turn to unsustainable methods such as food donation and landfill disposal (Riesenegger & Hübner, 2022). This highlights the urgent need for the implementation of better food waste management. Moreover, this research highlights the urgency of the food waste prevention stage by utilising data-driven and ML approaches for predicting accurate demand. For running data-driven and ML modelling, large relevant volumes of data such as sales trends, inventory levels, and external factors as parameters is needed (Dibsi & Cho, 2023;

Haselbeck et al., 2022; Kumar et al., 2021; Miguéis et al., 2022; Riesenegger & Hübner, 2022). Meanwhile, ML also enables dynamic pricing strategy which helps the retail supermarkets to decrease food waste while increasing their revenue (Kayikci et al., 2022; Ping et al., 2024; Sakoda et al., 2019; Scholz & Kulko, 2022). Moreover, accurate forecasting is provided by ML models such as Random Forest and XGBoost, which reduce food waste production and overstocking (Mitra et al., 2022; Nasseri et al., 2023). Overall, retail supermarkets are better equipped to handle the challenges of perishable food waste when data-driven and ML algorithms approaches are combined. This promotes a more resilient and sustainable retail ecosystem by lowering food waste while also improving operational outcomes, profitability, and customer satisfaction.

However, this research acknowledges potential limitations. The selection of the search keywords may have limited the research even though the authors believe the appropriate terms were selected. Furthermore, the article selection process can be viewed as subjective, and the findings might be biased. Therefore, further research is needed to explore the effectiveness of data-driven approach and ML for retail supermarkets in New Zealand in the prevention stage of reducing food waste.

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INVESTIGATING EQUITY IN REMOTE SALARIES IN THE DATA SCIENCE FIELD USING DATA ANALYSIS TECHNIQUES

Liman Wu and Waruni Hewage

OTAGO POLYTECHNIC AUCKLAND INTERNATIONAL CAMPUS

ABSTRACT

Numerous roles within the Information Technology sector have transitioned to remote working in the aftermath of the COVID-19 pandemic. This research presents a comprehensive analysis of salary trends in the Information Technology sector, data science field from 2020 to 2023, with a special focus on the impact of remote working. The primary objective is to explore how remote working influences salary structures in the data science field by examining a range of job-related variables. A quantitative research approach combining exploratory data analysis and statistical analysis was employed in finding insights on a publicly available dataset acquired from Kaggle. Findings of this research conclude that experience significantly influences salary in the Information Technology sector, data science field, overshadowing factors like company size and remote working types. It was also revealed that remote working constituted a substantial portion of the employment structure, reflecting the data science field shift towards flexible work arrangements. While remote working is increasingly popular, its impact on salaries is less pronounced than expected. For stakeholders in the Information Technology sector, data science field, this research highlights the importance of considering experience and geographical location in salary structuring and suggests a growing trend towards remote working, necessitating adjustments in employment practices and policies.

Keywords: Remote Salaries, Equity, Data Analysis, Data Science, Quantitative

INTRODUCTION

The COVID-19 pandemic has caused a significant transformation in the nature of work, particularly in the data science industry since increased functions are being performed remotely (PricewaterhouseCoopers (PWC), 2021). This research examined the current state of salary equity in this evolving environment from 2020 to 2023, with a focus on the impact of remote working on salary structures in the Information Technology sector (IT), data science field. The impact of remote working on pay has been less significant than expected, despite its growing popularity. Previous studies (Pabilonia & Vernon, 2023), show that remote workers frequently make more money than their colleagues who work in offices; nevertheless, the extent of this wage premium varies between industries and geographical areas (Brinatti et al., 2023). This discrepancy raises important questions about equity and fairness in salary, making this research crucial for stakeholders in the IT, data science field. The purpose of this research was to address the knowledge gap regarding the impact of remote working on salary structures. Understanding these dynamics is essential for ensuring fair and equitable salaries in the IT sector increasingly leaning towards remote working operations. By exploring these dynamics, the research aimed to provide insights to guide more equitable salary structures, accommodating the shift towards remote working and its complex implications for salary structures (Deloitte, 2021). This is particularly important as companies navigate the post-COVID-19 pandemic world, where remote working is likely to remain prevalent.

This research examined a wide array of job-related variables to study their impact on salary. It provides a perceptive viewpoint on the relationship between remote working and salary structures in the IT, data science field and is aimed at a broad readership, which includes IT practitioners, companies, academicians, and IT sector observers.

By providing stakeholders with evidence-based insights for strategic decision-making and policy creation within the IT, data science field, this research seeks to make a substantial contribution to the current conversation on employment practices specifically salary in the IT data science field this the digital era.

Primary objectives of this research were:

1) Examining the effect of different job-related factors on remote working salary structures.

2) Exploring the long-term trends shaping remote working policies and their effects on salary equity within the IT sector.

These objectives will be accomplished by providing answers to the research questions listed below.

I. How do different job factors affect remote working salary in the IT data science field?

II. What strategic adjustments do companies need to make to adapt to the evolving norms of remote working and salary structures?

The remainder of the article discusses the Literature Review followed by Methodology, Results and Discussion, Conclusion and Recommendations.

LITERATURE REVIEW

The shift towards remote working has profoundly transformed workforce dynamics, particularly within the IT sector, data science field, influencing salary structures and employment practices (PWC, 2021). This literature review explored existing research on the impact of remote working on salary to identify congruences and disparities.

Who are the Remote Workers

Remote workers can be categorised based on the percentage of their working hours spent working remotely. According to Absolute IT Recruitment (2023), there are different categories of involvement that define remote working: totally remote workers spend over 80% of their working time away from their company's office premises, partly remote worker or hybrid workers allocate half of their daily work at home, while non-remote workers spend less than 20% of their working hours remotely (Absolute IT Recruitment, 2023).

Similarly, Barrero et al., (2023) define remote workers as those who spend one day or more per week working at home with further distinctions between fully remote workers (100% of working hours remote working) and hybrid workers (partially remote working) (Brynjolfsson, et al., 2020). Deloitte (2021) also recognises the importance of these categories in adapting corporate strategies to manage remote working efficiently and equitably.

The categorisation helps to delineate the extent of remote working engagement, which is fundamental for understanding its impact on salary structures and employment practices in the IT, data science field. This structured approach aligns with the literature's emphasis on the varying degrees of remote working and their respective implications on workforce dynamics and salary strategies (Brynjolfsson, et al., 2020; Emanuel et al., 2021).

Transformation of Workforce Dynamics

The COVID-19 pandemic accelerated a substantial shift, establishing remote working as a permanent aspect for a substantial portion of the labour market (PWC, 2021). Companies are currently confronted with the task of ensuring continuous connectivity and cultivating a culture that encourages professional growth in a decentralised setting (PWC, 2021). The prevalence of remote working has experienced a significant surge from 2019 to 2023 (Barrero et al., 2023) This phenomenon not only signifies the influence of the COVID-19 pandemic but also a more extensive transformation in workplace culture and the embracing of technology that has occurred over several decades (Barrero et al., 2023). Video-calling software and Cloud storage technologies have made it easier to move to remote working (Deloitte, 2021). These tools are essential for daily operations in areas like the IT, data science field (Deloitte, 2021). These alterations need a reassessment of corporate tactics for efficiently managing a geographically dispersed workforce, which in turn affects the structure and adjustment of salary in accordance with these emerging standards (Deloitte, 2021).

Sectors that have digital and communication technology, such as those used in the IT, data science field, are more inclined to implement remote working practices (Barrero et al., 2023). Thus, the IT, data science field has a distinct benefit in utilising remote workers to gain a competitive edge in hiring and optimising salaries (Barrero et al., 2023); Remote working in the IT, data science field has multifaceted effects. Data science roles are well-suited for remote working arrangements due to their strong correlation with computer use, educational requirements, and pay levels (Barrero et al., 2023). Data scientists who can utilise remote working to access job opportunities in many different markets may experience an improvement in their salary prospects through this alignment.

Remote Working's Effect on Salaries

The shift towards flexibility in the labour market challenges traditional salary structures, as remote working becomes increasingly valued over location (Pabilonia & Vernon, 2023). During the COVID-19 pandemic, remote workers earned, on average, 14.2% more than their office-based counterparts, highlighting potential salary disparities across different sectors and job types. This trend, predating the COVID-19 pandemic, accelerated as remote salaries grew faster, particularly in

fields like management, computer science, and legal professions (Pabilonia & Vernon, 2023). These salary premiums reflect the economic benefits of remote working—cost savings and enhanced productivity—that companies are beginning to share with workers in competitive sectors like the IT, data science field (Pabilonia & Vernon, 2023).

The salary for remote working is greatly impacted by the economic realities of the specific location, even though the employment market is global in nature (Brinatti et al., 2023). This research finds that remote salaries are higher in regions with higher income per capita, indicating that local labour market conditions continue to play a crucial role in determining remote salaries globally (Brinatti et al., 2023). Furthermore, the remote working trend has a substantial impact on salary trends by increasing the diversity of applicants from different geographic locations, this can lead to a moderation in salary growth due to increased competition among job seekers (Hansen, et al., 2023). An analysis conducted by Hansen et al., (2023) examined more than 250 million job posts and revealed that the prevalence of remote working in job advertisements increased by over threefold in the United States and by fivefold in English-speaking nations such as Australia, Canada, New Zealand, and the United Kingdom between 2019 and early 2023; Nevertheless, the implementation of remote working differs among industries, with finance, insurance, and IT witnessing more significant rates than others (Hansen et al., 2023). This suggests that salary trends are affected unevenly across various sectors and geographies.

The moderation of salary-growth pressures has been encouraged by how remote working offers advantages (Barrero et al., 2022). The switch to performing duties away from the traditional office setting comes with a host of benefits for workers that do not involve salary. Instead, these are partly passed on through lowered wage increments (Barrero et al., 2022). The scale at which this dynamic operates helps to understand why there has been an unanticipated squeezing of salaries especially among low salary earners whose salary reduction was less compared to colleagues earning higher salaries (Barrero et al., 2022). This refined interpretation provides a contrast between the idea that compensation structure has changed because of remote working while salary adjustment due to it is complex slash not direct but subject to wider economic issues coupled with company owner's needs.

Professional Experience and Salaries

The notable rise in salaries in New Zealand's IT sector is primarily caused by a shortage of skilled workers, which is further intensified by global events and local economic circumstances (Absolute IT Recruitment, 2023). Despite the presence of uncertainties, there is a strong demand for IT specialists, which is causing salaries to increase (Absolute IT Recruitment, 2023). This trend is like what is happening in the IT, data science field, where specialised skills, especially in remote working environments, are being rewarded with higher salaries (Absolute IT Recruitment, 2023). Professional experience is becoming increasingly crucial in determining salary expectations, surpassing the importance of qualifications. Research conducted by Chen & Li (2023) emphasises that differences in salary are mainly determined by factors related to experience rather than academic qualifications, highlighting the importance of practical skills in the labour market.

Moreover, Flynn (2023) noted that there is a general movement towards valuing hands-on knowledge compared to academic qualification in many fields of which the IT, data science field is one of them. Similarly, research conducted by Burtch Works (2022) indicated that hiring managers are increasingly looking for workers who have been in the industry for long periods as well as having specialised abilities rather than holding higher qualifications, which reinforces experience in pay matters. The PayScale's 2023 Compensation Best Practices Report further upholds this position by observing how work experience significantly impacts on salary growth particularly within technological roles given the high demand for professionals despite market instability.

Adjustments in Salary Structures

To accommodate remote working, companies are adjusting their salary plans to reflect local cost of living (Deloitte, 2021). This illustrates the complex relationship between remote working and salary. Remote working may not inevitably lead to higher salaries, as salary modifications depend on experience and job market conditions (Deloitte, 2021; Martin et al., 2018). This adaption illustrates how local economic conditions and sector-specific needs affect salaries for remote working.

To reflect shifting work arrangements, companies are targeting equal and competitive salaries across geographies and employment positions (Deloitte, 2021). Fair practices must be incorporated into remote working legislation to keep up with its ever-changing nature (Deloitte, 2021). Remote working has a major impact on IT sector workforce and salary. To ensure justice and modify remote working policies, understanding the variables that cause these variations is crucial.

METHODOLOGY

This research uses secondary data related to the IT, data science field income patterns from 2020 to 2023 which was acquired from Kaggle with the author's permission. The dataset -Data Science Salaries 2023 (RANDOMARNAB, 2023), is licensed 'as is' without warranties of any kind. The origin of this dataset is from https://aijobs.net/salaries/ where actual salaries of professionals and employers globally have been anonymously aggregated in real time weekly for use in academic research such as Data Science Salary Analysis by Obi (2024). This indicates that this particular data set is suitable to explore patterns in the IT, data science field salaries other researchers have used it for the same purpose.

This dataset includes variables like geographic location, job roles, company size, and professional experience. After carefully analysing the variables and data, it was concluded that the dataset was suitable for the intended purpose. A meticulous data cleansing procedure was conducted to guarantee that the data was prepared to a condition for analysis. This involved using Power Query for tasks such as verifying the absence of empty or erroneous values, standardising header names for consistency, aligning data types (e.g., converting salary figures into a uniform currency format), removing irrelevant data, replacing abbreviations with full terms, and reordering columns for clarity. Further enhancements were made in Microsoft (MS) Excel, including encoding variables for regression analysis, categorising job titles, and adding columns for remote working types and country names for geographical analyses. Table 1 describes the variables of the cleaned dataset.

Table 1: The Classification of Final Set of Variables After Data Wrangling

VARIABLE	DATA TYPE	LEVELS OF MEASUREMENT
Work Year	Numerical/Discrete	Quantitative/Interval
Company Size	Categorical	Qualitative/Ordinal
Company Size Value	Numerical/Continuous	Quantitative/Level
Job Title	Categorical	Qualitative/Nominal
Job Title by Category	Categorical	Qualitative/Nominal
Experience	Categorical	Qualitative/Ordinal
Experience Value	Numerical/Continuous	Quantitative/Level
Employment Type	Categorical	Qualitative/Nominal
Salary in USD	Numerical/Continuous	Quantitative/Ratio
Employee Residence	Categorical	Qualitative/Nominal
Company Location	Categorical	Qualitative/Nominal
Country Full Name	Categorical	Qualitative/Nominal
Domestic/Int'l	Categorical	Qualitative/Nominal
Domestic/Int'l Remote	Categorical	Qualitative/Nominal
Remote Ratio	Numerical/Continuous	Quantitative/Ratio
Remote Types	Categorical	Qualitative/Nominal

It was decided to use quantitative data analysis methods as the primary data analysis methodology as the selected dataset. Exploratory data analysis techniques were used to identify patterns, behaviours, and relationships. Moreover, diagnostic analysis using statistical testing was conducted to assess the statistical significance of identified trends.

RESULTS AND DISCUSSION

How do different job factors affect remote working salaries in the IT, data science field?

To answer the research question, different job-related factors have been analysed: experience level, role in the company, type of work schedule among other factors. The objective of our thorough examination is to obtain a better understanding of what factors lead to how much one earns within the IT, data science field which is becoming increasingly important nowadays.

Experience

This dataset is for IT, data science field job salaries spanning 2020 to 2023. As shown in Figure 1 (a) (in USD), it has an average of around $137,570, which is remarkably close to the median of $135,000: this means that it is evenly distributed. The most common salary is $100,000. However, there is a considerable amount of variation, with the lowest and highest salaries differing by $444,868. From Figure 1 (b), the salary distribution specifically for the IT, data science field roles can be seen: again, the median is $150,000, the most common being between $100,000 and $200,000. There are several outliers beyond this range, indicating that a few are paid much more. The average income is $137,570, reflecting a stable field and aligns with the range from $130,000 to $171,000 base salaries for IT, data scientists (Glassdoor, 2023). There are 66 outliers in the dataset earning over $290,000, 64 being Senior to Executive level. This may indicate that experience is a key variable in determining the salary.

Figure 1: Summary Statistics of Salary in USD.

SALARY IN USD		
Mean	$	137,570
Standard Error	$	1,029
Median	$	135,000
Mode	$	100,000
Standard Deviation	$	63,056
Sample Variance	$	3,976,011,879
Kurtosis	$	1
Skewness	$	1
Range	$	444,868
Minimum	$	5,132
Maximum	$	450,000
Sum	$	516,576,814
Count	$	3,755

(A) SUMMARY STATISTICS　　　　**(B) BOX-PLOT**
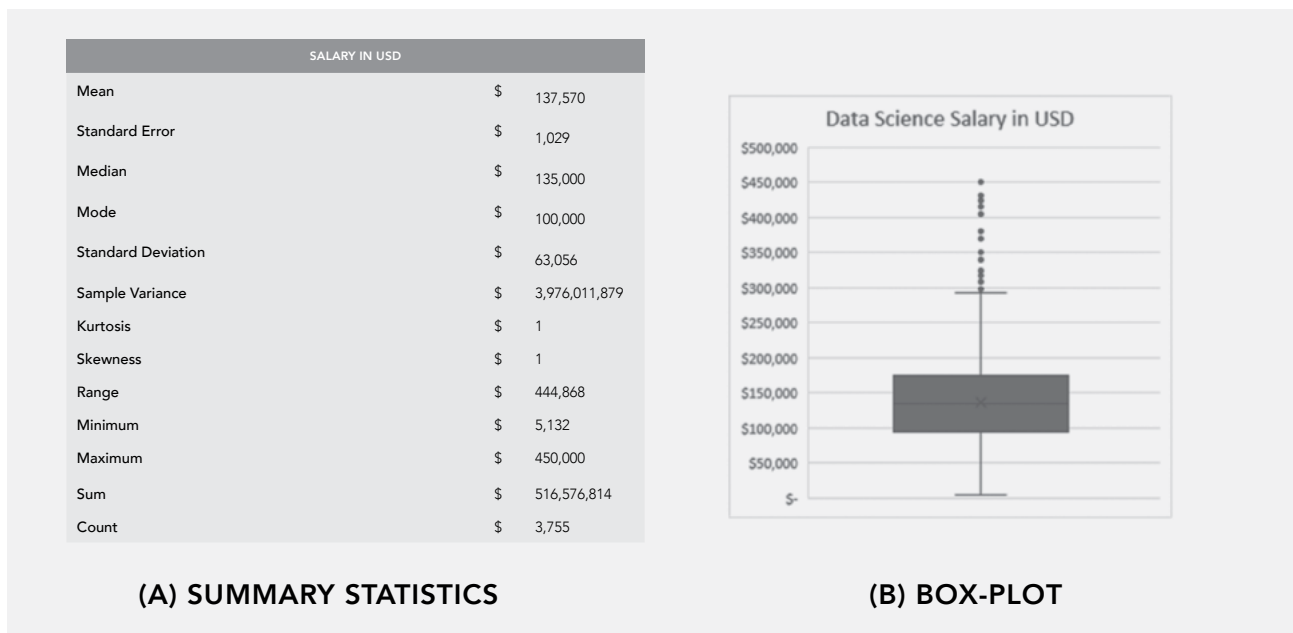
To evaluate the statistical significance of the relationships revealed during the exploratory analysis, diagnostic analysis was performed using linear regression and ANOVA tests.

Figure 2: Regression Analysis Between Salary and Experience
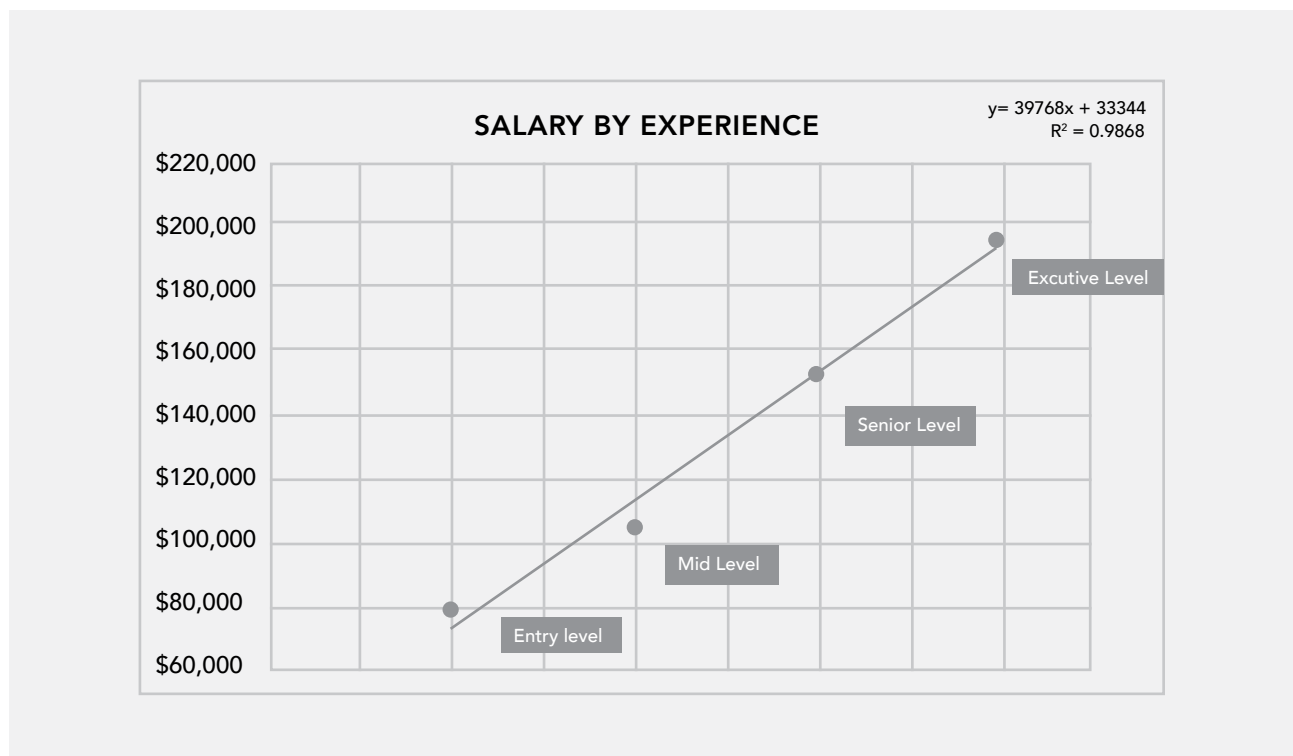
The regression analysis reveals a robust positive relationship between experience and salary. As experience increases, the salary also goes up because each additional level of experience significantly boosts the average salary by $39,768. This connection explains a vast portion of variance with a considerably high R-squared of 0.987. This number implies that the relationship accounts for almost 99% of the variability in salary, making the effect of experience highly practical. The p-value is 0.0066, which is less than the alpha level of 0.05, proving that the results are not due to chance. In conclusion, the analysis indicates that the IT, data scientist's salary is highly influenced by experience, which was precisely ascertained by the exploratory analysis. This finding aligns with other research indicating that experience significantly influences salary in the IT, data science field (Mogan, 2022; Glassdoor, 2023).

Figure 3: Regression Analysis Output -- Salary vs Experience

REGRESSION STATISTICS	
Multiple R	0.993375918
R Square	0.986795715
Adjusted R Squa	0.980193573
Standard Error	7273.552005
Observations	4

ANOVA					
	df	SS	MS	F	Significance F
Regression	1	7907432087	7907432087	149.466	0.006624082
Residual	2	105809117.5	52904558.77		
Total	3	8013241204			

	Coefficients	Standard Error	t Stat	P-Value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	33343.78903	8908.245515	3.743025377	0.064543	-4985.297854	71672.87591	-4985.297854	71672.87591
Experience	39767.90688	3252.831344	12.22562828	0.006624	25772.10321	53763.71054	25772.10321	53763.71054

RESIDUAL OUTPUT			
Observation		Residuals	Standard Residuals
1	73111.6959	5434.588471	0.915094077
2	112879.6028	-8353.66365	-1.406617662
3	152647.5097	403.5618861	0.067953092
4	192415.4165	2515.513292	0.423570492

PROBABILITY OUTPUT	
Percentile	Average of Salary in USD
12.5	$ 78,546
37.5	$ 104,526
62.5	$ 153,051
87.5	$ 194,931

In summary, experience emerged as a significant determinant of salary in the IT, data science field. The regression analysis shows a robust positive relationship between experience and salary, with an R-squared value of 0.987, indicating that nearly 99% of the salary variability can be explained by experience. Therefore, it could be inferred that the IT data scientists' earnings increase considerably once they accumulate more experience irrespective of their employment status.

Job Roles

Figure 4 reveals that senior-level professionals dominate the IT, data science field, suggesting a preference for experienced IT, data scientists. Entry-level and executive roles are smaller. This indicates that experience level plays a significant role in the IT, data science field (Morgan, 2022) and has the potential for higher-level salaries.

Figure 4: Experience Level Distribution

EXPERIENCE LEVEL
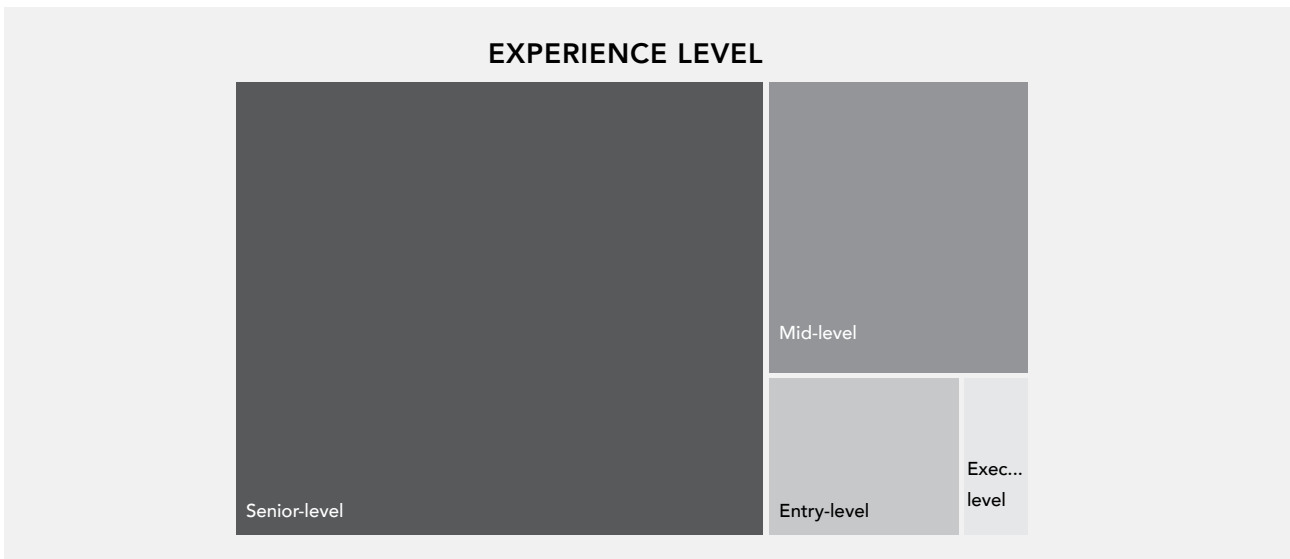
Figure 5 illustrates that in the IT, data science field, the highest salaries are held by the positions of executives together with Artificial Intelligence (AI) and Machine Learning Engineer roles. The persistence of this trend confirms the high application value of experience and narrowly specialised skills in this area. As for the average salary of first-year workers, it is lower, which is quite typical for most industries, where beginners receive less salary compared to more experienced professionals.

Figure 5. Average Salary by Job Categories and Experience.

SALARY BY JOB CATEGORIES & EXPERIENCE
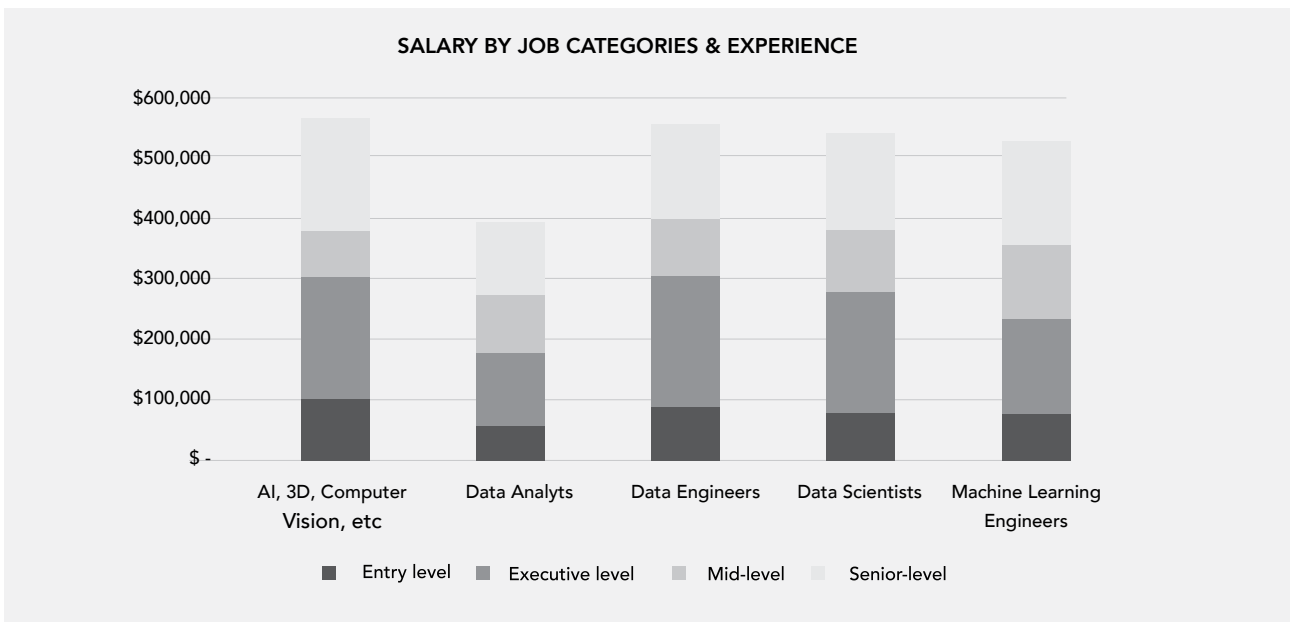
Figure 6 illustrates the distribution of the top ten IT, data science field roles segmented by work arrangement: remote working, on-site, and hybrid. For remote working positions, the role of Data Engineer appears to be the most common, with Data Scientist closely following. On the other end of the spectrum the role with the least remote working representation is Research Engineer, being particularly prevalent in on-site working arrangements.

Figure 6. Top Ten Data Science Jobs

TOP 10 DATA SCIENCE JOBS

Legend: Remote, On-site, Hybrid
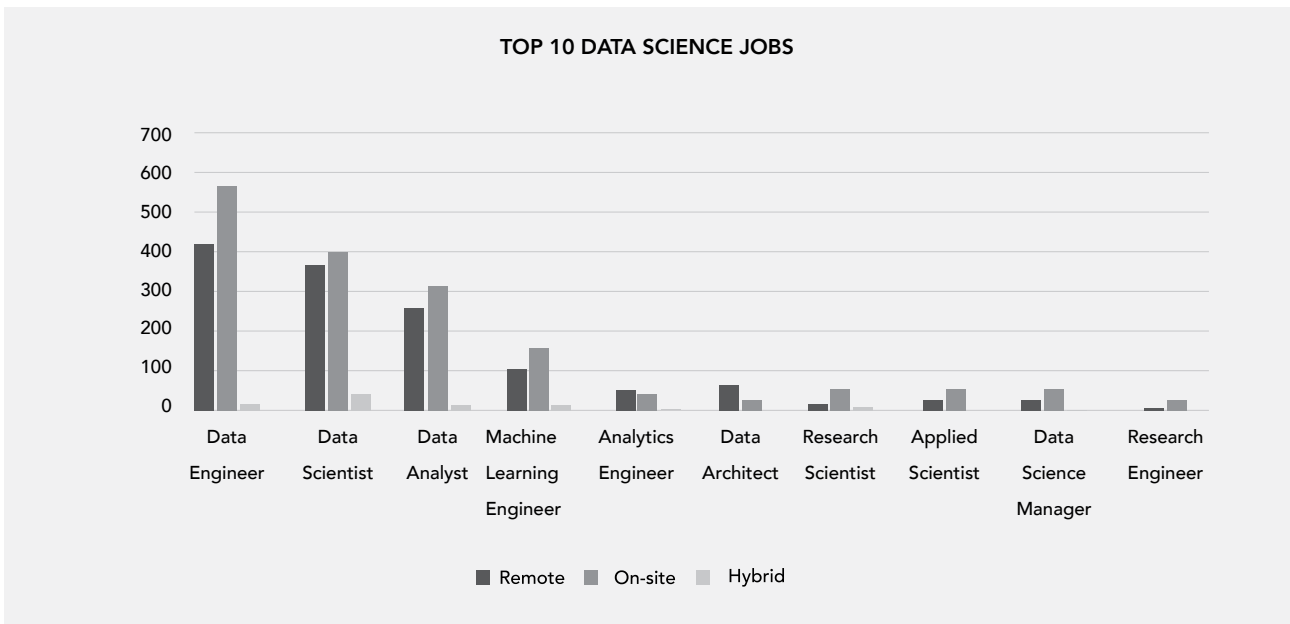
Figure 7 displays the top ten IT, data science field job salaries, categorised by work arrangements. Applied Scientist, Data Science Manager, and Principal Data Scientist roles earn higher salaries for being on-site than for remote working positions. Thus, it can be suggested that the leadership and high-responsibility roles receive a premium when being in-the-office. As such, the presence of highly paid on-site jobs may mean that some positions require being physically present. Among remote positions, the highest salaries are for Data Analytics Lead with the following role with the highest salary for remote job is Machine Learning Software Engineer.

Figure 7. Top Ten Data Science Job Salaries

TOP 10 DATA SCIENCE JOB SALARIES

Legend: Hybrid, On-site, Remote
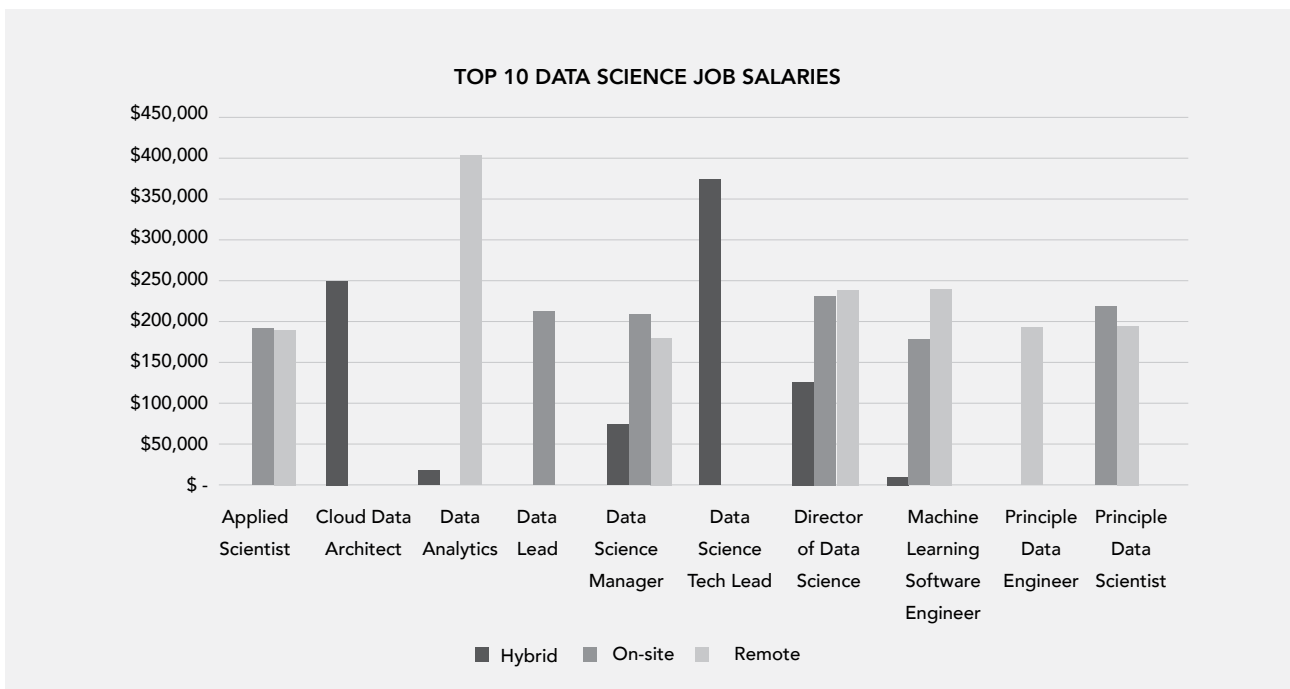
In general, the dataset indicates that the Senior Level Professionals dominate the IT, data science field and most of them are paid better than their entry level or executive role counterparts. Among remote workers, Data Engineers and Data Scientists are some of the most commonly sought-after positions. Only very few remote workers opt for positions like Data Science Manager or Research Engineer, which are normally not remote workers, even though such positions come with lower pay.

Work Arrangements

Figure 8(a) indicates that medium-sized companies make up to 84% of the workforce of IT data science specialists while 12% work in large companies and as little as 4% work in small companies. Smaller companies are less promising as they lack resources to carry out payrolls to data scientists who may have more limited job roles (Dragova, 2020).

According to Figure 8(b), a traditional on-site job is slightly preferable for the representatives of the three job roles studied, with 51% of professionals working in this mode. Remote working implying flexibility accounts for 44% due to the availability of remote working tools and technology and the emergence of the COVID-19 pandemic. Hybrid work arrangements are less common at 5%. From 2018 to 2021, fully remote workers increased fourfold, from 6% to 26.7%. In 2023, 27% of United States workers worked remotely, signalling a significant trend (Flynn, 2023).

Figure 8. Work Types and Company Size Proportion

(A) COMPANY SIZE PROPORTION   (B) WORK TYPES PROPORTION
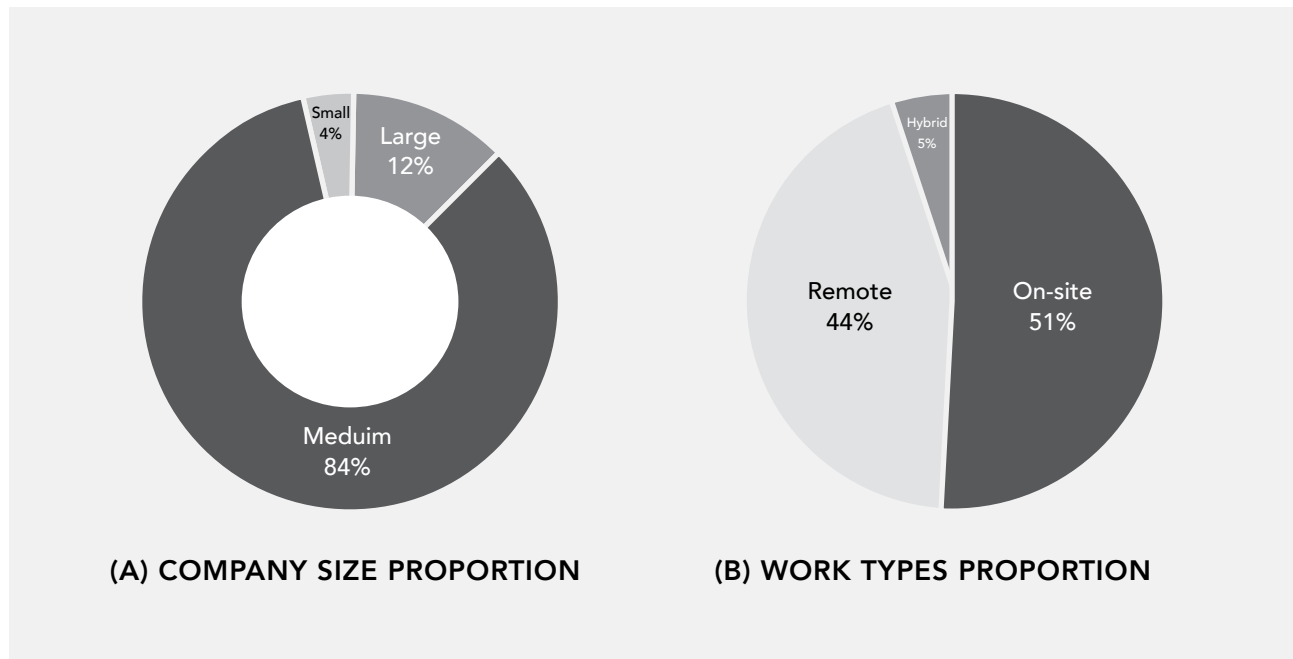
According to Figure 9 the IT, data science field average salary trends between the years 2020-2023 as seen within this analysis show that the average salaries at both on-site and remote working have increased significantly which means they were converging by around $150,000 in 2023. However, remote working salaries exceeded on-site salaries at the beginning of 2022 probably because of changing dynamics in remote working environments and competition between the remote working IT, data science field jobs (Burtch Works, 2022). As remote working employment opportunities grew more popular, corporations scrambled over themselves trying to lure the most skilled workers using various means such as paying higher salaries to telecommuters for such positions. As a result of these practices, remote positions became better paid relative to on-site roles, surpassing them in certain cases due to fierce competition and the dimensions of remote employment flexibility.

Figure 9. Data Science Salary Trend
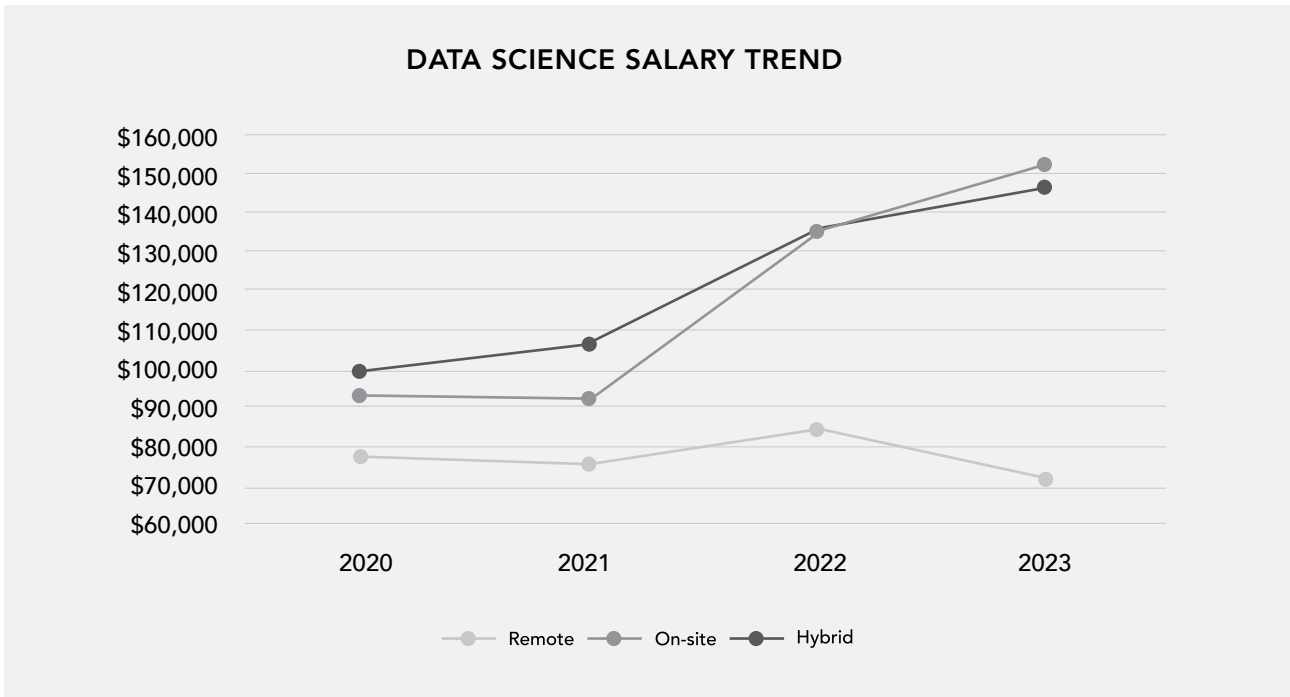
Based on Figure 10, the highest average salaries, especially for the remote arrangement, are paid in medium companies. Surprisingly, large companies can only afford to pay higher salaries for the on-site arrangement. At the same time, it might be suggested that medium companies have the potential for higher average salaries. The results for the small companies are quite expected as they cannot afford to pay high average salaries.

Figure 10. Average Salary by Company Size and Remote Types
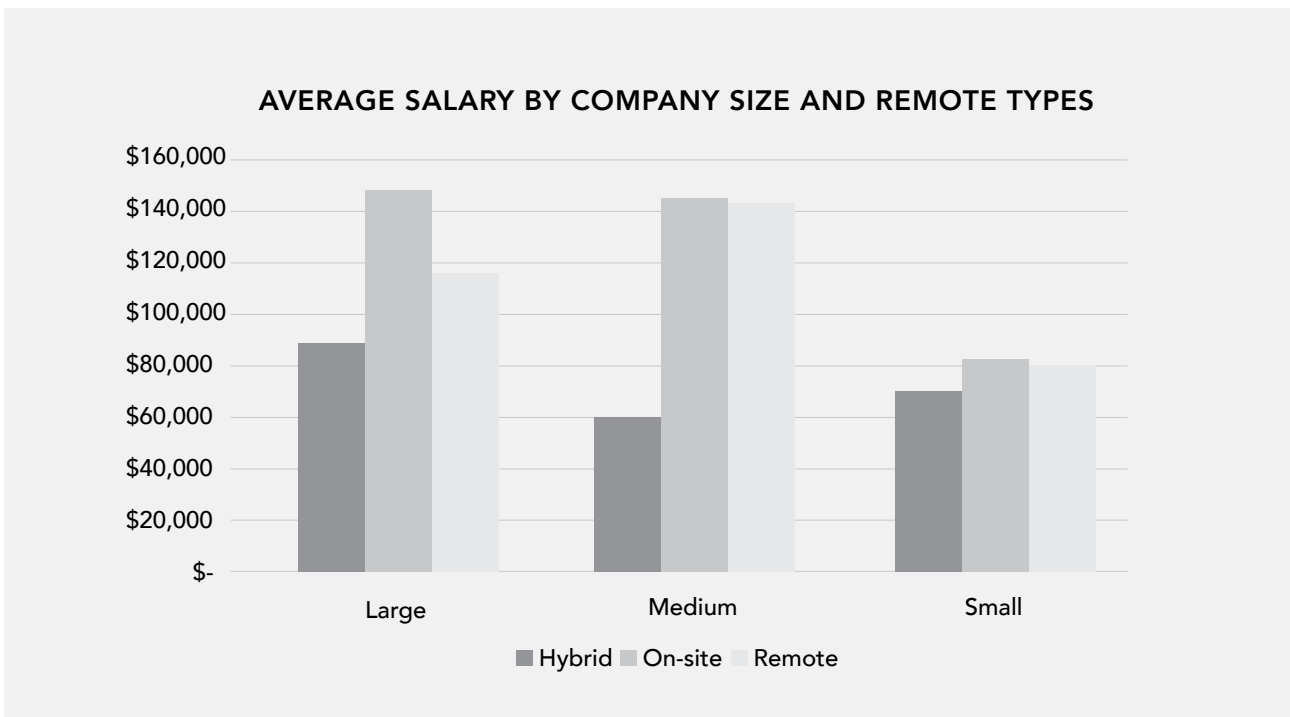
The ANOVA test results from Figure 11 indicate that there is no statistically significant difference in salaries across small, medium, and large companies, as the p-value is 1, which exceeds the common significance levels (0.05, 0.01). Therefore, we fail to reject the null hypothesis that there is no variation in salary due to company size.

Figure 11. ANOVA Single Factor -- Salary vs Company Size

SUMMARY				
Groups	Count	Sum	Average	Variance
Small	3755	516576814	137570.3899	3976011879
Medium	3755	516576814	137570.3899	3976011879
Total	3755	516576814	137570.3899	3976011879

ANOVA						
Source of Variation	SS	df	MS	F	P-Value	F crit
Between Groups	0.8828125	2	0.44140625	1.11017E-10	1	2.99652929
Within Groups	4.47778E+13	11262	3976011879			
Total	4.47778E+13	11264				

From Figure 12, it is evident that there is a statistically significant difference in salaries based on work type. A p-value of 0 is less than the commonly applied threshold of 0.05, allowing to reject the null hypothesis that the groups do not experience differences in their average salaries. The F-value is also much greater than the F-crit value, indicating that the work arrangement has a significant effect on salaries.

Figure 12. ANOVA Single Factor -- Salary vs Work Type

SUMMARY				
Groups	Count	Sum	Average	Variance
Remote	1643	224239027	136481.4528	4016201478
Combined	189	14817730	78400.68783	3760894653
On-site	1923	277520057	144316.2023	3576036515

ANOVA						
Source of Variation	SS	df	MS	F	P-Value	F crit
Between Groups	7.51155E+11	2	3.75578E+11	99.41362049	0	2.998125448
Within Groups	1.41748E+13	3752	3777929959			
Total	1.49259E+13	3754				

To summarise, the data shows the salaries of fully remote workers who put in over 80% of their hours remotely. The proportion is on the rise and will catch up with those located on-site at $150,000 per year by 2023. The trend underlines an increasing recognition and regard for telecommuting within the IT, data science field. Despite recent increases in working-from-home opportunities, most data professionals still have little preference for virtual work setups and continue to gravitate towards conventional office-based jobs if given such opportunities (Deloitte, 2021). Nevertheless, many individuals dealing in data have embraced flexibility associated with telecommuting hence bringing about a massive expansion in offsite-based employment and partially shared employment schemes.

What are the strategic adjustments companies should make in order to conform to the changing norms of remote working and salary structures?

We will suggest the following strategic changes after analysing the results from research question one to help companies embrace the changing remote work and wage dynamics in data science better.

Flexible Salary Structures

Companies ought to develop salary structures, which are adjustable depending on the local cost of living and factor in the

dynamics of remote working. In this way, the worker is given fair pay no matter where they operate. This approach ensures that workers are fairly compensated regardless of their work location (Deloitte, 2021).

Experience-Based Salary

To attract and retain talent in the IT data science sector, employers need to emphasise experience when structuring salaries rather than focusing more on educational qualifications. This would also attract and retain top performers in the industry (PWC, 2021; Morgan, 2022).

Remote Working Policies

A thorough remote working policy should be created by companies as a way of promoting professional development among workers who are scattered in different locations. These policies should be specific about what constitutes remote working, provide for self-advancement and provide for equal pay among workers (Deloitte, 2021).

Geographical Considerations

Considering that remote working provides access to global talent pools, companies should consider local salary scales and economic conditions in developing their salary structures (Brinatti et al., 2023; PWC, 2021).

CONCLUSION AND RECOMMENDATIONS

The results of this investigation leave no route for interpretation: experience is a much more important salary determinant than both a company size and mode of working. This observation is critical for the IT, data science field workers striving to receive the highest salaries they can: relying on this concept, they should focus on accumulating more relevant experience and skillsets.

How do different job factors affect remote working salaries in the IT, data science field?

In the field of IT data science, salaries are driven up by experience whereby the correlation between salary and years is quite positive to the extent that it accounts for nearly 99% variability in the former. The highest salaries within this field are executives and AI specialists. Most of them belong to senior levels. Experience is particularly significant for all professionals on the one hand while also considerably affecting those at an entry level on the other hand. Salaries for on-site and remote working workers experienced substantial growth from 2022 to 2023, reaching a similar level of around $150,000. In certain instances, remote working salaries have surpassed on-site salaries due to competitive factors. Medium-sized companies typically provide higher average salaries for remote working, whereas large companies tend to prioritise on-site working environments, which are linked to more lucrative salaries. In contrast, small companies struggle to provide competitive salaries.

What are the strategic adjustments companies should make to conform to the changing norms of remote working and salary structures?

To keep up with the constant changes in remote working job patterns and salary structures, companies should work on creating flexible salary packages that vary dependent on local costs of living as well as remote working requirements so that everyone gets paid fairly, regardless of where they are located. It is important to design salary structures with more weight on skills which come through practising than having higher qualification for better results in the job market. This includes creating detailed policies around working remotely for career growth opportunities, defining what qualifies working off-site; alongside such opportunities allowing for their personal growth; all these measures ensure salary equity. Moreover, as part of salary structuring, companies need to consider what is happening within their locations regarding salary structures and economic climates to tap into global human resources affordably.

Our findings on the impact of remote working in the IT, data science field revealed that while remote work in data science may result in higher compensation and greater flexibility, there is very little difference between the salary of remote working and non-remote working IT data scientists. It is important for professionals to obtain skills that are in demand and choose where to work remotely based on the possibility of earning more income. To be fair and attract a diverse talent pool companies need to match salaries with experience and prevailing local salary trends. This can be achieved through startup companies hiring the best professionals inexpensively. In addition, the IT sector would improve competitiveness by developing flexible remote working policies, engaging in partnerships with educational establishments and advising students concerning salary negotiation and career planning. It is possible that open salary policies together with telecommuting improve organisational commitment and promote knowledge sharing. In conclusion, even though the current research offers important findings concerning the salary structure within the IT sector of the data science field, the dynamic characters of employment and technology are likely to affect this specification further. As such, it could be beneficial for additional investigations analysing alterations to be conducted later on, particularly to explore how these changes impact key areas within the IT sector, such as data science and remote working dynamics, as well as the evolving trends in salaries across these fields.

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THE IMPACT OF REMOTE WORKING ON INFORMATION TECHNOLOGY WORKERS' PSYCHOLOGICAL WELLBEING

Jayani Dissanayake, Olufemi Omisakin and Indrapriya Kularatne

OTAGO POLYTECHNIC AUCKLAND INTERNATIONAL CAMPUS

ABSTRACT

This study is based on a systemic review of related literature on how remote working impacts Information Technology workers' psychological wellbeing. Remote working is a unique working environment that limits social interactions and face-to-face communication. Therefore, there is a concern that it has the potential to create adverse psychological effects such as isolation and lack of belongingness. Conversely, it might also positively facilitate psychological wellbeing because of increased flexibility and more time to invest in one's personal life. Significantly, due to the COVID-19 pandemic, the prevalence of remote working has increased, and for Information Technology workers this has become a key component. Their jobs can be efficiently conducted in remote working settings. Although numerous studies focused on the general wellbeing of remote workers, the psychological wellbeing of remotely working Information Technology workers has been under-investigated. Examining this area would help recognise unique and challenging areas that Information Technology workers encounter in remote working environments and take the required measurements to address them. The objective of this study is to identify how remote working affects the Information Technology worker's psychological wellbeing under remote working conditions. The study was conducted based on systematic analysis of 30 peer-reviewed journal articles published in reputed journals.

The critical evaluation of the systematic literature review found that remote working resulted in feeling left out, overworking, and lacking work-life boundaries, which negatively impacted Information Technology remote workers' psychological wellbeing. Also, this study uncovered that improved family relationships, less commute stress, and more time for leisure activities helped improve psychological wellbeing and happiness. These findings will contribute to understanding the nature of Information Technology remote workers' psychological wellbeing and how psychological wellbeing practices of organisations can be embedded.

Keywords: Remote work, Psychological wellbeing, Information Technology workers

INTRODUCTION

The concept of remote working has gained immense popularity during the last few years. The practice of remote working is defined as "the work performed through the use of Information Communication Technology (ICT) such as smartphones, tablets, laptops, and desktop computers) outside the employer's premises" (International Labour Organisation, 2020, p. 6). Although there were no unanimously agreed definitions of remote working, most studies agreed that remote working is working anywhere without going to the office and being able to carry out work with the assistance of digital technology (Kim et al., 2023; Lunde et al., 2022). Remote working was a new mode of working for many employees worldwide until the COVID-19 lockdowns, except in industries heavily dependent on technology, such as Information Technology (IT) (Yang et al., 2022). Also, it was primarily common among top-level managers, high-income earners, and freelancers (Mayer & Boston, 2022).

Working from home during the COVID-19 lockdowns accelerated the embracing of remote working (Thomas et al., 2021). Many employees had to shift work into the virtual environment to sustain the business during the COVID-19 social isolation (Charalampous et al., 2022). In New Zealand (NZ), before COVID-19, 16% of the workforce reported engaging in remote working (Green et al., 2020), and it increased to 42% during alert levels three and four in 2020 (Statistics New Zealand, 2020). Remote working during COVID-19 facilitated the development of technology that enabled remote working efficiency and understanding the benefits and challenges of remote working.

Many studies have focused on multiple facets of remote working and employee wellbeing. However, there is a knowledge gap in specific aspects of wellbeing that are influenced by remote working arrangements. While some studies have focused on the impact of remote working on factors such as job performance (Alfaleh et al., 2021; Perry et al., 2022; Rodríguez-Modroño et al., 2021), productivity (Alfaleh et al., 2021; Bhattacharya & Mittal, 2020) and overall wellbeing (Ferrara et al., 2022; Vayre et al., 2022) there is limited research on the psychological dimension of wellbeing. Moreover, most existing studies have focused on temporary remote working that occurred during the COVID-19 pandemic (George et al., 2022; Prasad et al., 2020; Sousa-Uva et al., 2021) with little attention given to remote working under a voluntary environment. Another gap in the literature is that studies based on remote working have mainly focused on industries such as education, banking, and ICT, which includes a broader sector that combines all manufacturing and services related to computer and digital technology (Li et al., 2019). However, IT workers and their psychological wellbeing have not been extensively explored, although in NZ most remote workers belong to the IT industry (Mayer & Boston, 2022). Therefore, this study is focused on addressing how remote working impacts IT workers' psychological wellbeing by examining articles related to remote working, the IT industry and psychological wellbeing.

In NZ, nearly 114,000 workers belong to the IT industry, 76% of whom engage in the hybrid working approach, and 12% work entirely remotely (Absolute IT, 2022). Information technology roles such as software development, project management and web development can be efficiently conducted outside the conventional office premises with the help of digital technology (Ng et al., 2022). Furthermore, IT companies that did not offer remote working prior to the COVID-19 pandemic became more flexible during and after the COVID-19 pandemic in offering remote working options (Nair, 2023). This was due to understanding that the work could be carried out productively without compromising the productivity of the work (Nair, 2023).

Remote working is a unique working environment that is different from a traditional office setting. It limits face-to-face interactions, scheduled working hours, and clear physical separation between home and work (Ferrara et al., 2022). Therefore, remote working has the potential to create loneliness, poor work-life balance, and a lack of belonging among work colleagues (Chan et al., 2022). As a result, it might negatively affect psychological wellbeing, defined as "a state of wellbeing in which an individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and is able to make a contribution to his or her community" (World Health Organisation, 2023, para. 3). On the other hand, with less travel time, remote working also provides more relaxing time and time to spend with the family and a personalised workspace to work, which might positively lead to psychological wellbeing (Kortsch et al., 2022).

Psychological wellbeing is a vital part of employee and organisational performance. Many studies have proven that higher psychological wellbeing leads to less turnover, absenteeism, and increased job satisfaction (Grant et al., 2013; Vaidya et al., 2023). As remote working is prevalent in the IT industry, workers have a high potential to experience psychological wellbeing effects (Prasad et al., 2020). Many studies have proven that individuals with sound mental or psychological wellbeing perform better concerning resilience, physical health, work, and social life (Islam et al., 2023; Miglioretti et al., 2021). In NZ, the number of people who experience psychological distress has been increasing (Wilson, 2020), and one in five adults are undergoing mental wellbeing issues, such as depression or anxiety (Mental Health Foundation New Zealand (NZ), 2023). According to Prasad et al. (2020), a worker's mental wellbeing impacts their job performance, regardless of occupation type and a lower level of mental wellbeing results in absenteeism, high turnover rates and presenteeism. Therefore, this systematic literature review focuses on how remote working impacts the psychological wellbeing of IT workers.

METHODOLOGY

Qualitative research techniques were adapted to conduct the systematic literature review. According to Mengist et al., (2020), a systematic literature review is a process that allows the collection of relevant evidence on the given topic that fits the pre-specified eligibility criteria and has an answer to the formulated research questions. This methodology was chosen for this study as it aims to examine articles related to IT workers remote working and psychological wellbeing to identify, appraise, and synthesise research evidence. Articles were gathered through reputable databases such as Emerald, PubMed, Frontier, Elsevier, Robertson Library and Google Scholar (Indeed, 2024). These databases were selected for their broad range of academic literature and credibility, as they provide access to high-impact, peer-reviewed journals (Indeed, 2024). Search engines used keywords including psychological wellbeing, IT industry, remote work, working from home, and telework to find relevant literature. In the initial stage, 63 articles were found, and it was narrowed down to 30 articles based on reviewing abstract and full-text screening. Thirty journal articles from 2019-2023 were analysed, and information from grey literature, such as government statistics and educational institutes, was also used to obtain comprehensive insight into the discussion. Findings were synthesised according to the common trends and themes related to the psychological wellbeing impacts of remotely working IT workers. Figure 1 shows the above-explained process for the systematic literature review for this study. The sequence depicted in Figure 1 is adapted from the journal article by Sehularo et al. (2021), which outlines the steps of a systematic literature review. However, the specific tasks for each step have been adjusted, and certain steps outlined in the original article have been removed to align with the requirements of this study.

Figure 1. Steps Followed for the Systematic Literature Review
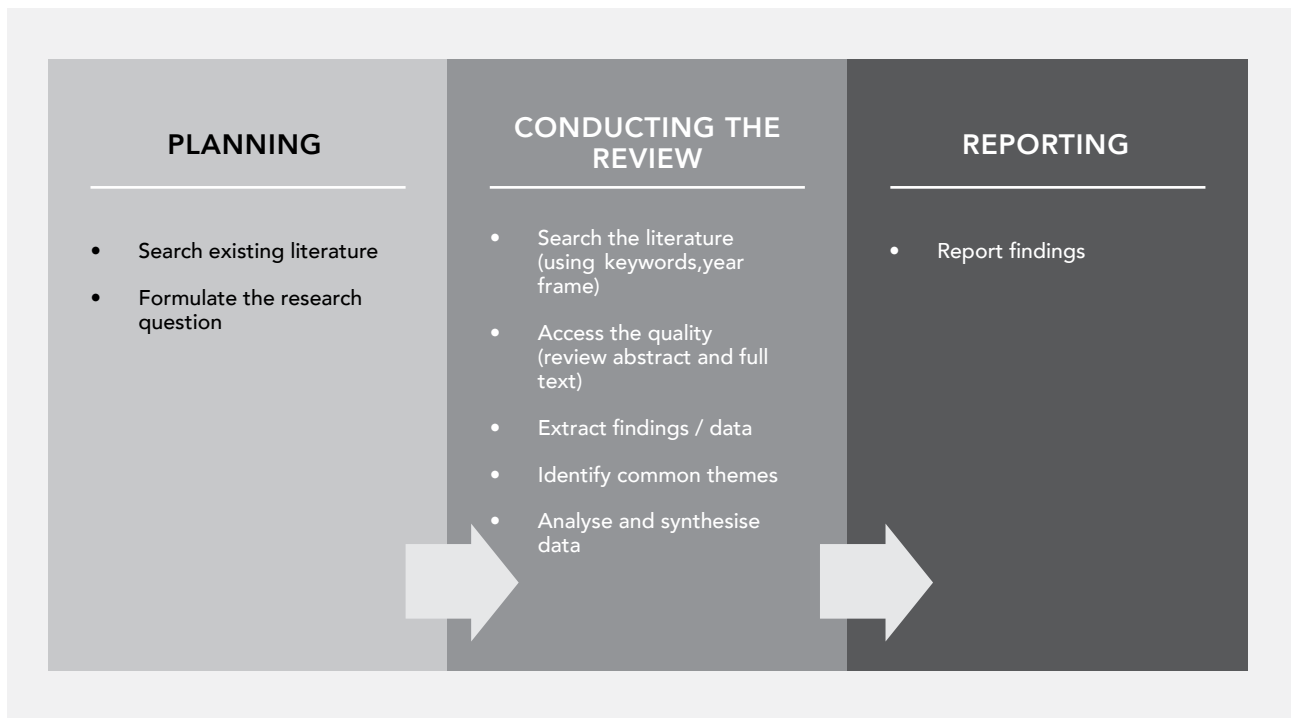
FINDINGS AND DISCUSSION

Rise of Remote Working and the IT Industry

The concept of remote working was first introduced in the 1970s (Arbelaez-Velasquez et al., 2022). It was initiated as a sustainable solution to save fuel consumption from travelling, and soon after, the feasibility of remote working was tested in the United States of America (USA) for government and private projects (Kim et al., 2023). However, it was not a well-known concept for the business sector worldwide until remote working during the COVID-19 pandemic. The COVID-19 pandemic helped to develop the infrastructure related to remote working, which led to understanding its viability instead of visiting office premises, especially for IT workers (Prasad & Satyaprasad, 2023). Before the COVID-19 pandemic, although remote working was already a feasible option for IT workers, it was not widespread due to the unfamiliarity of the concept (Nair, 2023).

The IT industry was less affected by the adaptation to working remotely during the COVID-19 pandemic (Mayer & Boston, 2022). According to Ng et al., (2022), the productivity and performance of the IT sector were not disrupted as it was already rooted in technology, Cloud computing, and virtual communication platforms (Karthikeyan Arasu et al., 2019). Also, the COVID-19 pandemic enhanced demand for online trends such as electronic-commerce (e-commerce), telehealth, and online education, which increased the demand for software development (Urien, 2023). As a result, IT was one of the most common industries that embraced remote working after the COVID-19 pandemic, as its high dependency on technology made it easier to reach effective performance without working in an office (Urien, 2023).

In the initial stage of the systematic literature review, VOSViewer software was employed to identify common themes that appeared in the literature and their combinations. Figure 2 the network diagram shows the most used themes associated with remote working IT workers' psychological wellbeing and their connection with each other.

Figure 2.Initial Network Visualisation (Author's Own)
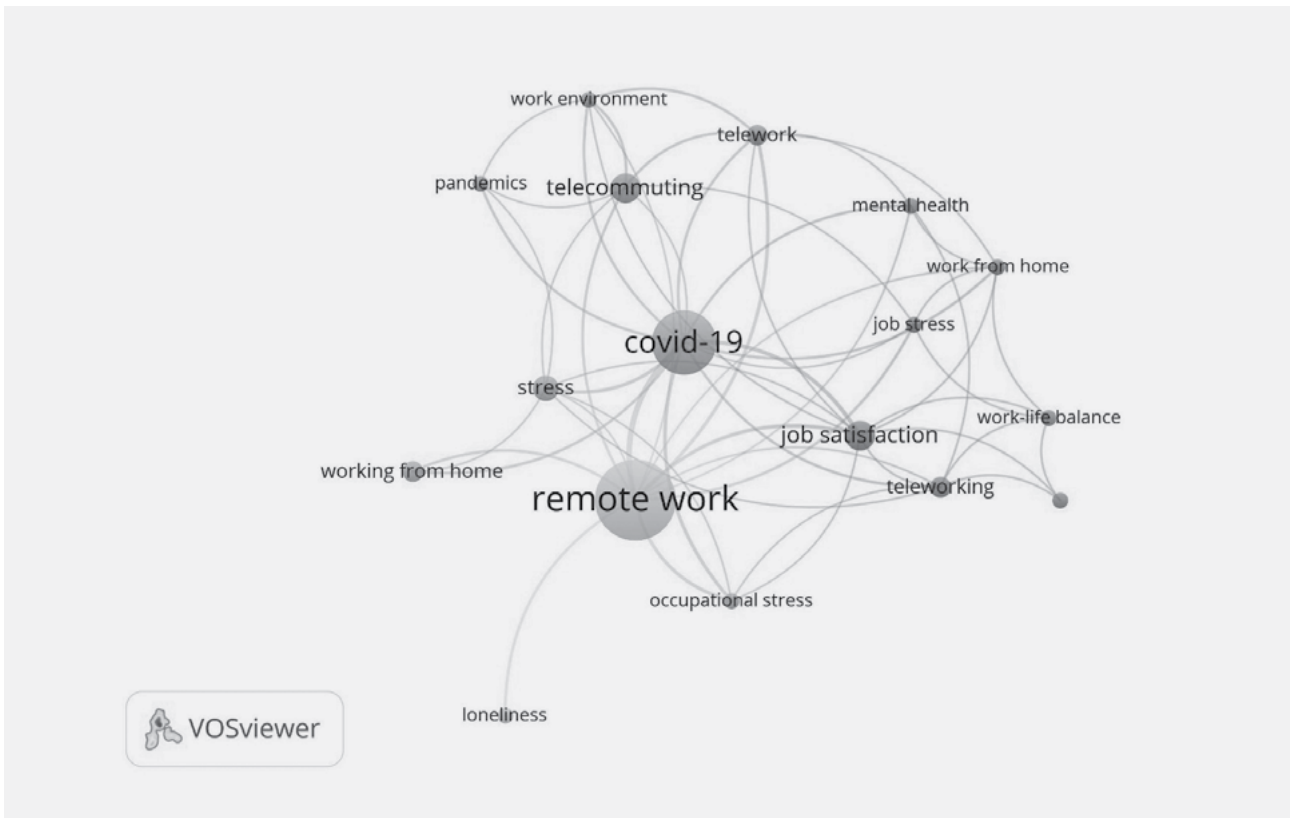
As shown in Figure 2, remote working is associated with psychological factors such as work stress, mental health, job satisfaction, social support, and work-life balance. However, it indicates that remote working is strongly, but distantly, related to themes such as loneliness and anxiety, which are adverse psychological outcomes. Also, stress is the key term most closely connected in many articles. Figure 3 also illustrates the density of each theme and how strongly they have been identified in the articles. Stress, the COVID-19 pandemic, and telework (synonymously used words for remote working) have appeared as the most common themes. It shows that articles related to remote working discuss the COVID-19 pandemic as a main theme.

Figure 3. Density Visualisation of the Key Themes Identified in the Literature (Author's Own)
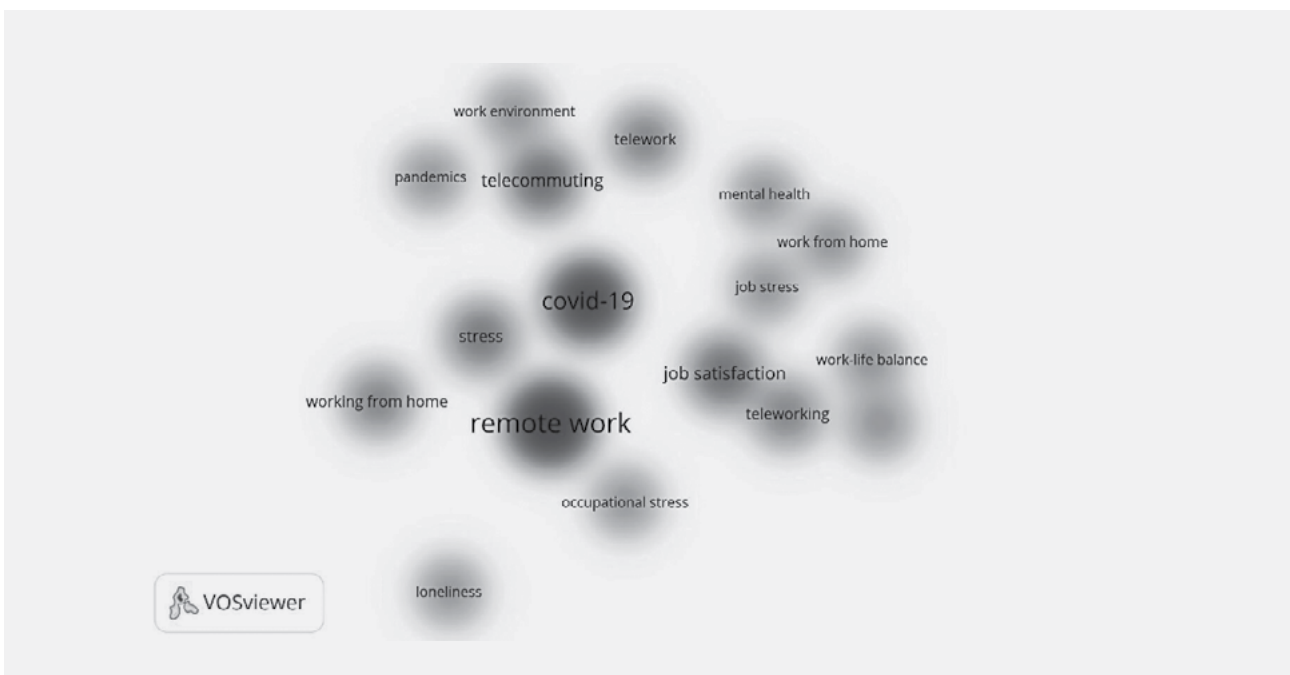
Work-life Balance

Work-life balance refers to prioritising personal and professional activities (Shirmohammadi et al., 2022). Studies have shown that workers who spend quality time on personal activities and job responsibilities are more likely to be satisfied with their jobs and feel valued by their team members (Alfaleh et al., 2021; Mohammed et al., 2022). However, findings related to remote work in the IT industry and psychological wellbeing are inconsistent. Charalampous et al. (2022) mentioned that time saved from travelling helped IT workers spend more time with their families, which improved relationships. Kangas et al., (2023) stated that spending more time with their children and more involved in their lives and not compromising family events due to office work was a significant benefit resulting from remote working. Alfaleh et al. (2021) found that remote working allowed workers to spend their time on hobbies, resulting in more joy in their lives that they could not experience working full time in office premises. This evidenced that more time spent remote working assisted in improving family relationships and spending time on personal hobbies that increased happiness and psychological wellbeing.

Similarly, some studies focused on comparing remote working in the pre-and post-COVID-19 pandemic era emphasised the difference in how IT workers' psychological wellbeing was affected. Prasad et al. (2023) mentioned that workers experienced a significant difference between the pre-COVID-19 pandemic, where workers attended the office five times a week and worked remotely during the COVID-19 pandemic. Working remotely made them realise that having more time for themselves and family improved their quality of life (Charalampous et al., 2022). In addition, Lange & Kayser (2022) stated that the COVID-19 pandemic made them realise IT work can be performed effectively without compromising the quality of the work while having the opportunity to maintain a better work-life balance.

Furthermore, Charalampous et al., (2022) noted that remote working during the COVID-19 pandemic allowed them not to apply for sick leave for minor ailments and allowed them more time to recover at home, which positively impacted their overall psychological wellbeing. These studies show that remote working during the COVID-19 pandemic has contributed to how IT workers understand remote working has improved their work-life balance and psychological wellbeing.

However, some studies found a negative relationship between spending more time at home and psychological wellbeing. According to Nair (2023) and Karthikeyan Arasu et al. (2019) some IT workers experienced exhaustion due to a lack of separation between work and family life. Ng et al. (2022) mentioned that remote workers had to engage in multiple roles during office hours, including meal preparation and looking after children, which delayed their work output normally achieved in the office environment. Some IT workers preferred the physical separation between home and office for greater focus and productivity (Charalampous et al., 2022). Especially, females who worked remotely during the COVID-19 pandemic who had to play multiple roles, leading to overwork, emotional exhaustion, and stress (Mitravinda et al., 2023). Therefore, a lack of clear separation between work and family life might negatively affect psychological wellbeing and lead to burnout and poor work-life balance.

Autonomy

In the workplace, autonomy refers to having freedom and ownership to make their own decisions (Ferrara et al., 2022). According to Ryff's model of psychological wellbeing, autonomy is one part of wellbeing that allows individuals to control their lives and feel satisfaction (Ryff, 2014). Lack of autonomy leads to poor motivation and low self-esteem, negative indicators of psychological wellbeing (Ryff, 2014). According to Karthikeyan Arasu et al. (2019), remote workers required less supervision than the workers in an office, which made them feel more autonomous compared to working in an office. Similarly, Consiglio et al. (2023) mentioned that micromanagement was experienced less by those remote working, and IT workers felt the freedom to make their own decisions. Also, according to a quantitative study by Prasad et al., (2020) which found that IT remote workers felt more independence because of a personalised work environment. Therefore, the lack of supervision and customised workspace of remote working enhanced the level of autonomy of IT workers and positively impacted their psychological wellbeing.

Some studies mentioned that remote workers commonly experience a feeling of self-control. Neidlinger et al. (2023) mentioned that remote working created more trust as they have more time to finish work saved from commuting. Similarly, Kangas et al. (2023) stated that as remote working allowed more time to complete day-to-day tasks with ease due to more time and flexibility, it enhances control over job responsibilities. Likewise, Mitravinda et al. (2023) mentioned that remote working IT workers were more fulfilled by their job responsibilities, with the autonomy they experienced in the remote working environment. These findings show that autonomy created in a remote working environment positively influences the feeling of freedom over life, which impacts IT workers' psychological wellbeing.

Social Interactions

Social interaction plays a vital role in psychological wellbeing (Alfaleh et al., 2021). According to studies, interactions with family, friends, and co-workers create a sense of belonging and support and being less lonely (Vaidya et al., 2023; White & Maniam, 2020). Findings related to how remote working affects social interactions and psychological wellbeing vary.

Karunarathne (2021) mentioned that remote working creates a physical distance between co-workers, resulting in a feeling of not belonging and exclusion from the team. Especially as remote working has been prevalent in the IT industry from the beginning, and workers initiate their jobs in remote working environments with minimum chances to meet each other and build close relationships (Karthikeyan Arasu et al., 2019). Similarly, Prasad et al. (2023) mentioned that the absence of face-to-face interactions hinder the spontaneous conversations common in an office setting, which help people better understand each other through facial expressions. Therefore, remote working might lead to a lack of effective relationship-building with co-workers compared to the office environment, which impacts the quality of psychological wellbeing.

Conversely, some studies emphasised that although remote working is less corroborative in creating close relationships with coworkers, it supports social interactions with family and friends. According to Charalampous et al. (2022), spending increased time with the family has strengthened the quality of the relationships. Also, Kangas et al, (2023) stated that remote working IT professionals had more time to provide support during difficult periods for their friends and family, thereby fostering a sense of togetherness in their relationships. Therefore, while remote working is challenging in terms of building strong relationships with co-workers, it is supportive of interactions with family and friends, resulting in psychological wellbeing.

Technological Stress

Technological stress is referred to as the pressure or tension caused by the overuse of work-related technology (Singh et al., 2022). Studies have found that excessive technology causes psychological issues such as burnout, increased fatigue and sleeping difficulties (Grant et al., 2013; Vayre et al., 2022). According to Prasad et al., (2020), technological stress is common among ICT workers as the job depends highly on computer use. Yang et al. (2022) found that remote workers are more significantly affected by technological stress than office workers, largely due to their increased exposure to computer screens. As face-to-face interactions and travelling from work to home are absent in the remote working setting, workers tend to work continually with computer technology, which reduces their psychological wellbeing (Consiglio et al., 2023). As IT remote workers use computer technology in high demand, their potential for adverse psychological wellbeing impacts caused by computer technology, such as stress and psychological exhaustion, are higher than that of office workers.

According to Singh et al., (2022) and Taser et al., (2022), there are multiple types of technological stressors. Table 1 shows common types of stressors that occurred due to the use of high levels of ICT and their definitions of it.

Table 1: Technological Stressors and Definitions

	TYPES OF TECHNOLOGICAL STRESSORS	DEFINITION
1.	Techno-invasion	Techno-invasion is the stressor where an individual feels non-work time to be invaded by work demands.
2.	Techno-overload	Techno-overload occurs when an individual faces excessive use of technology.
3.	Techno-insecurity	The feeling of insecurity that individuals face when they feel that others may know more about new technologies than they do.
4.	Techno-complexity	The stressor is caused by individuals' experience because they need to constantly learn how to use new technological applications and/or find it difficult to understand/disruptive.
5.	Techno-uncertainty	Techno-uncertainty occurs when individuals are unsure about the new technological applications and their use.

Note: Adapted from Singh et al. (2022) https://doi.org/10.1016/j.jbusres.2022.07.002 and Taser et al. (2022) https://doi.org/10.1016/j.chb.2021.107020

According to Table 1, techno-invasion is defined as constantly being exposed to technology (Singh et al.,2022). As remote workers face a lack of physical separation between work and home, they experience being online even after working hours (Harunavamwe & Kanengoni, 2023). Techno-overload refers to working longer and faster with technology, where employees cannot effectively benefit from technology due to exhaustion, and Singh et al. (2022) also stated that in remote working, using multiple platforms to communicate with workers and receiving lots of work demands within a short period leads to work burnout and lack of motivation. According to Taser et al. (2022), techno-overload is also related to physiological effects such as lack of sleep and eye strain, which reduce the overall psychological wellbeing of an individual.

Techno-insecurity is identified as a lack of familiarity with the use of ICT and experiencing anxiety due to that Singh et al. (2022). Consiglio et al. (2023) stated it is common for IT workers to be concerned that they will fall behind in job performance due to a lack of knowledge in the use of required technology. Grant et al., (2013) found that techno-insecurity was the highest-ranked stress among IT workers, and they felt they always needed to upgrade their skills to avoid being replaced

by others. Also, when beginning a new job in a remote working environment, IT workers often experience this type of stress, however eventually, it tends to reduce (Trivedi et al., 2024).

On the other hand, techno-complexity means adapting and learning complex ICT platforms frequently and facing challenges to familiarise themselves with the technology Singh et al. (2022). According to Yang et al. (2022), this type of techno-stressors is common in IT workers, and adapting and educating themselves during a short period is exhausting. Lastly, techno-uncertainty means feeling disturbed and hesitant due to constant upgrades and changes to ICT technology (Trivedi et al., 2024). The IT industry is expected to continuously upgrade and introduce new platforms to improve efficiency (Nair, 2023). With the fast developments, IT employees are required to learn and upskill themselves to achieve efficient performance outcomes at work (Karthikeyan Arasu et al., 2019). However, these job demands might negatively impact IT workers' psychological wellbeing, especially in remote environments, due to the absence of in-person meetings in the office environments.

Gender and Stress in IT Remote Workers

Relationships between gender, stress and remote working in the IT industry were emphasised in a few articles (Prasad et al., 2020; Tapani et al., 2022). Numerous studies conducted during the COVID-19 pandemic found that women were more stressed than males (Charalampous et al., 2022; Harunavamwe & Kanengoni, 2023). Charalampous et al. (2022) mentioned that women were expected to play multiple caregiving roles while working from home, which was a psychologically and physically tiring experience for many of them. Similarly, Trivedi et al. (2024) found that setting boundaries between work and family is more challenging for women, which leads them to overwork. However, after the COVID-19 pandemic lockdown, women preferred hybrid or fully remote working options, as they favoured a better family life balance. Karthikeyan Arasu et al., (2019) mentioned that the hybrid and fully remote working options in the IT industry reduced the gender gap and empowered women to engage in the workforce and be more financially stable. Furthermore, Alfaleh et al., (2021) mentioned that the remote working option supports women in attending to their children's needs while working and being more autonomous. Even for men, the hybrid or fully remote working options were preferable choices when opting for careers in the IT industry as they support family responsibilities and quality of life (Taser et al., 2022). Therefore, although the psychological wellbeing was challenging for women during the COVID-19 pandemic and after the lockdown, remote working supported women to make them more autonomous and empowered.

Psychological Wellbeing Approaches and Remote Working

Two main approaches were identified in the systematic literature when examining the psychological wellbeing of individuals. They are named hedonic and eudaimonic wellbeing. Hedonic wellbeing refers to how an individual feels and evaluates their life on specific experiences or activities in their life (Singh et al., 2022). In hedonic wellbeing, people measure the quality of life through joy, satisfaction, happiness, optimism, and pain avoidance (Ryff, 2014). In respect to remote working, findings related to workers' hedonic wellbeing vary. According to Kortsch et al., (2022), remote working workers avoid commuting which leads to having extra time to engage in daily activities and they feel more relaxed and enhances their hedonic wellbeing. Moreover, spending more time with family and having extra time to engage in hobbies also leads to more life satisfaction (Ng et al., 2022). However, Ferrara et al., (2022) mentioned the blurring of family and work life and overworking reduces hedonic wellbeing. In addition, a lack of social interactions and technological overload results in exhaustion and feeling left out, negatively impacting hedonic wellbeing (Alfaleh et al., 2021). The hedonic wellbeing of remote workers is affected by the lack of social interactions, but they feel happier and fulfilled because of less commuting time and more time to relax.

Eudaimonic wellbeing refers to achieving happiness through self-actualisation and having a purpose in life. Ryff (2014) mentioned that eudaimonic wellbeing includes key aspects such as autonomy, personal growth, and meaning in life. According to Ferrara et al. (2022), remote working develops autonomy as workers experience less supervision. Similarly, Ng et al., (2022) noted that remote working builds confidence by providing a more flexible and personalised work environment, which develops a eudaimonic approach to psychological wellbeing. Moreover, Prasad et al. (2023) found that the personal growth aspect is higher in IT remote workers as they have extra time to engage with family and personal development, which leads to self-improvement and a meaningful life. Related to eudaimonic wellbeing, remote working is supportive of enhancing personal development and improving family relationships, which helps the overall psychological wellbeing of remote workers (Charalampous et al., 2022). Therefore, eudaimonic wellbeing can be achieved in remote working environments through autonomy and control over workers' work schedules, creating a personalised workspace that enhances confidence and comfort.

CONCLUSION

Findings related to remote working IT workers and their psychological wellbeing are varied. During the systematic literature review it was noted that the main emphasis on remote working is centred on work-life balance and how it affects psychological wellbeing (Charalampous et al., 2022; Shirmohammadi et al., 2022). Spending more time with the family and having more time to engage in leisure activities improved family relationships and overall quality of life, which made

workers happier. On the other hand, remote working blurred personal and job responsibilities, resulting in overwork and playing multiple roles at home, which exhausts workers (Alfaleh et al., 2021). Another negative psychological effect of remote working highlighted in the literature was the lack of social interactions among co-workers and supervisors. Due to limited face-to-face interactions, remote working IT workers tend to feel left out, which makes them feel isolated and excluded (Taser et al., 2022). However, IT workers experience more autonomy and control over their decision-making as they experience a less supervised environment when working remotely, giving them more freedom.

In this systematic literature review, factors such as technological stress, gender, and psychological aspects related to wellbeing were also discussed. Information technology workers are prone to technological stressors caused by ICT due to constant upskilling related to technology and engaging in technological platforms without a break (Prasad et al., 2020). It caused exhaustion, lack of focus, and eye strain, affecting overall psychological wellbeing. In addition, gender-wise, female remote working workers engage in more caregiving roles than males remote working, which makes them tired, distracted and stressed. However, IT females' job engagement in remote working increased after the COVID-19 pandemic as they valued the work-life balance which made them more empowered (Tapani et al., 2022). In addition, avoiding commute time, spending more time with their family, and having more time to relax enhanced the hedonic approach to psychological wellbeing (Karthikeyan Arasu et al., 2019). On the other hand, it was found that developing autonomy and investing in self-growth enhanced the eudemonic approach to psychological wellbeing. This concludes that remote working IT workers experience positive and negative outcomes related to psychological wellbeing, which has been discussed in diverse aspects of the systematic literature examined.

This study contributes to hedonic and eudaimonic approaches to psychological wellbeing. Factors influencing hedonic wellbeing, such as job satisfaction, stress levels, and daily emotional experiences of remote working IT workers, were discussed. Also, the study examined how remote working can enhance or diminish hedonic psychological wellbeing through flexible work hours, reduced commuting stress, and isolation from physical office interactions. Furthermore, it identified aspects of eudaimonic wellbeing, such as autonomy and competence in fostering eudaimonic psychological wellbeing and how these elements can be supported in a remote working environment.

The main practical contribution of this study is to help gain insights into tailored psychological wellbeing programmes for IT workers which will avoid negative psychological wellbeing outcomes from remote working IT workers. Also, workers can understand how remote working affects their psychological wellbeing and better understand how to maintain this while working. In addition, further research on how organisations can support overcoming psychological wellbeing issues faced by IT remote working workers would be worthwhile. Furthermore, conducting research related to remote working in non-traditional work arrangements in the IT industry, such as temporary work and freelancing-remote working, would be valuable.

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LEARNERS' PERCEPTION OF COLLABORATIVE VALUE MANAGEMENT THROUGH BUILDING INFORMATION MODELLING

Rehan Masood[1], Nick Wilson[1], Nayani Landage[1] and Omer Altaf[2]

[1] OTAGO POLYTECHNIC, DUNEDIN

[2] OTAGO POLYTECHNIC AUCKLAND INTERNATIONAL CAMPUS

ABSTRACT

This study evaluates learners' perceptions of collaborative value management through automated quantity take-off.

The construction industry is known for delays, cost overruns, poor quality, and a high number of accidents. Collaborative value management is a strategy to determine the effectiveness of possible solutions to the problem. The fragmented nature of the construction industry leads to communication constraints among stakeholders. The intervention of Building information modelling helps in the digitalization of the information, improving the process integration and creating a collaborative environment to achieve value for the projects.

Construction Management Quantity Surveying learners learn how to do quantity take-off from two-dimensional drawings and interpret the information in their first year. In the last year, they get hands-on training on using automated quantity take-off using building information modelling. However, the shift from a manual to automated quantity take-off has inherent challenges that impact learning.

A qualitative research approach has been used. Fifteen learners' reports were reviewed to assess their reflection on automated take-off, by using a building information modelling approach, to achieve collaborative value management in design development using an artificial intelligence open-access online tool. The learners were in year three and most of them were working in industry. Content analysis was performed to determine the key aspects highlighted by the learners.

All learners reported that the automated take-off is productive in comparison to manual work. Key aspects include instant quantities, elements integration, realistic features, dynamic point of view, interactive representation, quick pricing, alteration provision, data sharing, buildability, and low human cost. Learners mentioned that this building information modelling-based automated approach is subject to client awareness, construction company capability, selection of the level of developments, technology integration, and compatibility. A small number mentioned using conventional and automated approaches for verification purposes and shared understanding.

This study established the need for automated take-off and identified the key aspects that hinder the learning process. This study highlights the significance of automated quantity take-off from learners' perspective of having practical experience.

Keywords: Value Management, Building Information Modelling, Collaboration, Quantity Take-off, Buildings, Learners

INTRODUCTION

The New Zealand construction industry is known for delays, cost overruns, poor quality, and a high number of accidents (Babaeian et al., 2021). Collaborative value management (CVM) is a strategy used to determine the effectiveness of possible solutions to the problem (Li et al., 2022). The fragmented nature of the construction industry leads to communication constraints among stakeholders (Tiazi et al., 2020). The intervention of building information modelling (BIM) helps in the digitalisation of the information, improving the process integration and creating a collaborative environment to achieve value for the projects (Oraee et al., 2017). Construction management and quantity surveying (CMQS) learners learn how to do quantity take-off (measurement) from two-dimensional (2D) drawings and interpret the information in their first year. In the last year (year three), they get hands-on training on using automated quantity take-off using BIM.

The shift from manual to automated quantity take-off has challenges that impact learning (Smithwick et al., 2014) but the practices significantly improved over time. However, perception plays a vital role in continuing the best practices on the job with the realization of the effectiveness of the technology for the digitalization of construction processes.

According to the BIM Acceleration Committee (2021) report BIM's use on construction projects grew from 34% in 2014, to 70% in 2021 in New Zealand. However, BIM capacity needs to be amplified with the integration of emerging technologies (Ministry of Business, Innovation and Employment (MBIE), 2024). Doan et al., (2021) reported multiple issues related to BIM in the construction industry in New Zealand like inconsistent awareness and understanding of BIM definition by construction practitioners. However, timesaving is a key benefit, and lack of BIM understanding a key barrier. The most critical barriers were reported as interoperability, government regulations, software cost, and client demand (Hall et al., 2023). The barriers were classified in the comparative study based on knowledge, technology, and internal and external strategy, which varied among Chinese professionals (Ma et al, 2023). Nevertheless, there is a knowledge and skill gap regarding BIM in the construction industry in New Zealand (Puolitaival et al., 2017). Developing clarity about BIM during and including within formal qualifications has a direct impact on quantity take-off practices.

OBJECTIVES:

This study evaluated the perceptions of CMQS learners towards collaborative value management through automated quantity take-off through BIM using Revit Autodesk. Learners were asked to compare the traditional tendering using 2D drawings with BIM-based collaborative value management for procurement.

LITERATURE REVIEW:

Building information modelling in the construction industry in New Zealand can be defined as "a collaborative set of processes, supported by technology, that adds value through the sharing of structured information for building and infrastructure assets" (New Zealand Building Information Modelling (NZBIM) Handbook, 2023). There are n-dimensions of BIM applications (Masood et al., 2014) not limited to three-dimensional (3D) coordination, designated constructability reviews, 4D scheduling and sequencing, 5D cost estimation, six-dimensional (6D) procurement, prefabrication, structural analysis, lightning analysis, mechanical (heating, ventilation and air conditioning (HVAC)) analysis, energy analysis, seven-dimensional (7D) operation and maintenance, geographic information system (GIS)-based visualisation, eight-dimensional (8D) modelling with prevention through design (PTD), nine-dimensional (9D) Lean construction and continuing. However, the application of BIM is beyond dimensions as practitioners from the architecture, engineering, and construction industries explore its vitality. The core difference between the traditional 2D drawing approach and BIM is that changes in any element such as plans, sections, and elevations, require changes in all drawings. On the other hand, the BIM model can be modified or rectified, and every element revised automatically (Yin et al., 2020).

Quantity surveying entails measuring the quantities of construction materials and estimating the cost of the construction projects (Altaf, 2023). The most critical aspect of quantity surveying is the accuracy of the quantity's estimation and measurement (Valinejadshoubi et al., 2024). Five-dimensional (5D) is the most promising dimension of BIM to get quick and accurate estimates with less rework and better collaboration (Altaf, 2023). However, quantity surveyors are still lagging in BIM skills especially 5D (Harrison & Thurnell, 2015).
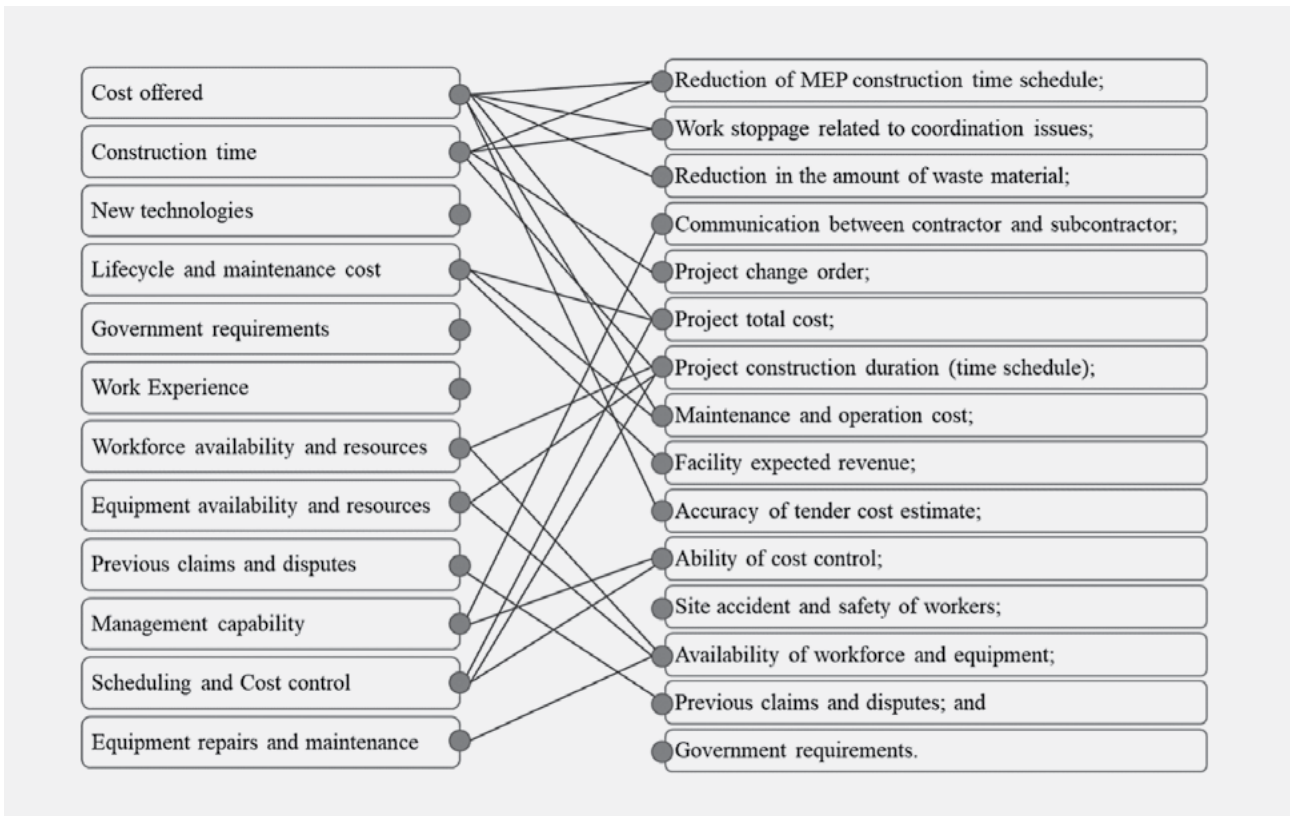
Figure 1: Mapping between BIM advantages and Tender Selection Criteria (Majzoub & Eweda,2021),

Tendering theory determines the prices through a tendering process for competitive equilibrium which demonstrates it as the sum of a valuation and a strategy (Runeson & Skitmore, 1999). This is the initial procurement stage where the contractor is selected based on competitive bids (Semaan & Salem, 2017). Building information modelling supports all the steps in the pre-bid stage (Tecture, 2024). However, requests for information leading to design reviews delay the tender process as 2D drawings require a significant amount of time to revise (Brooks, Zantinge, & Elghaish, 2023). Figure 1 shows the BIM advantages are very well mapped for tender selection criteria (Majzoub & Eweda, 2021). Building information modelling can be implemented in several procurement procedures; it is more effective if collaborative and integrated behaviour is promoted (Ciribini et al., 2015). Building information modelling intervention in the tendering process is a demonstration of CVM strategy through integrative BIM to quantify cost optimisation (Alfahad & Burhan, 2023). Collaborative value management demands project information completeness and stakeholder active engagement to attain innovative solutions (Rostiyanti et al., 2023). Nevertheless, automating the take-off with BIM provides an opportunity to address the changes by applying iteration in the building design for the agreed solution among the stakeholders. This eventually enhances the efficiency and effectiveness of the project in the early stage till completion and avoids claims.

RESEARCH METHODOLOGY:

A qualitative research approach was used to determine the perception of the CMQS learners (Fross et al., 2015). Fifteen CMQS learners' reports were reviewed to assess the reflection on automated take-off for CVM in design development which had been asked through an open-ended question. The CMQS learners are in the third year of their Bachelor of Construction Management (Quantity Surveying) qualification and most of them are currently working in industry (having a practical perspective). Research ethics category B was approved to access the assessment data of learners. Content analysis was performed to determine the classification based on the most frequent key aspects highlighted by the CMQS learners (Opoku & Egbu, 2018), refer to Table 1. CMQS learners answered the open-ended question focused on "Comparison of CVM and BIM with traditional 2D tendering". The most frequent content related to opportunities and challenges was compiled through ChatGPT and manually checked with samples for accuracy, consistency, and coverage. An approach widely applied to ensure the effectiveness of the content analysis (Firat, 2023). The ChatGPT tool used techniques of artificial intelligence (AI) to generate natural language responses based on prompts (Kalla & Smith, 2023). However, human intervention to review helps the moderation of the outcome, and accuracy is critical (Hung & Chen, 2023). This helped to ensure the relevancy of the findings in the given context.

Table 1: Most frequent benefits and challenges reported by CMQS learners.

BENEFITS		CHALLENGES	
Cost and timesaving	7	Data quality and consistency	6
Visualisation and clash detection	7	Lack of integration and standardization	4
Efficiency and collaboration	4	Lack of expertise	4
Risk Reduction and Safety enhancement	4	Cost of implementation	2
Improved planning and design	3	Reluctance to change	1
Post construction benefits	2	Prolonged learning curve and tech. familiarity	1
Buildability	2		

FINDINGS AND DISCUSSION:

The following are key benefits of using BIM identified by the CMQS learners:

Cost and Time Savings (Rank 1):

This benefit ranked at the top. Building information modelling minimises project management requirements by realising errors in the early stage of the project. Faster communication, coordination, and 3D visualisation through BIM have proven to contribute to time and cost savings (Bryde et al., 2013). The tendering phase has limited time to award the project so utilising the BIM model helps to reduce the time to address the request for information. Further, during this phase, various issues raised by contractors and subcontractors help to avoid costly scope variation claims. Quantification of materials is the core of achieving the benefit of estimation accuracy and appropriate control budget. Five-dimensional BIM implementation is inevitable to achieve this benefit, especially in quantity surveying (Altaf, 2023). This helps to not only quantify the material but also the cost of the materials which reduces the chances of a material variation claim. Time and cost are both crucial performance dimensions for the realisation of value addition.

Visualisations and Clash Detection (Rank 2):

Another benefit the CMQS learners mentioned, is the visualisation of the buildings, through BIM which helps to address the constructability issues. This leads to scope change variation later in the execution phase of the projects. However, visualisation brings the stakeholders to the table to evaluate the aspects of the project beyond constructability such as sustainability and safety (Barros & Sotelino, 2023). Nevertheless, stakeholders' efforts are reduced in the tendering process as there is no need to go through all the project documentation as all the information is embedded within the model. Similarly, BIM helps to identify the overlapping (or conflicts) of building elements or services through clash detection. This broadly helps in addressing the coordination issues between consultants and contractors, as well as contractors and subcontractors. Further, it is easier to revise the design in a BIM setting and communicate to stakeholders for updated information. This feature helps in cost-benefit analysis to optimise the design solutions to gain value and efficiency on construction projects (Chahrour et al., 2021). Both visualisation and clash detection brought transparency and accountability in the tendering process to share the risks among the parties on a mutual basis. This avoids the chances of potential conflict on the projects.

Efficiency and Collaboration (Rank 3):

Building information modelling provides a collaborative platform to exchange information for decision-making which helps in achieving efficiency. This is ranked third by the learners. However, the decision-making needs to be mutual among the project stakeholders to identify and rectify the issues but relational and contractual obligations play a vital part (Noor et al., 2021). The changes made within the BIM model are reflected across all models, allowing for real-time collaboration and data sharing. Any change is visible to everyone and provides an opportunity to accept or reject. The collaboration among services engineers, structural engineers, and architects is enhanced, enabling immediate detection of service clashes and ensuring everyone works on the latest version of the project (Mamatlepa & Mazenda, 2024). Building information modelling helps in achieving integrated project delivery which is essential to achieve collaboration through BIM induction. Building information modelling has redefined and reorganised the roles and responsibilities of the clients, architects, and contractors (Sebastian, 2011). Building information modelling collaboration greatly impacts efficiency by reducing delays and improving productivity (Eze et al., 2024). However, there is a need for alignment of understanding, interpretation, and communication to ensure successful collaboration to value the construction project (Park & Lee, 2017). It is critical that stakeholders set the agreement of the level of development (LOD) of the BIM models, normally ranging up to 500. However,

LOD changed by discipline and services. Further, procurement strategies such as two-stage early contractor involvement (Finnie et al., 2024) support the collaborative platform.

The remaining benefits highlighted by CMQS learners in descending order are risk reduction and safety enhancement, improved planning and design, post-construction benefits, and buildability. Building information modelling helps in automating checking the safety rules to avoid the risk of accidents on construction projects (Zhang et al., 2013). Building information modelling-based approaches in virtual reality helps in collaborative decision-making (Du et al., 2018). Building information modelling is useful for developing the as-built model to compare with the model developed from construction drawings (Lin et al., 2016). Building information modelling helps in the constructability analysis of the proposed design of the buildings (Zhang et al., 2016). Nevertheless, the understanding of the construction project with virtual modelling is a prime benefit that helps the stakeholders realise their needs during the tendering process.

The following are key challenges of using BIM identified by the CMQS learners:

Data Quality and Consistency (Rank 1):

Learners reported that the most critical challenge associated with BIM implementation was data quality. This leads to inconsistencies in the model, especially when drawings come from different sources, which can make it difficult to upload and use the model accurately. Building information modelling authorship plays a significant role in who will create, manage, update, and retain the models (Masood et al., 2014). There is a need for standardisation across several avenues, but the BIM object library should be centralised and shared to address the data quality issues (Tsay et al., 2023). The inaccuracies or errors in the 2D drawings can potentially lead to hurdles in BIM implementation. However, BIM can rectify the deviation in drawings during the modelling process depending on the standardised input (Gharouni et al., 2021). It has been widely said in the construction industry that garbage in will be garbage out, which is absolutely right with BIM implementation and adds no value. Nevertheless, the scrutiny of the BIM models is essential to ensure the quality and consistency of the model.

Lack of Integration and Standardization (Rank 2):

Lack of integration between software and file formats can pose challenges. There are possible issues around interoperability and compatibility of the model built by subcontractors to the main model e.g. HVAC (Jaskula et al., 2014). The absence of universal standards for incorporating details may result in mislabelling and overlooked errors. This happens when there is a lack of assessment for interoperability as parametric information is lost during the exchange (Bataw et al., 2016). Several approaches such as CostX software in quantity surveying successfully integrate BIM functionalities (Zhang et al., 2024). The absence of standardisation in BIM software can be a barrier. Different companies may use different types of BIM software, leading to a lack of consistency and potentially hindering collaboration. There is no consistency in international, national, and cross-discipline levels for BIM standardisation (Edirisinghe & London, 2015). There is a need to advance the standardisation of BIM to enhance collaborative efforts. In the tendering process, the BIM model development protocol should be introduced and agreed upon among the stakeholders. The client may provide a BIM model of the construction project as part of tender documents. Otherwise, contractors and subcontractors need to invest in the development of the BIM models despite having low certainty of acquiring the project.

Lack of expertise (Rank 3):

Low adoption of BIM primarily due to a lack of skilled construction practitioners competent to use BIM tools. Building information modelling competency is based on interlinkage at individual, firm, industry, and global levels but it follows the process of assessment, acquisition, and application (Succar et al., 2013). However, BIM practitioners have created special groups within the construction industry from technicians, managers, coordinators, and collaborators. However, there is still a lack of expertise. On a recent account, a designated occupation has been assigned to deal with BIM models including technicians and managers. BIM education, formal, informal, or continuing, plays a significant role in training the new generation to implement BIM on projects. However, the focus should be beyond a single course to integrate BIM with other digital technologies (Wang et al., 2020). The availability of educational resources potentially improves the skill set of the construction workforce. Building information modelling in the New Zealand construction industry has developed guidelines to create BIM models with appendices from A to K covering all key aspects. (**https://www.biminnz.co.nz/nz-bim-handbook**)

The remaining challenges highlighted by learners in descending order, are the cost of implementation, reluctance to change, and prolonged learning curve. Upfront costs of BIM are key hindrances in adoption including expenses of software, training, and licenses (Gracia et al., 2018). There is still a reluctance to change current practices for BIM. Building information modelling has reshaped the practices, processes, and transactions in the construction industry in New Zealand which allows the construction workforce to change (Vass & Gustavsson, 2017). Like other technological interventions in construction for which it takes years to mature, BIM is not exceptional. The learning curve for BIM depends on several aspects but the most critical is the firm-level engagement that is associated with the client, construction project, and regulatory requirements to determine the BIM maturity level (Xue et al., 2018). Nevertheless, the engagement of quantity surveyors in the BIM process is crucial.

CONCLUSION:

The adoption of BIM in the construction industry in New Zealand offers a comprehensive and transformative approach, positively impacting efficiency, collaboration, risk management, cost savings, and the overall quality of construction projects from planning to post-construction phases. Building information modelling holds immense potential for digitalisation and revolutionising the construction industry in New Zealand, and addressing these challenges is crucial for its widespread and effective adoption. Overcoming issues related to learning, data quality, cost, expertise, and resistance to change will be key to unlocking the full benefits of BIM and ensuring its seamless integration into construction industry practices in New Zealand. This study established the need for BIM practices taking the example of automated take-off in the learning and training process for CMQS learners and highlights the benefits and challenges that learners perceived during the process from academia to the real-life world. It is vital to capture the transition from manual to automated practice and analyse the learning process of technology through the lens of benefits and challenges capturing the theory and practical viewpoint. The CMQS learners shared their experience of BIM implementation which helped them to enhance their cognitive skills through visualisation. The construction practitioner with the hat of learners helped to gauge the construction industry insight for advanced practices but also raised the need for improvement. Learners also demonstrated the realisation of BIM's potential to achieve value on projects through collaboration among the stakeholders. Automated quantity take-off based on BIM provides a collaborative platform to create value through efficient information exchange and decision-making. The main limitation of this study is the sample size of the CMQS learners and secondary data through final reports. Quantitative studies need to be conducted to evaluate the benefits and challenges of using BIM. Further, the case study approach is another potential way to validate the findings.

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EXPLORING THE CONTRIBUTION OF SITE MEETINGS IN NEW ZEALAND CONSTRUCTION PROJECTS

Leijun Shi and Srividya Krishnamoorthy

OTAGO POLYTECHNIC AUCKLAND INTERNATIONAL CAMPUS

ABSTRACT

The construction industry has made a major contribution to the growing economy of New Zealand. Due to its rapid development in the past two decades, most construction projects have encountered time delays and cost overrun issues, which have caused a constant stream of disputes in construction. An Infometrics report (Kiernan, 2022) highlights "Current projects across various construction projects taking between 67% and 111% longer than normal to reach the milestone of their first inspection". Poor management, supervision and coordination, and lack of communication were reported to be major causes of construction project failures. It was observed that there was scope for site meetings to contribute to resolving these issues. In our study, a mixed approach of quantitative and qualitative methods was adopted with the aim of exploring, through a survey and a literature review, how site meetings contribute to successful construction project completion. The questionnaire included 11 questions for which 96 participant responses were received and analysed. The major finding of this research was that the site meetings have the potential to significantly resolve a range of construction project-related issues such as quality, safety, scheduling, payment and stakeholder communication. Site meetings provide an opportunity to evaluate the resource utilisation onsite, review the progress of the construction project, and facilitate scheduling and coordinating upcoming tasks. Furthermore, the research identified the key contributing factors as being the lack of coordination, traffic and site conditions, and unclear communication influencing contractual parties that do not attend the site meetings.

Keywords: Construction, Poor management, Project failure, Site meetings, Successful completion

INTRODUCTION

According to Statistics New Zealand (Statistics NZ, 2023), building construction in New Zealand has been developing rapidly from the early 2000's. Despite the negative impact of COVID-19, building consent approvals increased in 2023, with the monthly number for new buildings consented to being higher than three years previously. However, almost all construction projects are more likely to experience delays due to miscommunication between contractors, subcontractors, and clients (Shah, 2016).

In New Zealand, more than 90% of construction firms have experienced delays, in most cases the project being delayed between 20-60 working days (Statistics NZ, 2023). The construction project delays are caused by overrun time and cost, disputes, and the poor quality of work-related issues (Ametepey et al., 2018). As indicated in a study conducted in 2013, the construction industry ten years ago was already facing long-term challenges, with around 70% of construction projects experiencing time delays and cost overruns amounting to 14% of the average contract cost (Hussin et al., 2013). These problems have since led to a sharp rise in construction disputes, as shown in a Global Construction Disputes Report (Arcadis, 2022) in which the global average value of disputes is said to have increased to 52.6 million US$.

Furthermore, the construction industry presents a unique factor: construction projects are never identical but will vary at least in accordance with the team members involved (Anantatmula, 2010). Site meetings are a valuable management tool which can address the uniqueness of individual construction projects (Oke et al., 2016). According to Cahill and Puybaraud (2008), and Murray (2008), improving the working relationship between clients, designers and contractors is an essential factor which can help to reduce construction costs and meet the client's requirements. Site meetings can be an effective bridge for communication between different groups. To achieve successful construction project management, site meetings are adopted as an effective management tool to avoid or reduce disputes and ensure the construction projects

can be delivered successfully (Oke et al. 2016). Hence, there is clearly a need to explore the contribution of site meetings to successful construction projects. It is evident that much research has been conducted to evaluate the role of site meetings to address specific issues in construction projects. However, there is much scope for investigating the overall contribution of site meetings in the successful completion of construction projects in New Zealand, as well as to better understand the issues for the parties involved. This study seeks to examine the key features of site meetings conducted during the construction stage and specific construction project-related issues that were addressed during these site meetings.

RESEARCH AIM AND OBJECTIVES

Aim

The aim of our research was to analyse the key features of site meetings and provide evidence to demonstrate the contributions of site meetings on construction project performance.

Objectives

- To identify the critical factors influencing successful completion of the construction project.
- To identify the key factors contributing to construction project failure.
- To study the key features of site meetings.
- To analyse the contribution of site meetings on construction project performance.

LITERATURE REVIEW

The primary goal of the literature review was to offer a comprehensive overview of the relevant critical factors identified for successful construction project completion and to provide an overview of the significant effects of site meetings on overall performance of construction projects.

Critical factors for successful completion of construction projects

Many researchers in different countries have identified various critical factors that influence construction project performance and success. Cooke-Davies (2002) observed that project management success is not the same as construction project success. Objective management, monitoring construction project performance, feedback systems, teamwork, risk management and stakeholder management were all identified in this study as key critical success factors in construction project execution. Iyer & Tha (2006) concluded, in a survey of construction projects in India, that the two most critical success factors are the commitment of all those involved and the owners' level of competence. Furthermore, Arian (2007), found that the most important factors which align with strategic, technical and managerial subsystems of construction projects in the Pakistan construction industry are the project goals, leadership style, clarity on the scope of work, teamwork, planning and programming techniques, the team selection process, and the construction project managers' competence and authority. Meanwhile, Boyer et al. (2008) decided that leadership, innovative concepts, business planning and marketing, triple bottom-line planning, community engagement and risk management are the key factors in successful construction project implementation. Similarly, in a study conducted by Ogwueleka (2012) focusing on Thailand, India and Pakistan, it is reported that there are 16 essential factors for achieving satisfaction in the completion of construction projects. The findings identified project objectives, technical design, risk management and the role of top management as the critical success factors (Ogwueleka, 2012). In addition to cost, schedule and technical aspects, other factors in the success of a construction project include safety, client satisfaction, employee satisfaction, payment schedule, benefits, environment and professional development (Silva, et al., 2016). Rajasekaran & Valli (2014) identified 17 factors for construction project success through a literature review and a survey of engineers, site engineers and contractors in India. Of these factors, construction quality, on-time project completion, compliance with specifications, client satisfaction, and technical performance were the top five elements influencing successful construction project performance. Furthermore, Jari & Bhangale (2013), conducted their research by dividing the different aspects involved into two groups, "Project Success Criteria" (PSC) and "Project Success Factors (PSF)". The first of these categories includes the expectations of the owner, designer and contractor, while the second includes time, cost, quality, construction project management (control, scope and change), stakeholders' satisfaction, the construction project team and top management support. Their conclusion was that time, cost, quality and risk control can be considered as the most significant factors for construction project success. McDonagh (2010) researched the critical factors in land development in New Zealand and the study revealed that risk analysis, strong communication, regular review of the development plan, and market conditions all have a role to play in the overall success of the construction project. Project understanding and a competent project team were identified as the most important Critical Success Factors (CSFs) in a study conducted in Australia (Baccarini & Collins, 2003). This study emphasised the need for the project manager to promote a strategic approach rather than focus on project management techniques.

Key factors contributing to construction project failure

Construction projects may not always be successfully completed on the assigned budget and schedule due to a range of different reasons. Poor management, planning and scheduling, and lack of communication and coordination were identified as serious factors for construction project failure in a case study of Australia, Malaysia, and Ghana (Shah, 2016). According to Baccarini and Collins (2003), meanwhile, the lack of clear objectives or development management and organisation, as well as inappropriate reporting strategies and performance measurement systems are the main causes of construction project failure. Financial concerns and shortcomings of the bidding process were reported as significant factors by Shahhosseini et al. (2017). El-sokhn & Othman (2014) saw management and financial factors as major contributors to project failure. Their study revealed that most projects fail during the construction phase, where the skills of the contractor and project manager play a significant role (El-sokhn & Othman, 2014). In Improving New Zealand Construction Industry Productivity (New Zealand Institute of Building, 2021) there is an overview of various factors for construction project failure, the most common problem being the failure to provide adequate time for design including time to integrate and coordinate with the stakeholders.

Key features of site meetings and its effects in construction project performance

The construction industry is known to be constituted of various indispensable professionals. Oley and Macmillan (2005) analysed the interaction between clients, consultants and contractors in construction project team meetings, and illustrated the different patterns of communication in four types of team meetings through observations of a major United Kingdom construction project, including progress meetings, technical meetings, interim technical/cost reviews and strategy/problem-solving meetings. The authors indicated that the objectives of each type of meeting were to identify the issues related to progress, resolve technical and design problems, review cost-related items and consider future issues to avoid disputes. Bicharra Garcia et al. (2004) proposed a four-step meeting plan, and a system to improve the effectiveness of meetings, while Mäki (2015) focused on design-related issues in site meetings through two case studies of construction projects in central Finland. The latter revealed that the meetings were too long, spanning between three and four hours, and that site managers played an important role during these site meetings where most issues were initiated by them. In Awe Foluso et al. (2022), a few aspects of project performance such as delivering quality projects, achieving on-time completion, and identifying problem resolutions were reported as key benefits of site meetings conducted during construction. Almost all project-related issues can be discussed in site meetings, and this will include project payments, which helps to track all payments that are due and over-due to the contract parties (Denim 2007). The wide range of variations normally occurring on the construction project site can be addressed in a site meeting, which will help the client to see if the amount for unforeseen work has been overrun or not (Sergeant & Wieliczko, 2014). Preventing claims and disputes, using programme charts for time management, holding regular site inspections and testing, cost checking, proposing quality control planning, and evaluating workmanship and specifications were all identified as objectives of site meetings in sustainable construction (Oke et al., 2016).

METHODOLOGY

In this study, both qualitative and quantitative approaches were adopted. A questionnaire was used for the collection of primary data, which was further validated using literature review information in the discussion.

Survey

The questionnaire proved to be an effective and easy method for collecting data and achieving the research objectives. It contained ten closed-ended questions and two open-ended questions and was prepared using Google Forms and shared through LinkedIn. Three questions were designed to understand the participants' demographics such as their experience in the construction industry, as well as their familiarity with site meetings. One question was based on the 'level of importance', and a four-point Likert scale was used to assess the participants' attitudes regarding the importance of site meetings. The adopted scales were 4 = very high / strongly agree, 3 = high / agree, 2 = neutral / likely, and 1 = low / disagree. Participants were required to record their responses from the options provided for each question. It was ensured that no confidential data was collected, and the anonymity of participants was maintained.

Participants' characteristics

The study was conducted over a period of three months. The study area was the Auckland region, with a focus on participants connected to the construction industry. The questionnaire was shared with construction industry professionals performing different roles in construction projects and 96 responses were received. Figure 1 shows the roles of the participants. Subcontractors accounted for 21% of participants, which was the highest proportion, followed by contractors (17%) and suppliers (16%). Site managers and project managers made up 14% of the total number, while council workers made up 12%.
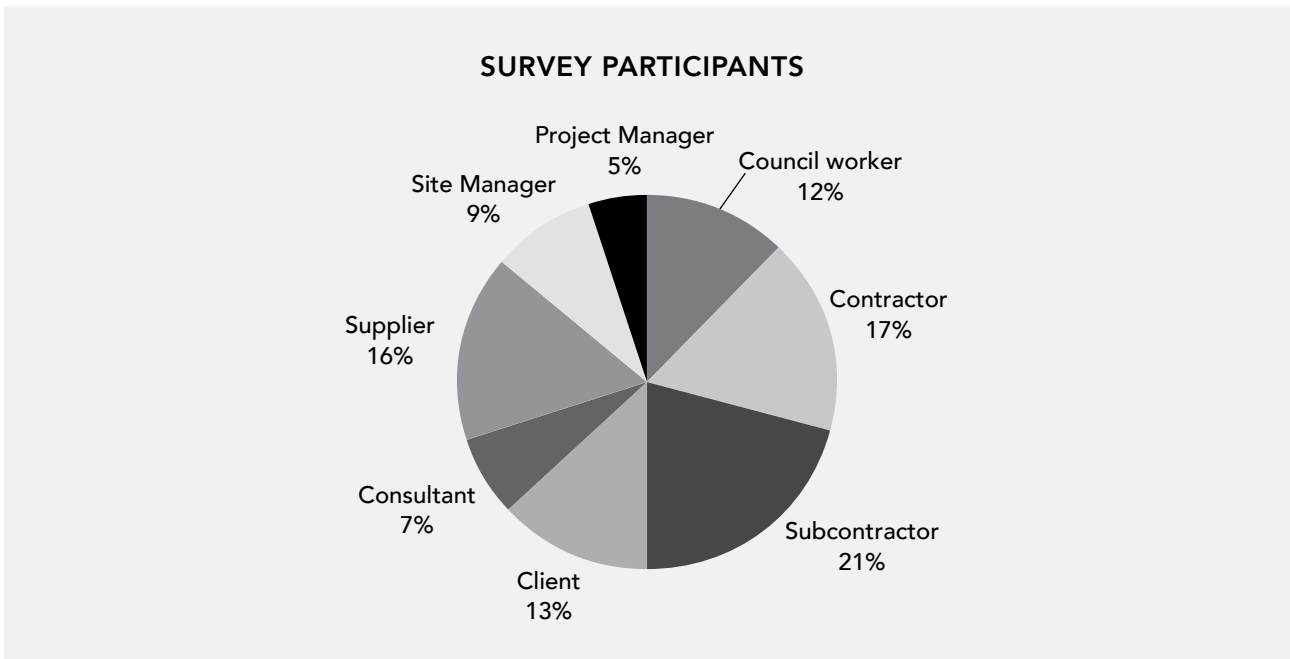
Figure 1: Roles of Survey Participants

SURVEY PARTICIPANTS

Table 1: Demographics of the Survey Participants

EXPERIENCE	FREQUENCY	PERCENTAGE
3- 5 years	29	30%
5 -10 years	49	51%
above 10 years	22	19%
Experience in Site meeting		
Preconstruction	32	33%
CONSTRUCTION	46	48%
POST CONSTRUCTION	18	19%

Table 1 presents the demographics of participants. The data shows all the participants' experience in the construction industry with 51% of participants reporting experience of 5 to 10 years and 23% reporting more than 10 years' experience in the construction industry. The data revealed that most of them attended site meetings conducted at the pre-construction and construction stages. Post-construction meetings were held after the project completion, allowing the contractor to review the construction project with the clients to ensure a successful delivery.

RESULTS AND DISCUSSIONS

Frequency, agenda, and duration of site meeting

As indicated in Designing Buildings (2023), site meetings can be planned and formally scheduled, whether weekly or monthly, depending on the stakeholders involved and the complexity of the construction project which might require a more regular schedule. Our survey investigated the frequency and flexibility of site meetings attended by research participants. This is illustrated in the figure below showing the results regarding the frequency and duration of these meetings, as well as their level of formality (as evidenced by the use of agendas).

Figure 2: Participant Responses on the Frequency, Agenda and Duration of Site Meetings
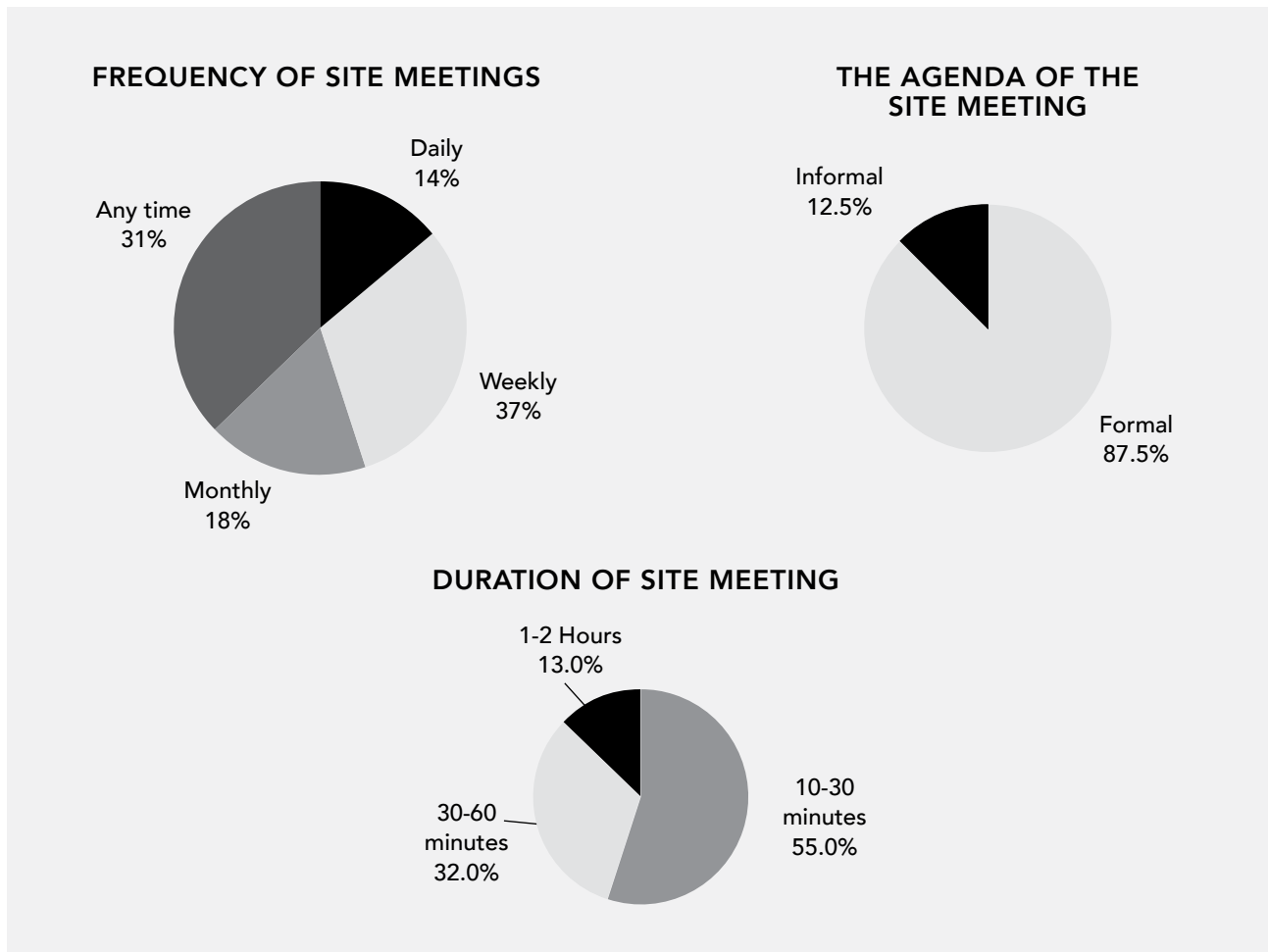
Of the participants, 37% stated site meetings occur weekly, while 31% reported that during construction projects they attended site meetings at any time, with 18% saying this was monthly attendance and 14% daily attendance. This can be compared to a study in Nigeria where monthly site meetings were more popular than other scheduled meetings (Awe Foluso, et al., 2022). Meanwhile, the regularity of site meetings in our results can be viewed in terms of the research by Gorse & Emmitt (2007), in which regular face-to-face site meetings are stated to be more important for the success of construction projects. It is also important to point out here that 87.5% of the participants in our survey said the meetings they attended were formal, which implies they were all based on a clear agenda. Having an agenda is important for controlling the flow of site meetings and enabling them to be more focused on project direction (Ludwig, 2009).

Issues addressed and outcome achieved in the site meeting

Construction industry site meetings play a critical role in project discussions and alignment because they establish solid relationships between stakeholders and lay the foundation for future deliberation (Smith, 2020). Research conducted by Oke et al. (2016) concluded that during site meetings, issues related to construction projects such as cost, time, quality, function, adherence to standards, scope, human resources, risk management strategies, health and safety issues etc. should be considered. Our own survey investigated the issues discussed in the participants' site meetings, as presented in the following diagram.

Figure 3: Participant Responses on Issues Discussed in Site Meetings

ISSUES ADDRESSED IN SITE MEETINGS
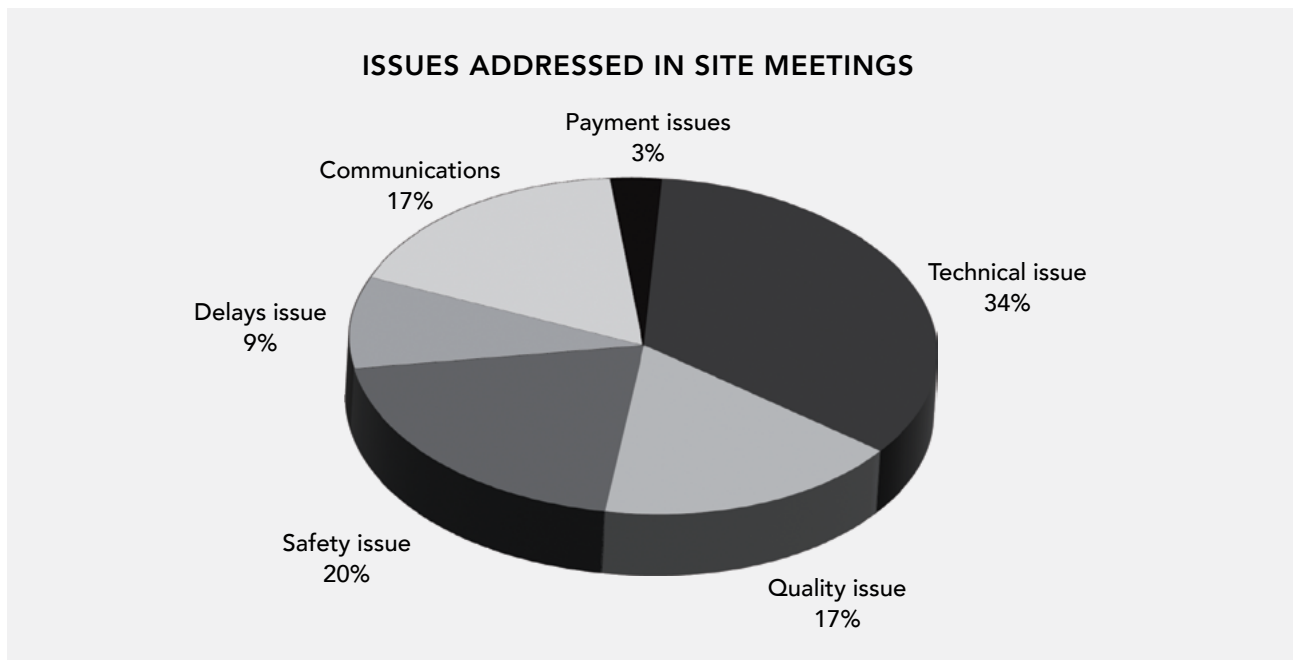
Technical issues were the top of the discussion list, making up 34% of all issues discussed during site meetings. By contrast, payment issues were the least discussed, constituting only 3% of all issues discussed. Site safety issues and challenges were also important discussion points, accounting for 20% of all issues discussed. Both issues relating to quality and communications contributed to a combined 34% of all discussion points. However, delays did not rank among the most frequently discussed issues during site meetings, with only 9% of the participants responding that such issues were discussed.

As for the outcomes achieved in these meetings, it is evident from Figure 4 below that discussions about the construction project site tasks, arrangement for tasks and coordination were the topmost responses from the participants. Each of these aspects accounts for over 20% of all outcomes, closely followed by instructions which account for 20% exactly. These responses indicate that the issues that may hinder successful completion of construction projects the most were coordination and task management, and they could potentially be addressed through site meetings. Our analysis reveals the extent to which conducting site meetings can significantly address critical issues in construction project progress, thereby supporting the conclusions of other studies on this topic (Bicharra Garcia et al., 2004; Mäki, 2015).

Figure 4: Participant Responses on Outcomes Achieved in the Site Meetings

OUTCOME ACHIEVED IN SITE MEETINGS
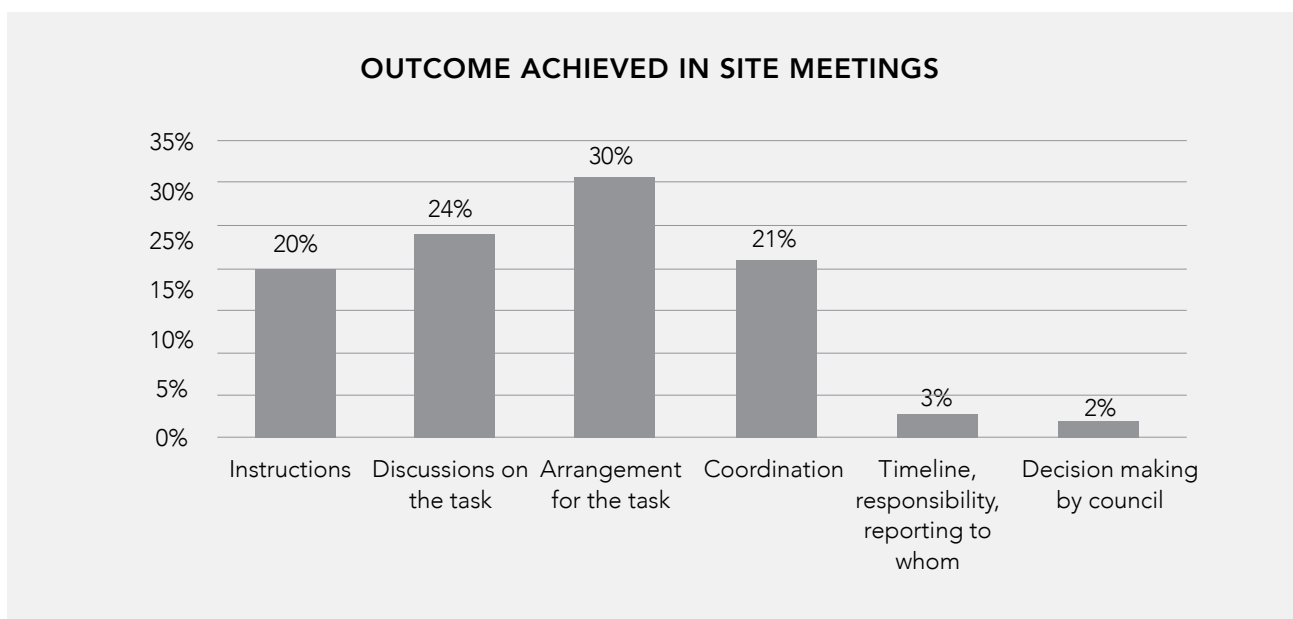
The importance of site meetings and the barriers to attending

The four-point Likert scale was adopted to collect responses on the importance of site meetings. A total of 46% of responses were very positive, supporting site meetings with a rating of 'Very High', followed by 40% who rated them as 'high'. Although 9% of the responses were 'neutral', these results clearly show the vast majority of participants in our survey agreed that site meetings could be used as a tool for collaboration and avoiding disputes. To understand the barriers that prevent participants from attending site meetings, an open-ended question was included in the questionnaire. There was a range of responses from participants which were further categorised and rated using the content analysis method. The following diagram provides an overview of their responses to this question.

Figure 5 Participant Responses on Barriers to Attendance in Site Meetings
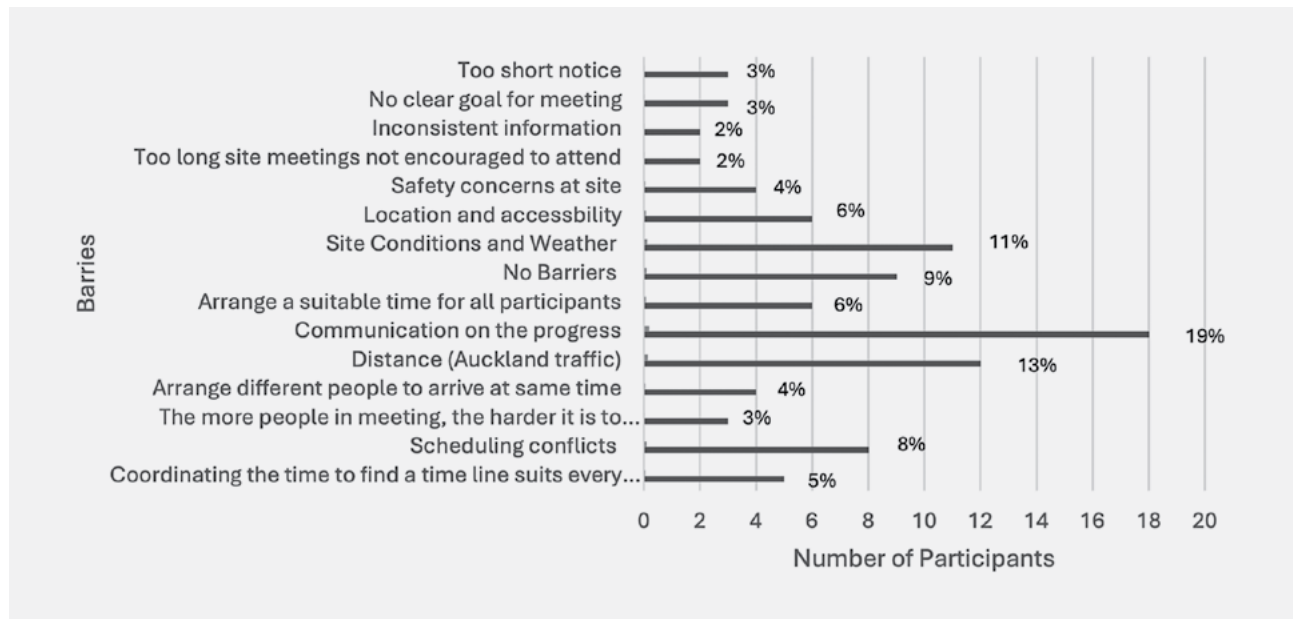
As for the barriers which prevented them from attending, these are summarised below.

Table 2: Ranking of Barriers to Attending Site Meetings

CATEGORY	COUNT	PERCENTAGE (APPROX.)	RANK
Communication	20	21%	1
Distance (Auckland traffic)	18	19%	2
Weather	12	13%	3
Scheduling conflicts	10	10%	4
Coordination	8	8%	5
Too short notice	6	6%	6
Duration	6	6%	6
Site Safety	4	4%	7
Agenda	3	3%	8
No Barriers	9	9%	9

Table 2 displays the categories of all barriers stated by participants. The top three categories identified were communication, followed by Auckland traffic, and weather conditions. Scheduling clashes with other meetings and poor coordination between stakeholders were also identified as important barriers. The analysis also indicated that an appropriate duration and sufficient notice in the scheduling of meetings came in technically sixth position (each with 6% of responses).

CONCLUSIONS

This study was focused on the key features of site meetings in order to analyse their importance in reducing construction project failures. The results indicated that site meetings needed to be properly communicated and scheduled regularly with a clear agenda for discussion. Effective risk management, coordination, communication, and monitoring of progress in construction project sites were identified as the key to a successful build. Improving working relationships between clients, designers and contractors also emerged as an essential factor for construction project performance. Site meetings can be an effective bridge for communication between different stakeholders. The analysis of participants' responses revealed that site meetings play a significant role in addressing the issues related to technical aspects, quality and safety, delays and conflicting issues such as payments and communication. While some issues may not always be resolved through site meetings, they nevertheless provide a platform for clear instructions or arrangements for conflict resolution, effectively avoiding time and cost overruns as well as potential disputes. Hence, the contribution of site meetings in reducing construction project failures and increasing performance is considerable and should not be underestimated. The study also identified the key barriers to participating in site meetings as lack of planning and coordination, traffic, site conditions and unclear communication.

RECOMMENDATIONS

The following recommendations may be considered for enhancing the effectiveness of construction project site meetings:

- The application of digital project management software could be an effective tool for planning and organising site meetings.
- All meetings should be well planned and communicated early to all intended stakeholders with clear objectives.
- The site meeting agenda can be prepared with pre-determined timeframes for each section of the discussion, which will assist in keeping the meeting on-track and moving forward.

The agenda should be prepared without missing details and should include clear action plans, thus helping to avoid miscommunication and misinterpretation.

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Conceptual Article

OBJECT-EARLY VERSUS OBJECT-LATE: PERSPECTIVES ON CONCEPT ACQUISITION IN UNDERGRADUATE SOFTWARE ENGINEERING COURSES

Barry Dowdeswell, Tariq Khan, Asanthika Imbulpitiya, Waruni Hewage, Kathiravelu Ganeshan and Farhad Mehdipour

OTAGO POLYTECHNIC AUCKLAND INTERNATIONAL CAMPUS

ABSTRACT

Teaching Object-Oriented programming is a core element of undergraduate software programming courses. Using a custom-developed Ontology of programming language elements as well as case studies from three institutions, this article explored the order of presentation of both procedural and abstract concepts, including Object-Orientation. The findings are considered with reference to issues raised in both current and historical literature that examines concept acquisition in this context.

The literature suggests that in the past, first-year failure rates were often woefully high. Teaching abstract object concepts too early can hinder the establishment of a clear procedural understanding of coding. Similarly, presenting concepts in the wrong order is confusing and counter-productive for novice developers. The article concludes that the choice of programming language is not necessarily as significant as the order and way in which language concepts are presented and reinforced.

Keywords: Software Languages, Procedural Programming, Object-Oriented Programming, Teaching Paradigms, Concept Reinforcement.

INTRODUCTION

Part of the motivation for this research was the shared experience of the authors, who all teach first-year programming courses together at Otago Polytechnic Auckland International Campus (OPAIC). When developing new courses or revising existing material, we are all cognizant of how important it is to introduce programming concepts in a logical, consistent order. When writing program code to address a requirement, it is vital to help learners acquire both a theoretical understanding as well as know how to make the best choice of constructs and commands from what the language provides. That is an iterative process which can be undermined whenever irrelevant or unrelated concepts are introduced at the wrong time. Computing languages also evolve over time, introducing new capabilities and complexities. The literature review in the next section contains examples of how practitioners in other educational institutions addressed these challenges.

During introductory courses, students learn how programming languages store information in entities called variables. A computer program is a set of instructions which manipulate or process the information stored in variables. As the program runs, it can generate more information or solve problems. Mathematical operations are performed on numeric variables while functions such as string concatenation change data held in character type variables. Variables are defined by assigning them a unique name and, in type-specific languages, specifying the type of data they will hold (Omar et al., 2014).

Figure 1: A chess board used in the author's classes

Object-Oriented paradigms emerged in the early 1960s to address the issues of complexity and scalability (Gabbrielli & Martini, 2010; Saidova, 2022). Objects can be used more efficiently to implement individual entities such as the pieces in a chess game. Multiple instantiations or instances of an object represent the Queens, Bishops, and other pieces. Each object instance holds the unique board rank and file of that piece, its colour, and other properties. Objects also contain or encapsulate code functions such as validating a proposed move for that type of piece. However, the literature shows that for many students, mastering Object-Oriented paradigms is still a daunting task. Related object concepts such as Polymorphism and Inheritance are often challenging to understand and implement.

The primary research question explored in this article is "What is the optimal order for introducing procedural and object-oriented concepts to novice students?". The literature often highlights the issue of Object-Early versus Object-Late approaches (Astrachan et al., 2005; Kiper & Abernethy, 1996). A number of related concerns are implicit in this: how well do students emerge from this time and what are they proficient at? What skills do they lack? How well do they acquire and hone the skills required to design more complex programs later, apply appropriate software architectures, and become proficient with a range of different languages? More importantly, how do they develop the native instincts and cunning required to debug applications effectively?

Understanding the prior experiences of other faculties is invaluable to those contemplating a change to their own chosen language. In the context of these questions, how well does the programming language promoted by a faculty support the learning outcomes of their course? The skills that institutions help students build in their introductory courses often directly affects their level of achievement in subsequent years. How effectively students acquire foundational programming concepts at this early stage is a critical contributor to their long-term ability to be productive and later, employable.

BACKGROUND HISTORICAL PERSPECTIVES FROM THE LITERATURE

Severance (2012) comments that at some point in the 1960s and 1970s, academic computer scientists transitioned from concentrating all their effort on building hardware to also include learning how to write software. They recognised that they also needed to learn how to teach their students to write code. Kemeny and Kurtz (1964) had developed their Beginner's All-Purpose Symbolic Instruction Code (BASIC) programming language at Dartmouth College in 1964. It provided a foundational teaching tool that became well-accepted both in education and industry (O'Regan & O'Regan, 2012). Today, the True BASIC language (Bantchev, 2008) and Microsoft Visual Basic .NET (Balena, 2004) still embody the core language defined by Kemeny and Kurtz.

Literature was chosen that profiled a faculty's choice of a teaching language, including their experience migrating from one or more languages to another. Studies provided both empirical and qualitative feedback on these processes. Concerns about introducing objects too early and how to mitigate the effects were contrasted. The range of options about object paradigms and the merits of teaching them is diverse. There is also evidence that the failure rate in first-year courses during this time was disturbingly high.

Agder College in Norway was a typical example (Hadjerrouit, 1998). In 1998, they migrated from Simula and C++ to Java. They cite their primary reasons as being the need to have a language that supported object-orientation, concurrent

programming, and had applicability to web design. Agder's experience needs to be seen in the context of other early adopters, coming only three years after Java's first commercial release in 1995 (Horstmann, 2021). The Simula language (Dahl & Nygaard, 1966) had been taught at Agder since 1967, supporting classes and object creation since its inception. Hence the opportunity to teach object concepts using an appropriate paradigm, examples, and language had not been lacking.

Hadjerrouit explains that Agder's key learning requirements included their desire to teach algorithmic thinking as well as general programming principles. They emphasized design and modular program construction as well as the acquisition of problem-solving skills. Like many others, Agder believed that when choosing a new language, pedagogical considerations such as simplicity and support for object-orientation should take precedence over the pressure to choose a language just because it is favoured in industry. Hadjerrouit states that this was the main reason they originally taught two languages. However, they found that after a three-year investigation, only 60% of their students felt comfortable programming in Simula. The majority also had great difficulty with C++, even though Agder used a limited subset of the language (Stroustrup, 1986).

The literature reports common themes about what constitutes a good teaching language and what the difficulties are with the course languages available. The need to acquire clear, proven debugging skills is imperative. However, bug finding is hard when learning in command-line environments. An Integrated Development Environment (IDE) provides additional debugging capabilities that support C++ and Java better (Hadjerrouit, 1998). Gosling, the creator of Java, states that the language was designed to be simple enough that programmers can achieve fluency in the language quickly and that it has novice usability (Gosling et al., 1996). Hadjerrouit countered saying that Java is not simpler than Simula. While Java is syntactically very similar to C/C++ and Simula, it is not necessarily easier to learn.

Figure 2 shows examples of programs which all print "hello, world" and the current value of a variable which manages a counter. The examples include code written in BASIC, the C language, Java, and Microsoft C#. Why do students find these languages so hard to master? Part of the answer lies in the differing ways students grasp concepts while learning. Procedural programming in BASIC and C is more concrete, since they do not support objects. This encourages the incremental step-by-step introduction of ideas. Each concept, such as creating and using an integer variable, is small and easy to illustrate. However, objects are complex data types. They are entities that are like variables but have multiple data types and values that are changed by mutator methods. This is an abstract concept that is not intuitive for beginners. This issue of teaching object principles early in a course, referred to as "Object Early", is a common thread in the studies examined (Astrachan et al., 2005; De Raadt et al., 2002). The BASIC and C examples are not Object-Oriented: they print using language keywords. In contrast, the Java and invoke the more complex display console object methods. Students using these programs may not be aware they are using objects when they begin to program in these languages.

Figure 2: Programming Language examples including BASIC, C, Java, and C#

```
REM BASIC EXAMPLE
10 LINE = 0
20 FOR COUNTER = 1 to 10
30    LINE = LINE + 1
40    PRINT "hello, world ", LINE
50 NEXT COUNTER
```

```
// C EXAMPLE
#include <stdio.h>

int main() {
    int line = 0;
    for (int counter = 0; counter < 10; counter++) {
        line++;
        printf("hello, world %i \n", line);
    }
    return 0;
}
```

```
// Java EXAMPLE
class HelloWorld {
    public static void main(String[] args) {
        int line = 0;
        for (int counter = 0; counter < 10; counter++) {
            line++;
            System.out.println("hello, world " + line);
        }
    }
}
```

```
// C# EXAMPLE
namespace HelloWorld {
    internal class Program {
        static void Main(string[] args) {
            int line = 0;
            for (int counter = 0; counter < 10; counter++) {
                line++;
                Console.WriteLine("hello,world " + line);
            }
            Console.ReadLine();
        }
    }
}
```

However, the lack of complex C-style pointers in Java is perceived to be an advantage over C and C++. Milne cites pointers as being the single most difficult concept for students in each of the language construct categories they surveyed

(Milne & Rowe, 2002). More than one article recommended the use of a reduced subset of C++ for teaching (Dale & Weems, 2014; Hadjerrouit, 1998; Hasker, 2002).

Faculties often describe their approach to teaching coding as requiring students to write English-like pseudo-code statements that they later translate into program code (Hadjerrouit, 1998; Van Rossum et al., 1999). In many introductory courses, that approach worked well. Conditional branching control structures are readily understood if they are expressed first as English sentences in the form: if this is true then do that. Otherwise do this. Building indented statement blocks reinforces the concept that debugging becomes easier if the structure is clear. Since the Python language mandates indentation in control structures, it enforces this practice; there is no option but to indent correctly (Van Rossum & Drake Jr, 1995).

However, Robins (2012) notes that typical introductory programming courses demonstrate an unwanted bi-modal grade distribution, exhibiting a greater than expected aggregation of both high and low marks. Dehnadi and Bornat 2006 reported first-year programming failure rates between 30% and 60%. When Bennedsen and Caspersen analysed data from a range of smaller sized classes, it showed a much wider distribution. They saw the pass rates vary from 0% and 60% across 67 institutions between from 2004 to 2007. This represents an overall failure rate of 33% across these institutions for that period. Their later research in 2019 showed a decrease in the failure rate to 28% that they contrast with the 42% to 50% failure rate seen in US college algebra courses (Bennedsen & Caspersen, 2019).

In contrast, DeClue (1996) proposes that object instances may be an easier concept to grapple with since they are more analogous to real-world objects. Osborne and Johnson (1993) argue that objects are intuitively more like co-operating, real-world machines from the student's point of view. This should be advantageous, since the effect is to raise the level of abstraction for novice programmers at a time when they need it most (Osborne & Johnson, 1993). However, there is still vigorous debate about the issue of teaching Objects-Early versus Imperative-Early. Koffmann commented on the introduction of object-orientation into courses, stating that it reinvented the 'new math' syndrome and that many practitioners were not aware that they had (Astrachan et al., 2005). Gabriel, commenting in the midst of the academic debate that followed Dehnadi and Bornat's findings, asks what it means when a programming paradigm fails: "it can fail when the narrative it embodies fails to speak truth or when its proponents embrace it beyond reason" (Gabriel, 2002, page 2).

While Object-Orientation is important, is the paradigm still too abstract for beginning students? What features are most desirable in a teaching language? Students who have experience with at least one programming language often perform better on introductory courses (Hagan & Markham, 2000). They propose that the more languages a student is familiar with, the steadier their overall performance is over the duration of their studies.

RESEARCH METHODOLOGY

This research presents a framework for classifying and analysing the concepts that are taught and the order in which they are presented by employing terms organised into a custom ontology. Ontologies are common vocabularies of terms built by researchers to enable them to classify and share codified information about a problem domain (Noy & McGuinness, 2001). Ontologies are built using well-defined and clear rules so that concepts can be codified as classes. Figure 3 is an extract of the final ontology which is available for download from our public GitHub repository (Dowdeswell, 2024).

Course material consisting of lecture notes, textbooks, and hand-outs from three university first-year programming courses were obtained. A pilot study was conducted using Auckland University of Technology (AUT) lecture material from all 28 lectures that were delivered in a single semester (Skene, 2014). Each lecture transcript and presentation slide was analysed and summarised into a brief paragraph. OPAIC, AUT, and Stanford also provided extensive background information on the material and how it was developed over time.

Stanford also provided extensive background information on the material and how it was developed over time. AUT's courses catered for 350 students per semester. OPAIC offers two introductory courses, Programming 1 and Programming 2, which are often taken consecutively by students who are predominantly international and have English as their second language. OPAIC classes are smaller, with no more than 30 students in each cohort. A third set of international lecture notes, videos, and hand-outs were obtained from Stanford University. Their undergraduate classes are some of the largest in the world with over 650 students in their CS106A course (MacKay, 2014). Stanford also offered their CS106X course that only teaches C++, focusing on game design. It is targeted at more advanced beginners.

Stanford University's Protégé Ontology Editor was used to capture the concept classes. It has a built-in code generator that can take a´ collection of prototype classes and classify them using automated processes and custom rules (Stanford, 2024). Once an ontology has become sufficiently rich and mature, it is possible to automate the mining of large amounts of textual data. This codification speeds up the analysis of the underlying structure for large amounts of textual data. Each of the key concepts identified in the AUT University pilot study represented a potential candidate for inclusion in the ontology. One of the tasks in the pilot analysis was to identify topics which were mentioned in sufficient detail to be considered important. These represent thresholds between discussions that are not highly significant in relation to the curriculum but are present in the transcripts and those that are considered to be key concepts.

Ethics Approval was discussed initially for this research, but an Ethics Committee Approval was not sought since individual students were not involved or interviewed during the data collection and analysis. No individual student assignments or marks were provided by the faculties.

Figure 3: Example Classes from the Ontology in Protégé showing the properties of an individual class
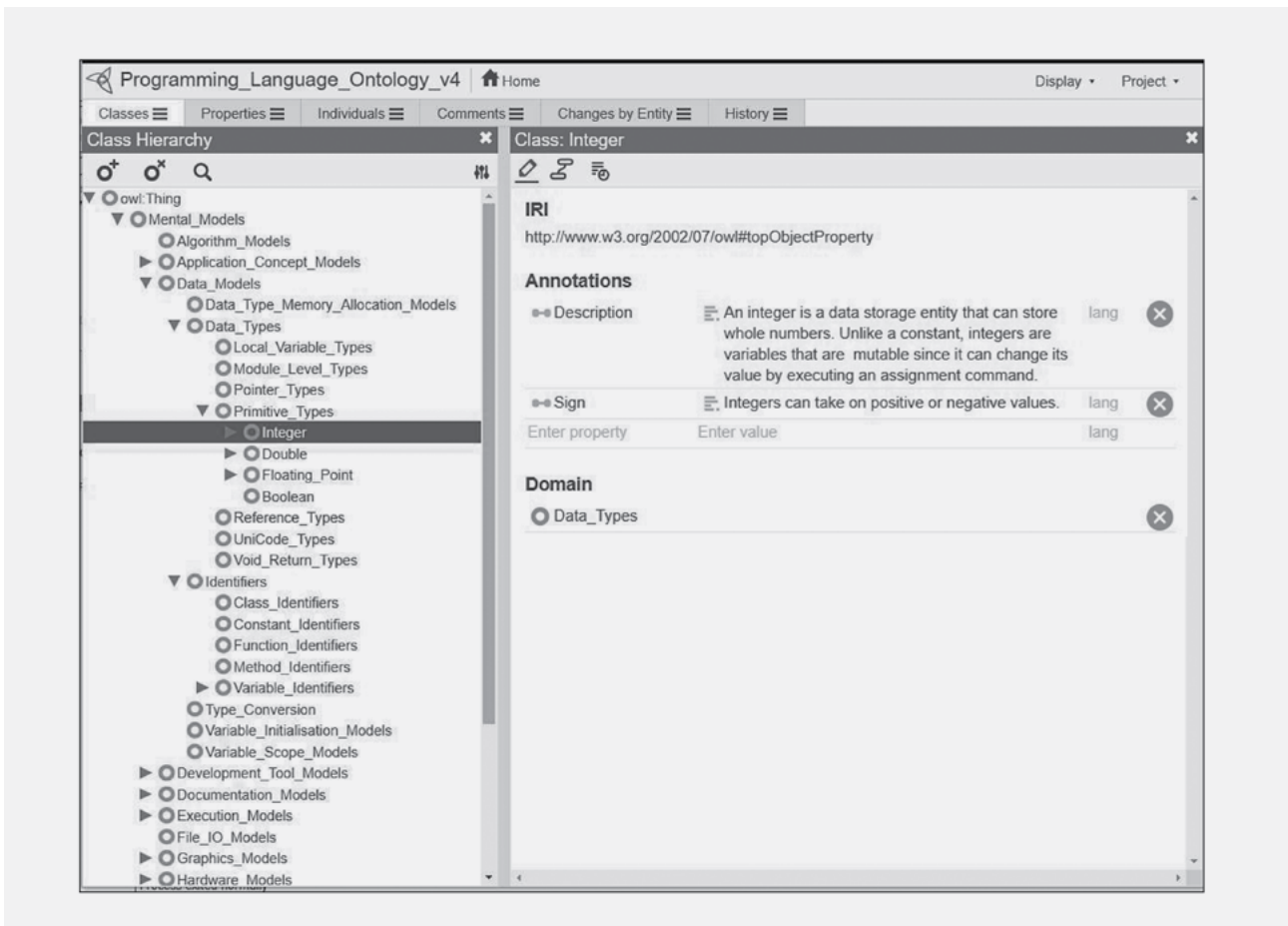
COMPARING COURSES: THREE CASE STUDIES

Robins (2010) suggests that faculties should pay close attention to the order in which related topics are presented. Hence the order in which each concept was introduced in a course, how it was developed, and how often it was reinforced later was of particular interest. Do courses that are more successful introduce concepts in different, unexpected orders? Are particular concepts represented more intuitively in some programming languages than others?

Figure 4: Karel the Robot, used to introduce procedural concepts at AUT and Stanford
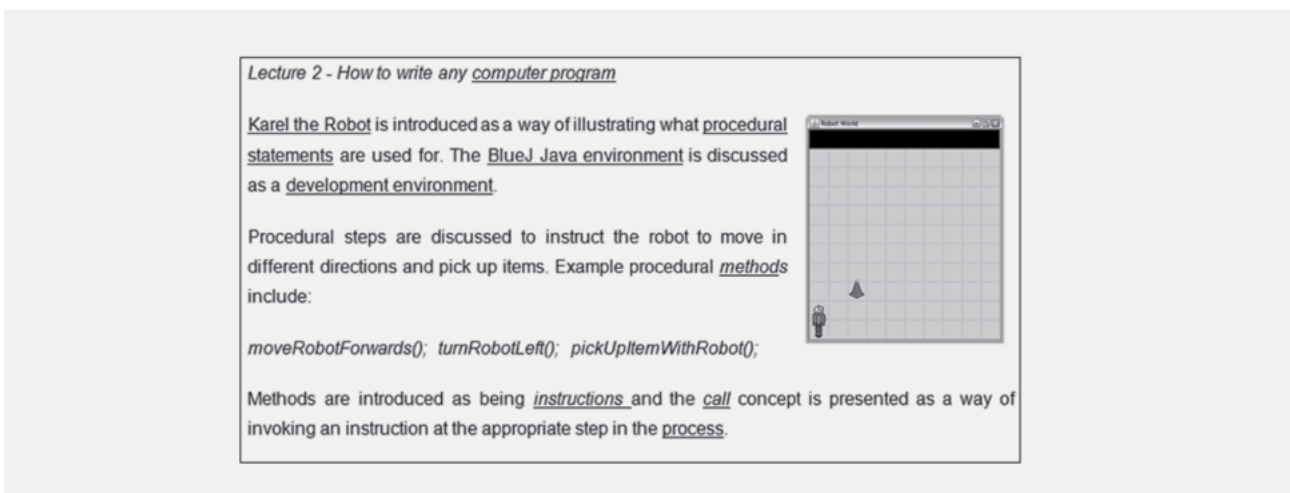
Ontology concepts were identified within the context of discrete topics and the lecture they were presented in. The full comparison available from the repository compares the three institutions, showing how these concepts were developed as the course progressed. Many key concepts were illustrated with reference to Karel the Robot, shown in an extract from the course notes in Figure 4. Karel was a programmable entity used in many code examples. Instructing Karel to perform a task illustrated procedural statements, methods, and function calls. However, it was not explained at this stage that Karel was an object. In this context, the students used Karel as a tool with multiple capabilities without needing to know that it was an object.

During the pilot studies, several example ontologies from different disciplines were examined. The most promising example was that of Lee et al. (2005) who developed an ontology for the Java language. They codified entities present in the Java language by classifying each of the language constructs for branching, control, variable declaration, and method construction separately. In our study, the concepts that students were being taught were more important than the actual implementation of the language statements. Hence the classes evolved to represent Mental Models of the concepts that the students were being exposed to. For example, when two different instances of variable declaration statements were encountered in lectures, such as the BASIC Dim aNumber as Integer or the Java int aNumber = 22; both were codified as members of the Integer class in the Variable Identifiers branch of the ontology tree. Instead of being language-specific, the ontology abstracts language features with a granularity that is sufficient to allow both the Java and the equivalent BASIC or C statements to be identified using the same classes. In this way, each class codifies a separate Mental Model for each teaching concept.

Noy and McGuinness (2001) point out that ontologies are seldom written in one pass. Rather, draft ontologies are trained and refined by testing them against sample data until they begin to more accurately classify concepts. This was observed while building the current version of the Programming 1 and 2 ontology that was used here. Generating it required four iterations, adapting it by generating similar classes in Protégé´ that represented the mental models of the concepts that the students were being exposed to. The most common change was to rename a class to make its purpose more obvious or to move it to a more logical branch of the ontology tree. Abstract concepts such as Inheritance, Recursion, Polymorphism, and Data Hiding moved several times, as did the data type classifications for variables.

ANALYSIS AND CONCLUSIONS

The original research question was concerned with identifying the optimal order in which concepts should be introduced in first-year programming courses. Table 1 is an extract from the comparison of the three courses analysed using the ontology. For each institution, the classification codes of the lecture content taught in that week are shown in parallel. A brief summary of the content discussed in the lecture is included in Table 1 below.

All three faculties begin their courses by presenting similar content, focusing on variables, procedural programming, and conditional control statements. Later, OPAIC and Stanford teach method calls by value and reference in Week 9 while AUT teaches it in Week 14. Objects are explicitly discussed in Week 4 at Stanford, in conjunction with inheritance. By Week 5 at Stanford, classes are presented as being complex variables while AUT defers this until the second half of the course in Week 22. The emphasis in both AUT and OPAIC is to develop procedural concepts that allow conditional control structures to be used simply. Karel was used at AUT to illustrate how to issue commands via program statements. Looping constructs are taught as a way to allow Karel to repeat steps. The value of understanding syntax is emphasised in AUT's system more emphatically than the Stanford approach, where they teach graphics methods and coding examples in-parallel with their Karel illustrations. By Week 7, AUT has taught clear examples of control structures and ways of writing code that instructs Karel. By the same point, Stanford is demonstrating how to invoke object methods and explains return values.

Whenever an Object-Oriented concept was identified, the class is highlighted in red in the analysis. Stanford is Object-Early; they begin teaching objects in their fourth week. This suggests they align with Osborne and Johnson (1993), believing that objects are more intuitive when taught at the same time as fundamental procedural code constructs. In contrast, OPAIC and AUT are Object-Late and do not explicitly mention objects until Weeks 12 and 17 respectively. The approach taken in the early OPAIC C# lectures is to use objects such as the intrinsic Random object as well as the Integer and String classes without identifying them as objects. Students learn to use parsing methods for type conversion without having to know that they are calling class methods.

Table 1: Extract of the First-Year Programming Course Comparison from the Three Institutions
Italics to provide additional contextual information that may not always be obvious from the choice of ontology classes applied.

LEC	AUT UNIVERSITY	OTAGO POLYTECHNIC	STANFORD
1	Procedural_Programming_models Computer_Models Hardware_Models Stored_Program_Models Programming_as_a_Process_ Models *AUT introduces programming as being like the steps in making a cup of tea.*	Programming_as_a_Process_ Models Visual_Studio_IDE_Models *Explanation of the course and how it flows. Illustrating what programming is by considering the steps required to make a cup of tea. Writing the first program Hello_world*	Karel_the_Robot_Models *Stanford is an introductory lecture with mostly administration and protocols*
2	Procedural_Programming_Models Karel_the_Robot_Models Immediate_Command_Models BlueJ_IDE_Models Call_Statements Langauge_Syntax_Models Conditional_Expressions If_Structure Loop_Structure *AUT introduces program commands without mentioning variables.Illustrates the effect of immediate commands and conditional tests.*	Procededural_Programming_Models Variable_Identifiers Data_Types Langauge_Syntax_Models *Becoming confident in Visual Studio and writing programs that run in the console, not the GUI.Declaring and assigning variables.*	Algorithm_Models Stored_Program_Models Karel_the_Robot_Models Conditional_Expressions *Introduces to conditional expressions using Karel*
3	Hardware_Models Primitive_Types Java_Langauge Assembly_Language *Comparing langauge construcs and attributes*	If_Structure *Operator precedence and evaluating boolean conditions for if conditions.* *Formatting variables.* *Casting*	Karel_the_Robot_Models Java_Langauge In-Line_Comments Conditional_Engineering_Models Quality_Models *Introduction to Java and quality concepts.*
4	Text_Identifiers Semi_Interpreted_Langauge_Models Debugging_Models *First mention of debugging to find errors.*	Constants_Models *Coding styles and displaying information correctly*	Historical_Background_Models Compiler_Models Object_Orientated_Models Inheritance_Models Java_Langauge Decomposition_Models *Introduces Object Models and Java as an object-orientated langauge, including inheritance.They also examine their first complete Java program.*
5	Langauge_Syntax_Models *Why syntax and formatting is important.How it relates to control structures*	Loop_Structure Random_Numbers. *Using Random numbers and loops to generate Values that can be used in simple dice roll games.*	Variable_Identifiers Data_Types Classes_as_Types_Models Objects_as_Variables_Models Method_Invocation_Models Graphic_Models Coordinate_Models Expressions *Objects and complex variables. Introduce methods that act on classes that manage graphics.*
6	Control_Structure_Models Indentation Nesting *Why indentation and formatting is important how it relates to control structures.Nesting control structures and flow.*	If_Structure Loop_Structure Logical_Operators *Branching and logical conditions. Introducing or and AND NOT conditions.*	Precedence_Rules_Expressions Floating_point Boolean Type_Conversion Variable_Scope_Models Conditional_Expressions If_Structure Nesting *Variable types and operator precedence.*

This explicit introduction to objects at Stanford exposes students to abstract concepts very early while they are still learning procedural coding. AUT and OPAIC appear to be more evenly paced, teaching similar concepts which are related to each other at the same time. Concept acquisition in technology courses relies on Robins (2010) concept of the Learning Edge Momentum effect. Students learn on the edges of what they already know, so teaching similar concepts closer together helps to make them progressively less abstract as more and more concrete concepts are understood. However, this momentum can also be lost if unrelated concepts are taught together since learners fail to understand how they are related. Positive examples from the study include the first introduction to variables which is immediately reinforced by learning about integers and doubles as examples of related Data Types.

Osborne and Johnson (1993) stress that becoming object-orientated is not about learning more syntax rules. Rather, it introduces abstractions that require a whole new way of thinking. Instancing, references, polymorphism, and inheritance are deeply abstract concepts. It is interesting to consider how early Stanford explores these topics while many students are still wrestling with procedural statements. Osborne observes that in his classes, abstraction is only presented after students have had concrete experience with the underlying concepts. This reinforces the OPAIC and AUT belief that static objects can be successfully taught without needing to introduce instances and references early on.

In conclusion, the analysis suggests that the way concepts are presented is more important than the choice of language. Much of the early literature cited about migrating to Java describes difficulties with the language that may no longer be an issue today. Java has evolved to incorporate many of the features of C and C++ without the need to introduce pointers. Even in 2006, the study by Chen et al. (2006) found few differences in what they called the outward layout or surface characteristics in the design of students' programs. Further, these differences were not attributable to Object-Early or Imperative-Early paradigms. Rather, the literature suggests that the problems lie with both the order and the way topics are taught and how well the hierarchy of related concepts is delivered.

Nicklaus Wirth, the creator of the Pascal language, asserted that people seem to misinterpret complexity as sophistication (Wirth, 2002, page 2). That bears further consideration in this context. Wirth went further stating that "As computing professionals, it is our duty to speak up against a culture that equates computer literacy with mastering the intricacies of a production programming language".

FUTURE RESEARCH DIRECTIONS

This topic suggested a number of future avenues of research, some of which may prove to be quite extensive. OPAIC runs courses in blocks rather than semesters with smaller class sizes. Do shorter courses with smaller classes have a significant effect on students' learning and retention of concepts?

The programming ontology provided a valuable way of classifying the content of the material examined. However, it was not possible within the scope of this article to use the classes to analyse what assignment and examination questions were really testing. This could then be used to correlate the anonymised student marks to gauge the success of teaching individual concepts identified in the curriculum. Analysing this over a number of iterations of a course while factoring in course changes would provide valuable insights.

Modern software engineering addresses the needs of a range of computing platforms, including desktop, web, and mobile. How should we address the differing characteristics of these technologies when students' progress from their first courses to learn about programming in other environments?

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A BRIEF GUIDE TO SPEECH RECOGNITION SOFTWARE IN TERTIARY EDUCATION

Lorraine Skelton

OTAGO POLYTECHNIC AUCKLAND INTERNATIONAL CAMPUS

Speech recognition software is rapidly expanding in the field of academia, becoming an essential tool for students, educators, and researchers alike. With the increasing demands on academic work—whether drafting research papers, transcribing interviews, or taking notes—efficient and accurate tools are effective in streamlining these tasks. Speech recognition software offers the ability to convert spoken words into text quickly and accurately, significantly enhancing productivity and facilitating many aspects of learning and research. This article discusses the ways in which speech recognition software can be used in academic settings and also reviews the best options currently available, evaluating each in terms of accuracy, ease of use, features, and cost-effectiveness. Popular options such as Dragon NaturallySpeaking developed by Nuance (https://www.nuance.com), Microsoft 365 Dictate (https://www.office.com), Google Docs Voice Typing (https://docs.google.com), Otter.ai (https://www.otter.ai), and Apple Dictation (https://www.apple.com) are reviewed to provide a guide for selecting the most suitable tool.

Note-Taking and Transcription: A study by Farrús et al (2023) notes that speech recognition software enhances note-taking, allowing students and academics to focus on the content rather than the act of writing or typing. The study also highlights the efficiency of automated transcription tools, emphasising their role in increasing productivity during lectures and meetings.

Accelerating the Writing Process: The software is beneficial for speeding up the writing process, particularly for those who find dictation a more natural form of expression. This method encourages a more dynamic approach to writing, making it easier to produce written content quickly. Research by Pennington and Rogerson-Revell (2018) discusses how speech recognition technology is increasingly integrated into academic writing processes, significantly reducing the time spent on drafting and editing documents.

Enhancing Accessibility: Accessibility in academia is greatly improved with speech recognition software, as it provides an alternative input method for individuals with disabilities. The study by Farrús (2023) highlights the inclusive benefits of speech recognition, especially for students with physical disabilities that make typing difficult.

Supporting Language Learning and Pronunciation: In language learning, speech recognition provides immediate feedback on pronunciation, aiding both educators and students in enhancing their spoken language skills. The review by Farrús (2023) explores the role of automatic speech recognition in language learning, focusing on its application in improving pronunciation and linguistic feedback, especially important for students who are studying in a second language.

Facilitating Research Data Collection: For qualitative research, speech recognition software automates the transcription of interviews and focus groups, which speeds up the data collection phase. The benefits of this automation are discussed in several academic works, including a study by Pennington and Rogerson-Revell (2018), which underscores the efficiency gains in research environments.

Boosting Productivity: By automating tasks such as writing and searching through documents, speech recognition software significantly enhances productivity. The integration of this technology into daily academic workflows is explored in research by Pennington and Rogerson-Revell (2018), which identifies productivity gains as a key advantage of using speech recognition in academia.

The next step is choosing the right software, from a variety of software options available, each with different features and pricing models. The choice includes decisions around accuracy, ease of use, compatibility with existing systems, and specific academic needs. There are several existing software products to consider, each with specific key criteria that may help in making an informed decision about which one to choose.

Dragon Naturally Speaking by Nuance is widely regarded as the industry leader in speech recognition software and has a lot of experience, having been developed in 1997. It boasts a high level of quality, especially around precision and customisation, offering up to 99% accuracy, with an ability to learn and adapt to the user's voice over time. Dragon also supports the creation of custom vocabularies and voice commands, which is particularly beneficial for users in specialised fields within the academic world, and having been purchased by Microsoft in 2021 it now has seamless integration with applications such as Microsoft Word and Google Docs, enhancing workflow efficiencies. It can also transcribe pre-recorded audio files, which is essential for researchers who conduct interviews or focus groups. The programme can also be used off-line. Dragon Naturally Speaking is however the most expensive option on the market at around NZ$1,120, but it can be justified as an investment for those engaged in complex academic work, and is especially suited to researchers, academics, and students who require top-tier accuracy and customisable features for detailed projects.

Microsoft 365 Dictate is a built-in feature in Microsoft Office applications such as Word, Outlook and PowerPoint, making it easy to use for drafting emails, documents and presentations. It is a convenient and cost-effective option for users already subscribed to Microsoft 365, but this also means that you need to be online to use it. 365 Dictate offers real-time transcription with basic voice commands for punctuation and formatting, and supports multiple languages, catering to a diverse academic audience. Microsoft 365 Dictate is included in the Microsoft 365 subscription, which costs about NZ$130 per year, which adds value for those already using this suite of programmes. Although it lacks the advanced features and accuracy of premium tools like Dragon, it is an accessible and efficient option for everyday academic tasks and can be suitable for students and educators who are already part of the Microsoft ecosystem and require a basic, integrated speech recognition tool.

Google Docs Voice Typing is a free tool available within Google Docs and provides a simple solution for users who need basic speech recognition capabilities without additional costs, making it an ideal option for budget-conscious users. It requires no additional setup or software installation and is easy to activate within Google Docs. It also benefits from Google's cloud-based collaboration features, enabling multiple users to work on a document simultaneously.

Google Docs Voice Typing offers the best cost benefit for users who need basic voice recognition without financial investment. While it lacks the advanced features and accuracy of paid software, its ease of use and integration with Google Docs make it a useful tool for students and educators looking for a free, straightforward speech recognition solution.

Otter.ai is a cloud-based transcription service known for its real-time transcription capabilities. It offers both free and premium plans, making it accessible to a wide range of users. It can be used for live transcription of lectures, meetings, and interviews in real-time. It also supports collaborative work on transcripts, which is particularly useful for group projects and can integrate with platforms such as Zoom for automatic transcription of virtual meetings. As Otter.ai offers a free tier with basic functionality and premium plans starting at around NZ$160 per year, this makes it a cost-effective choice for those who need live transcription and collaboration features. Although it does not offer the same level of customisation as Dragon, its affordability and functionality make it an excellent option for students and academics, who need to transcribe live events and collaborate on notes.

Apple Dictation is a built-in tool available on macOS and iOS devices. It provides a convenient option for Apple users who need a basic dictation tool and works across all Apple devices, offering a consistent experience on MacBooks, iPhones, and iPads. Apple dictation is activated easily via a keyboard shortcut, making it suitable for quick dictation tasks and it supports offline dictation for short periods. Apple Dictation is free for all Apple users, making it an attractive option for those who need basic dictation capabilities without additional costs, but it is less suitable for longer, more complex tasks, as it lacks advanced features and higher accuracy.

CONCLUSION

Selecting the right speech recognition software will depend on individual need, the complexity of the tasks to be done, and budget constraints. Dragon Naturally Speaking remains the best investment, despite its higher cost. Google Docs Voice Typing stands out for its cost-benefit, offering a free and easy-to-use tool that meets basic academic needs. Otter.ai provides a good choice for those requiring live transcription and collaboration at an affordable price, and who need high accuracy and advanced features. Microsoft 365 Dictate and Apple Dictation offer cost-effective solutions within their respective ecosystems, making them suitable for users already utilising Microsoft Office or Apple products.

In summary, the best speech recognition tool is one that aligns with the specific demands of your academic work, offering the right balance between cost, accuracy, and functionality. By carefully considering these factors, academics and students can enhance their productivity and streamline their workflow.

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WOMEN IN NEW ZEALAND'S CONSTRUCTION INDUSTRY: BARRIERS AND WELLBEING ENABLERS

Hetaswi Patel and Firas Majthoub Almughrabi

OTAGO POLYTECHNIC AUCKLAND INTERNATIONAL CAMPUS

ABSTRACT

The construction industry is a component of New Zealand's economy playing a role, in boosting the country's gross domestic product and creating numerous job opportunities. Despite its impact and continuous growth, the industry faces a noticeable gender gap, especially in the lack of female representation in the construction-related roles. This study aims to explore the challenges that prevent women from participating in the New Zealand construction sector focusing on semi-skilled and trade positions. While previous research has investigated barriers to women's involvement across industries, there is a need for more comprehensive investigations, specifically addressing the construction industry especially concerning skilled and semi-skilled jobs.

By identifying and examining the obstacles that hinder women from entering and progressing within the construction industry this research aimed to provide an understanding of the complex mix of cultural, structural, and organisational factors that influence women's participation in construction careers. Going beyond simply recognising gender disparities this study seeks to uncover the dynamics of expectations, workplace environments and systemic challenges that restrict women from making full and equal contributions to the construction industry workforce.

Moreover, the goal of this study was to identify and assess the support systems and conditions that can create an atmosphere for women's involvement and welfare in the construction industry. By highlighting these challenges and suggesting solutions to overcome them this study aimed to enhance gender diversity and equality, in the construction industry.

Tackling these barriers and nurturing a more inclusive work environment is crucial for effectively addressing persistent skill shortages and ensuring the long-term sustainability and growth of the construction industry in New Zealand.

This study employs a mixed research methodology, combining qualitative analysis through an extensive literature review with quantitative data collection via a survey questionnaire, thus providing a comprehensive understanding of the study topic from both documented and numerical standpoints.

Keywords: Construction industry, Gender gap, New Zealand, Skill shortages, Women participation

INTRODUCTION

The construction industry has a significant impact on the economic health of New Zealand. The construction industry contributed approximately $15.8 billion NZD to New Zealand's gross domestic product (GDP) in the fiscal year ending in March 2021 (Statista, 2024). The Ministry of Business, Innovation, and Employment (MBIE) (2021) stated that several key factors have predominantly driven the increased demand for construction workers in New Zealand these factors include the Christchurch rebuild, the high housing demand in Auckland, and the overall upswing in building activity across the country due to the COVID-19 pandemic recovery efforts. As a result of Auckland's high population density, the majority of construction workers are based in this region (Huang & Wilson, 2020). However, the construction industry also plays a crucial role in providing income and employment in other regions, including the Bay of Plenty, Taranaki, Canterbury, and Otago (Ministry of Business, Innovation and Employment, 2021). According to the Building and Construction Industry Training Organisation (2022) although women make up 50.85% (2.53 million) of New Zealand's total population of 5.12 million, less than 3% of construction tradespeople are women. Compared to other Western countries, a very tiny percentage

of New Zealand's construction industry employees are women. They make up barely 13% of the workforce in the construction industry but drop to just 3% when it comes to working on the tools, compared to 47% across all occupations (Qualified Building Solutions Limited, 2024). This illustrates the low participation of women in the New Zealand construction industry and the necessity to address this issue to alter the scenarios.

RESEARCH OBJECTIVES:

Investigating the factors that negatively influence the uptake of women in the New Zealand construction industry and identifying the enhancers that support women's wellbeing in the workplace.

RESEARCH QUESTIONS:

- Investigating the potential factors that are negatively affecting the increased participation of women in New Zealand's construction industry.
- Identifying probable supporting enhancers of women's wellbeing in the construction industry workplace.

RESEARCH GAPS:

Lack of Comprehensive Data on Gender-Specific Barriers:

Existing research on the New Zealand construction industry often lacks detailed data on the specific gender-related barriers women face. Studies tend to be broad, without focusing on the unique challenges that women encounter in this industry (Taffard et al., 2019).

Inadequate Focus on Wellbeing Enablers:

There is a significant gap in the literature regarding the positive factors that contribute to women's wellbeing in the construction industry workplace. Most studies emphasise the negative aspects and barriers without exploring what works well.

EXPECTED OUTPUTS:

Comprehensive Identification of Barriers:

The study will produce a detailed list of the specific barriers women face in the New Zealand construction industry.

Wellbeing Enablers:

Identification of key factors and practices that positively influence women's wellbeing in the construction industry workplace. This will provide a basis for policy and practice recommendations.

LITERATURE REVIEW

Review of the challenges women face in the construction industry:

The construction industry has long been recognised as a male-dominated field, presenting unique challenges for women who choose to pursue careers in this sector (SpringerLink, 2020). Despite progress in recent years, women continue to face various obstacles that hinder their full participation and advancement (Pamidimukkala & Kermanshachi, 2023). This literature review examined the key challenges women encounter in the construction industry.

Respect and dignity:

In a 2021 survey of 1,001 women in the construction industry, respondents reported significant challenges in garnering respect, particularly from leadership (Levelset, 2021). While 80% of women felt respected by their co-workers, only 65% believed that their company's leadership listened equally to men and women (Levelset, 2021). This disparity highlights a persistent issue in the construction industry: many women are dissatisfied with how difficult it is for them to be heard, believing their experience and knowledge are not accorded the same weight as men's (Dean, 2021). These findings underscore the ongoing struggle for women to achieve equal recognition and influence in the construction industry, especially at higher organisational levels.

Construction is a Male-Dominated Industry:

Despite the construction industry's claimed intention to employ more women, building remains a male-dominated industry (PWC, 2016). When there are so many men present, even the most powerful and self-assured woman may feel uncomfortable. Even while the male-to-female ratio is slowly improving, it may be years before men no longer outnumber women in the construction business (Lekchiri, 2020).

Workplace facilities:

According to Hislop (2021), women working on construction sites often have to leave the site to use a restroom because there usually aren't any restrooms just for women on-site. Since there are fewer women in construction, it's uncommon to find gender-specific restrooms. As a result, women should be ready to use unisex portable toilets which are hardly known for being clean, and sharing one with multiple male coworkers can be an unpleasant experience (Kristina, 2022).

Work-family Balance:

Inter-role conflict develops when the energy, time, and behavioural demands of the work role intersect with those of the family and personal life roles (Smoktunowicz et al., 2017). Work-family conflict constitutes a subset of work-life conflict (Frontiers, 2020). Work-family conflict increasingly influences workplace and personal outcomes such as productivity, turnover, family wellbeing, health, and stress (Obrenovic et al., 2020). Work-family conflict has a direct impact on an individual's career, family, and wellbeing (Kossek & Lee, 2017). Due to the nature of the construction industry, many women are forced to make difficult career and family decisions (Vainikolo, 2017). In some high-risk occupations, women may not be able to lift as much as men. A poor work-life balance discourages women from pursuing jobs in the construction industry (Kumar & Chaturvedi, 2018). In addition to gender discrimination, workplace harassment, and behavioural issues, women in the construction industry confront a variety of additional psychological challenges (Rotimi et al., 2023). In patriarchal countries where women are seen as primary caregivers, mixing work and home responsibilities can be hazardous (Sharma et al., 2016). In addition, the organisational culture of the construction industry will impede any attempts by women to negotiate work-life balance (Kumar & Chaturvedi, 2018).

Wellbeing Enablers in the Construction Industry for Women

- Trying to alter the construction site.

  Making the construction industry more welcoming to women may involve fostering a more inclusive workplace culture (Construction Sector Accord, 2020). Jo Duffy, the organiser of the Women in Construction Forum, told Radio New Zealand that construction workers may experience feelings of isolation (Scoop Media, 2017). Changing this would need actively including female employees in workplace debates and social dynamics, as well as making practical improvements such as ensuring the cleanliness of on-site restrooms (Tradestaff, 2017).

- Ensuring compatibility with caring responsibilities

  In predominantly male-oriented industries, motherhood plays a crucial role for women, particularly in sectors where men have traditionally engaged in extended hours away from home (Torres et al., 2024). Instead of focusing on how to maintain women in the workforce, the discussion should be on how to accommodate all parents and those with greater caregiving responsibilities (Center for Creative Leadership, 2024). Balfour Beatty (2022) suggested that to prevent a loss of skilled labour, companies should encourage those with family responsibilities to continue working.

- Rooting out discrimination and sexism

  In the construction and infrastructure industries, numerous women still report suffering sexism on the job, and Every act of sexism, racism, and bullying and harassment must be challenged, and the entire industry must endeavour to establish such a culture (Norberg & Johansson, 2020). Women in the construction business should not face more discrimination, harassment, or intimidation than men. Everyone, regardless of gender, should have equal access to employment opportunities (Perlo Construction, 2023). Employers are obligated to provide employees with essentials, such as safe restroom facilities and properly sized protective equipment (Balfour Beatty, 2022).

Steps initiated in New Zealand to encourage women's participation in New Zealand's construction industry.

The Building and Construction Industry Training Organisation is a division of Te Pūkenga - New Zealand Institute of Skills and Technology. It oversees apprenticeship programmes within the New Zealand construction sector. Renowned for its strong work ethic and dedication to the professional development of its employees, this organisation plays a pivotal role in the industry. However, it is noteworthy that women constitute only 2.6% of the participants in these apprenticeship programmes, a figure that is disproportionately low compared to the overall female population in the country (Climo, 2017). This statistic highlights the significantly low participation rate of women in the construction industry.

The low participation of women in the construction industry can be attributed to several barriers. Based on interviews conducted with approximately 35 successful women in trades, the following reasons were identified:

- The gender pay gap in New Zealand stands at 9.4%.
- The male-dominated culture of the trades.
- Difficulty in finding employers willing to hire women.
- Lack of knowledge about the opportunities within the trades.
- Persistent gender stereotypes (Taffard et al., 2019).

Steps towards diversifying New Zealand's construction industry:

To increase women's participation in the construction industry in New Zealand, it is essential for employers to adopt a collaborative strategy focused on attracting, recruiting, and retaining women in these roles (Hegarty, 2020). To promote gender diversity, the construction industry must become more open and adaptable so that women seek out and keep jobs (OneStaff, 2023). Importantly, this transformation cannot be accomplished by focusing solely on women, but rather by implementing a systemic approach to culture change for all workers across the whole construction industry. In order to bring in this change there have many initiatives undertaken by several organisations within the construction industry and some of them are stated below.

The project goal of BCITO is that women make up to 30% of people in construction trades roles by 2040 and women make up to 10% of BCITO apprentices by 2025 (Scoop Media, 2024)

The National Association of Women in Construction (NAWIC) supports women to explore, establish, and maintain successful professions in the construction industry (Ministry of Education, 2023). Its membership offers the opportunity to be connected to other women in the construction industry, to learn from, be supported by and network with (NAWIC, 2024).

Māori, Pasifika, Trades Training is an institution that provides scholarships to Māori and Pasifika learners who aspire to become part of the trades sector and encourages Māori and Pasifika women to become part of trades and building (Māori & Pasifika Trades Training, 2024). The Skills Organisation provides trades training in New Zealand and actively encourages more women to enter the trades by organizing initiatives such as get-togethers for women from various trades to meet and connect (The Skills Organisation Incorporated, 2021).

METHODOLOGY

In this study, the data were gathered through two distinct sources. Firstly, secondary data were collected by thoroughly reviewing and understanding the existing literature, including but not limited to journal articles, reports, government data analysis, and official websites. Secondly, primary data were acquired through an online survey distributed to multiple construction industry stakeholders such as industrial manufacturers, suppliers, engineers, designers, contractors, and subcontractors. The target was to ensure their active contribution to the study and to acquire insight into their perceptions regarding the barriers and wellbeing enablers for women in New Zealand's construction industry.

RESULTS/FINDINGS

This section provides a comprehensive presentation of data collected from the online survey. The online survey methodology utilized (a) eleven structured closed-ended questions with predetermined answers and (b) an open-ended question to ensure flexibility, and comprehensive data collection.

The demographic profile section revealed insightful details about the participants (see Table 1). Notably, 63% of participants had less than five years of experience in the construction industry.

Table 1: Experience in the Construction Industry

EXPERIENCE IN THE CONSTRUCTION INDUSTRY	PERCENTAGE
Less than 5 years	63%
6 -10 years	26%
11 - 15 years	7%
16 - 20 years	4%
21 - 25 years	0%
More than 25 years	0%
Duration	6

The main contractor category was the most represented at 41% (see Table 2). This information established a foundational understanding of the online survey participants, allowing for a contextualised analysis of the subsequent findings. Knowing that a significant portion of the participants are main contractors helped in interpreting trends and patterns in the data.

Table 2: Business Category of Participants

BUSINESS CATEGORY	PERCENTAGE
Contractor	41%
Architect	4%
Engineer	7%
Manufacturer	7%
Consultant	0%
Sub - Contractor	26%
Other	15%

Data analysis involved a thorough examination of the obstacles and enhancers impacting women's participation in the construction industry. The structured close-ended questions were assessed using mathematical formulas such as mean and standard deviation. These statistical analyses provided valuable insights into the prevailing trends and perceptions within the construction industry.

The main goals of this study were twofold:

1. To analyse obstacles faced by women in the construction industry: Participants were asked to rate various obstacles they encounter using a Likert scale ranging from 1 to 5. This provided a thorough assessment of the challenges they face.
2. To identify wellbeing enablers for women in the industry: After addressing the obstacles, participants moved on to evaluate wellbeing enablers.

In this study, the responses from the online survey were analysed using statistical methods, specifically the mean and standard deviation. The frequency used in these calculations represents the number of responses for each option in the survey. To calculate the mean, the sum of all observed values (i.e., the outcomes for each survey question) was divided by the total number of responses. Thus, the formula for the mean ($\bar{x}$) is:

Mean ($\bar{x}$) =Sum of all data points /Number of data points.

The range is an essential measurement, as the figures at the top and bottom of it represent the most extreme deviations from the mean ($\bar{x}$). However, they provide little insight into the variation of observations around the mean. The standard deviation (SD) comes into play here (Hargrave et al., 2024). As the square root of the variance, standard deviation is a statistic that represents the dispersion of a dataset relative to its mean ($\bar{x}$). The standard deviation is computed as the square root of variance by calculating the relative deviation of each data point from the mean ($\bar{x}$) (Hargrave et al., 2024).

Investigating the potential factors that are negatively affecting the increased participation of women in New Zealand's construction industry.

This section of the online survey identifies numerous factors that have a detrimental impact on the uptake of women in the New Zealand construction sector, either directly or indirectly. The analysis made it easier to spot obstacles and understand the full scope of issues relating to future work implementation.

Table 3 below provides an examination of the factors that negatively impact women's participation in the construction industry in New Zealand, based on research and online survey results.

Table 3: Reasons Negatively Influencing the Healthier Uptake of Women in the New Zealand Construction Industry

CHALLENGE	FREQUENCY	MEAN	STANDARD DEVIATION
Difficulty to reach a senior position	27	3.44	1.03
Leaving the construction industry due to gender imbalance	27	3.41	0.87
Lack of support from superiors at the workplace	27	3.11	0.92

Analysis and Context

- Difficulty to reach senior positions (M=3.44, S=1.03): Men tend to attribute women's lack of career advancement to their perceived lack of relevant experience. In contrast, women were more likely to attribute their slower progress to male stereotypes, biased assumptions, and being excluded from informal networks.

- Leaving the construction industry due to gender imbalance (M=3.41, S=0.87): This statistically significant concern indicates that participants agree gender disparity is a factor in women leaving the profession.

- Lack of support from senior managers in the workplace (M=3.11, S=0.92): The mean score suggests that senior managers' support for women in the organisation is a statistically significant factor.

Identifying probable supporting enhancers of women's wellbeing in the construction industry workplace

The second objective of this study was to identify probable supporting enhancers of women's wellbeing in the construction industry workplace. Table 4 below for the four major wellbeing enablers which can help to improve the uptake of women in the construction industry.

The most statistically significant factor for improving women's wellbeing in the construction industry workplace was providing specialist advice for women entering the industry (Mean = 4.26, SD = 0.77). The second most impactful factor for increasing women's participation in the construction industry was maintaining better workplace policies and ensuring a thorough understanding of existing ones (Mean = 4.15, SD = 0.65).

The third factor that can help enhance women's uptake in the construction industry is ensuring that women receive equal pay for work of equal value (M=3.93, S=0.77). In the past, the gender pay gap was perpetuated by differences in education, the kind of professions men and women undertake, and the industries in which they work, as well as the fact that women are more likely to work part-time (Ministry for Women, 2023). The fourth factor considered whether government mentoring programs could support women's wellbeing in the construction industry, thereby enhancing their participation in the future (M=3.89, S=0.99).

To make the construction industry more welcoming to women, a reform in culture is required; eliminating the persistent culture of bullying and harassment will benefit everyone (Hurd & Dyer, 2024). The last factor with the lowest mean (M=2.96, S=1.07) was related to the question if New Zealand's construction industry has failed to provide a safe environment to attract more women. This is a strong statement supported by data, indicating that the New Zealand construction industry is actively encouraging women to enter and remain in the industry, thereby contributing to its diversity.

Table 4: Supporting enablers in the construction industry workplace for women.

STRATEG	FREQUENCY	MEAN	STANDARD DEVIATION
Providing specialist advice for women seeking to enter the industry	27	4.26	0.75
Maintaining better workplace policies and understanding existing ones	27	4.15	0.65
Ensuring women receive equal pay for work of equal value	27	3.93	0.77
Government mentoring programmes to support women	27	3.89	0.99
New Zealands's construction industry has failed to provide safe environment to attract more women	27	2.96	1.07

Online survey related statistics:

A significant portion of this study was devoted to examining the major challenges women experience in the construction industry. To explain this and determine the negative elements contributing to the low number of women in the construction industry, a set of three closed-ended questions (part of the eleven closed-ended questions of the survey) were developed and included within the online survey, with the following results:

There is a lack of support for women from their managers in the construction workplace: 37.04% neither agree nor disagree, 26.63% disagree, 25.93% agree, 7.41% of the participants strongly agree and 0% strongly disagree.

Women leave the construction industry due to the gender imbalance: 44.44% agree, 29.63% neither agree nor disagree, 18.52% disagree and 7.41% of the participants strongly agree.

It is more difficult for women to reach a senior position in the construction industry: 40.74% agree, 25.93% disagree, 18.52% neither agree nor disagree and 14.81% of the participants strongly agree.

Overall, the different barriers and reasons stated under the literature review were significant reasons for the lower uptake of women in the construction industry in New Zealand.

CONCLUSION:

The conclusions drawn from the study findings, recommendations for addressing barriers faced by women in the construction industry in New Zealand, and workplace strategies promoting wellbeing are presented. Additionally, the primary contributions of the study are discussed, and avenues for further investigation are suggested. The recommendations were derived from input solicited from the construction industry participants via open-ended questions in the online survey.

The historically low participation of women in the construction industry globally has been attributed to its male-dominated nature (Khattar, 2024). This study aimed to identify specific barriers and enhancers for women's participation in the New Zealand construction industry. It commenced with an extensive literature review to establish a knowledge foundation and identify research gaps.

The primary objectives were twofold: firstly, to investigate barriers inhibiting women's participation, and secondly, to identify workplace factors promoting positive wellbeing. A mixed-methods approach was employed, combining a literature review with an online survey of the construction industry experts.

Objective one focused on understanding the reasons hindering women's uptake in the construction industry. The online survey data highlighted significant issues, including the gender pay gap, underrepresentation of women in senior positions, and challenges in creating a more inclusive environment for future female workers.

Objective two aimed to identify supportive enhancers for women's wellbeing in the construction industry workplace. Both the literature review and online survey responses underscored key factors, such as providing tailored guidance, implementing better workplace practices, ensuring equitable pay, and leveraging government initiatives.

Based on the findings, recommendations were proposed to address the construction industry's skilled labour shortage and promote diversity. These include advocating for strict policies against bullying and harassment, expanding support programmes for women apprentices, urging government intervention to implement flexible workplace policies, and fostering a more inclusive construction site culture.

In essence, there is a critical need to address barriers and enhance workplace support specifically to increase women's participation in the construction industry in New Zealand. By implementing the recommendations, the construction industry in New Zealand can overcome challenges and foster a more inclusive and diverse working environment for women.

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FROM IMMIGRANT TO INFLUENTIAL BUSINESS TRANSFORMATION AND INNOVATION CONSULTING: AN INTERVIEW WITH VÉRONIQUE MANTI.

Lorraine Skelton

OTAGO POLYTECHNIC AUCKLAND INTERNATIONAL CAMPUS

ABSTRACT

The world is becoming increasingly interconnected, with approximately 3.6% or 281 million people living outside their country of birth. New Zealand, with its unique blend of cultures and opportunities, reflects this global trend, as 28% of its population comprises individuals who began their lives elsewhere. The journey to a new country can be filled with challenges, from navigating unfamiliar cultures and languages to adapting to new professional landscapes. One such individual who has successfully made New Zealand her home is Véronique Manti. In a recent interview, Véronique shared her inspiring professional journey, detailing how she overcame these challenges to become a prominent Business Transformation and Innovation Consultant in New Zealand.

INTRODUCTION

Véronique's story is one of resilience, adaptability, and a relentless pursuit of excellence. An immigrant to New Zealand in 2003, Véronique began her journey as a Project Coordinator at a large bank during a significant merger. Today, she is a highly respected business transformation and innovation consultant, known for her ability to drive change and foster innovation across diverse sectors. In this interview, Véronique shares her insights and experiences, offering a glimpse into the journey that led her to become a leader in her field. Her journey began before the move to New Zealand.

VÉRONIQUE MANTI

"I began my career as an Event and Marketing Manager after studying marketing and communication. It was during this time that I was first introduced to IT projects, becoming the process owner for a client relationship management system at a commercial law firm. This role piqued my interest in how technology could drive business processes."

"When I moved to New Zealand in 2003, I worked as a Project Coordinator for a large bank undergoing a merger, which paved the way for my development as a Project Manager. I naturally gravitated towards managing stakeholder expectations and creating communication plans—essentially engaging in change management before it was widely recognised as a discipline."

However, the path to being a Change Manager was relatively recent, as the subject itself is new to New Zealand. The Change Management Institute New Zealand has only been operating here since 2005.

"My official introduction to change management came about six years ago while working for an IT services and consulting company. I was inspired by a Change Management Framework based on Prosci, which had been developed in one of their Australian offices. However, at the time, the New Zealand market wasn't quite ready for a dedicated change management practice."

Being involved with a relatively new approach meant that in order to gain experience and practice, Véronique had to move companies.

"I joined another consultancy that supported my professional development and completed Prosci training at the start of the pandemic. Upon returning to the office, the organisation underwent a merger. This was a turning point in my career, as I joined the Transformation Office and began working on key projects to support the merger. Concurrently, I developed a Change Management Practice for the consultancy's clients."

It was at this stage that Véronique decided to formalise her years of experience by pursuing a BAppMgt in Business Transformation, to consolidate her knowledge and pursue further professional practice as the demand for Change Management Specialists grew.

"This specialisation met a growing demand in the market, leading to exponential growth in my career, and after working for consultancies for a few more years, I transitioned to working independently as a contractor in October 2022."

When the Change Management Institute was initiated, the focus was on the smooth transition of technology into the workforce, but as Véronique notes, companies are realising that all changes need an integrated approach.

"This move opened up new opportunities beyond IT-based projects. I found myself working with a large Kiwi company setting up a new business unit and with another company's innovation team. I discovered a passion for where people, systems, and processes intersect, and how to best combine these elements to build successful teams and launch new products, services, and business units."

Véronique uses an adaptable set of techniques, depending on the specific needs of the transformation she is working on and draws from various methodologies, including design thinking, human-centred design, Lean Start-Up, Project Management (both waterfall and agile), and Change Management frameworks like Prosci and Kotter's 8 steps.

"I'm a voracious reader and draw inspiration from a wide range of subjects, such as psychology, behaviour, leadership, change, and communication. I also learn a great deal from the leaders I work with, who often have different backgrounds from mine, making the experience incredibly enriching".

She enjoys collaborating with visionaries to bridge the gap between the current business state and their vision for the future, through the right combination of people, processes, and systems, often resulting in new operating models. As with any future initiative there are challenges, especially with a lengthy and complex transformation.

"A recurring challenge in digital transformations is that the technology element is often ready before the people and business are fully prepared for the change. To address this, I conduct regular readiness assessments with business leaders to gauge their teams' preparedness for adopting new ways of working. I've also observed that while digital teams often work in an Agile methodology manner, businesses prefer a more Waterfall methodology approach, as it provides the clarity needed to manage change effectively."

While resistance to change is a natural human response, Véronique addresses this using the SCARF model by David Rock; Rock argues that we have a strong drive to seek out five key things: Status, certainty, autonomy, relatedness and fairness. This allows for a tailored plan of action with the relevant leaders to address staff concerns. Leadership plays a critical role in this process, as they actively involve their teams, seek and respond to feedback, and help balance their day-to-day responsibilities with the demands of the transformation.

Success is measured through a combination of factors, including the achievement of project goals, the adoption rate of new processes or technologies, and the overall impact on business performance. Performance indicators include increased efficiency, cost savings, or improved employee engagement and customer satisfaction.

AI is currently a big influence on technology change, and there are concerns about machines replacing jobs, although Véronique sees this as an opportunity to automate mundane tasks, allowing people to focus on higher-value work that requires creativity, problem-solving, and emotional intelligence.

"I'm particularly passionate about how to best deliver on strategy through effective operating models—bringing together people, processes, and systems to create environments where both individuals and businesses can thrive. The integration of AI will soon play a crucial role in how we reorganise and reinvent our work. Learning about emerging trends and technologies is essential to provide the best possible advice and services to my clients."

Continuous learning is key to staying ahead in this field, and Véronique's journey in business transformation and innovation consulting is a testament to her adaptability, continuous learning, and passion for helping organisations navigate change. Her expertise in integrating people, processes, and technology positions her as a valuable partner for businesses looking to thrive in an ever-changing world.

Véronique's journey is a powerful reminder that success in a new country is not just about adapting but also about thriving by continuously evolving. Her story illustrates how perseverance, a commitment to lifelong learning, and a deep understanding of the intersection between people, processes, and technology can lead to remarkable achievements. As New Zealand continues to be a vibrant fusion of cultures and ideas, professionals like Véronique are helping to shape the future of its business landscape. Her work in business transformation and innovation is not only transforming organisations but also paving the way for a more agile, resilient, and forward-thinking approach to change. Véronique's insights and experiences serve as an inspiration to others navigating similar paths, proving that with the right mindset and tools, the challenges of a new beginning can be turned into opportunities for growth and success.

DEVELOPING CRITICAL THINKING CAPABILITIES FOR INTERNATIONAL POSTGRADUATE LEARNERS IN A NEW ZEALAND ITP

Andrew Widjaja & Edwin Rajah

OTAGO POLYTECHNIC AUCKLAND INTERNATIONAL CAMPUS

ABSTRACT

This is an exploratory study evaluating key factors contributing to the development of critical thinking capabilities for international postgraduate business learners in a tertiary education organisation in NZ. The study adopted qualitative methods through semi-structured interviews and purposive sampling to obtain primary data from 26 participants from three different groups: learners, lecturers and managers in a tertiary institute. The findings of the data analysis through thematic analysis showed:

- The top six challenges for critical thinking development for international postgraduate learners are language barriers, cultural background, previous education system, time management, and prior experience with critical thinking.

- The study proposed three approaches to improve critical thinking capabilities: pre-course strategies, in-course strategies, and post-course strategies.

INTRODUCTION

Critical thinking (CT) is a key capability for every individual to function effectively as a global citizen (Facione & Facione 2013, Peach & Clare 2017). CT has been defined as the ability and willingness to form objective judgments based on well-supported reasoning, evidence, key principles or criteria, and key perspectives (Guo, 2013; Cone et al., 2016). CT is important for individuals to effectively contribute to making well-reasoned judgements in the decision-making process (Kalelioğlu & Gülbahar, 2014). Studies show that critical thinking capabilities are even more imperative to function in the 21st century, and individuals are expected to possess higher order thinking capabilities to function effectively in increasingly complex contemporary work and social environment (Kalelioğlu & Gülbahar, 2014; Sellars et al., 2018). Mehta (2015) points out the training and development of CT capabilities for individuals begins in early childhood and continues through tertiary education level in New Zealand. CT is an ongoing process which continues well after the formal education process and continues throughout the professional work and social lifespan of an individual (Brookfield 2002, Thornhill-Miller, Camarda et al. 2023). Postgraduate study requires all learners to have adequate levels of CT ability to perform in the learning tasks to complete their study programme (Saadati, Tarmizi, & Bayat, 2010). However, studies have shown that international learners appear to have inadequate levels of CT capabilities reflected by lower levels of understanding, analysis and evaluation which contributes to lower levels of performance (Crenshaw, Hale, & Harper, 2011; Fell & Lukianova, 2015).

- What are the key challenges and barriers for the development of CT capabilities for international postgraduate learners?

- What strategies or approaches provide a supportive context for international postgraduate learners to improve their CT capabilities?

LITERATURE REVIEW

It is asserted that CT skills are essential for learners to function effectively in academic and work contexts (Saldıray and Doğanay 2024), and it is one of the top ten most in-demand capabilities for employment (Cai & Sanrakan, 2015). A survey in 2013 by the American Association of Colleges and Universities (AACU) found that 75% of employers wanted tertiary institutions to place more emphasis on critical thinking, real world problem-solving, communication, and creativity, and 93% of these employers thought these skills should have a higher priority in tertiary studies (Haynes, Lisic, Goltz, Stein, and Harris (2016). Another study stated that CT skills were ranked as one of the most important skills related to professional development (Allen and Van der Velden. 2012; Thornhill-Miller, Camarda et al. 2023). Hence, the evidence shows strong support for a greater need for the workforce to be equipped with higher levels order CT skills (Zare and Othman (2015).

In the context of New Zealand education, CT is classified as a lifetime skill by the Tertiary Education Commission in the Statement of Intent 2015–2019 (Mehta, 2015). Educators have echoed employer perspectives that the cultivation of CT skills is a core purpose of higher educational institutions (Hill, Walkington, & France, 2016). However, employers have indicated the current levels of CT capabilities of college graduates are reported to be deteriorating (Camarata, 2017). Thus, a key role of higher education is to support the development of CT capabilities through questioning and reflecting on their own experiences to enhance levels of higher order thinking skills (Evans, Nguyen, Richardson, & Scott, 2018).

The evidence points to CT capabilities being learnt skills, in that they are developed over a period of time and refined with continuous practice (Njiraini, 2015). Against this backdrop, the idea has been mooted that international learners are perceived to have less well-developed CT capabilities, for example lacking skills of analysis, and not having sufficient levels of critiquing and interpretation (Egege & Kutieleh, 2004). Whilst all learners face challenges in developing their CT skills, international learners also have to contend with thinking critically in a second language which exacerbates the challenges for development of their critical thinking capabilities (Aston 2023; Floyd, 2011). This would suggest communication – written or verbal skills may also be a contributor to lower levels of CT capabilities. For example, this may be the case when teachers report that international learners' writing is frequently descriptive or that learners are not able to mount logical, coherent and persuasive reasoning to support critical thought in writing (Fell & Lukianova, 2015). Thus, weaker levels of communication and writing skills might be a contributing factor linking the lack of criticality in learner evidence in assessments (Fell & Lukianova, 2015). Poorer levels of CT capabilities in international learners have also been associated with cultural and linguistic differences, where some cultures do not encourage CT (Shaheen, 2016), for example when criticality is seen to be challenging the status quo and considered disrespectful. The cultural context might also be associated with educational approaches in places where the learner originates from, for example, where learning adopts surface learning approaches (Egege & Kutieleh, 2004; Shaheen, 2016), didactic and passive learning, rote learning approaches (Fell & Lukianova, 2015), all of which do not lend themselves to supporting in-depth development of critical learning capabilities.

Hence this study contributes to knowledge enhancement aimed at providing clarity on international learners' challenges in developing higher levels of CT. This knowledge can support stakeholders such as international learners, higher educational providers, and employers/managers in their reflection on the challenges and strategies to improve levels of CT.

RESEARCH METHOD

We collected qualitative primary data using semi-structured interviews for this study. The qualitative data was obtained from international postgraduate learners (existing and graduates) studying in Auckland, lecturers who have taught on postgraduate programmes, and managers with industry experience. As this study intended to tap into "rich" data rather than data quantity, we opted to apply qualitative methodology using purposive sampling from a relatively small sample of participants for the study (Lopez & Whitehead, 2013). Data collection was drawn from 26 participants comprising 3 groups of participants and online interviews. Prior to data collection, this study obtained ethics approval. Each of the participant groups were asked to respond to semi-structured interview questions on barriers and challenges for developing critical thinking (CT) capabilities and approaches to improve CT capabilities of learners. This study adopted thematic analysis to analyse interview transcripts (Braun & Clarke, 2012; Nowell, Norris, White, & Moules, 2017). This thematic analytical approach enabled the study to report that it yielded information on two key themes and several sub-themes for each key theme (Braun & Clarke, 2012).

FINDINGS

The findings section presents thematic qualitative data analysis from the three participant groups: students (S), graduates (G), lecturers (L) and managers (M).

The qualitative data analysis is organised along two overall themes. The first theme reports on CT barriers which relate to the first research question, while the finding for the second theme (research question 2) reports on participants' suggested strategies for improving CT capabilities.

THEME 1: BARRIERS TO CT

Overall findings - Student participants (S, G)

The findings show that language barriers, cultural backgrounds, previous education systems, time management, and prior experience with CT are barriers that international postgraduate students face in developing CT capabilities. We present participant evidence of these specific sub themes below:

Language barrier

"English is my second language... quite hard to express my opinion, my argument in writing." (S1)

"The way of thinking in Chinese is different from English. I need to do CT in English. This is the language barrier for me." (S8)

"English is not my first language... the hardest one is when I'm writing the assignment because they require us to write in high level, like academic writing." (G2)

Culture

"In Indonesia, you tend to not think critically about things, you do accept things as they are. It could be based just on the cultural... like respecting your elders, you don't question your elders, you don't question your seniors." (S6)

"In Korean culture, we don't speak our own opinion... Just listen… you just hesitate to say it when you have conversations with older people, it might be rude to say your opinion." (S10)

Previous education system

"In Indonesia, how they teach is quite different, it's more like one way. It's hard for me to talk with the lecturer, because we are like not like in the same level." (G2)

"In China… only see one-sided opinion, and it develops stereotype opinions. The education environment… I teach you and you just listen, you don't ask questions. The teachers really can't take challenges. They will take it as disrespectful if you ask a question." (G5)

"The teachers always have the right to say things as a norm, the students have to believe what the teacher said is true. The habit of argument or discussion, we don't have that kind of thing in our education system. We don't think twice about that, it's more like one-way communication." (S7)

Time management

"There's a lot of literature and then how you compare this literature with the other one. It just takes up your time. You need to read a lot of things". (G3)

"It's only lack of time… It does not allow me to analyse everything critically. (S2)

"…the time… you can get lost in your own train of thoughts... time management, sometimes thinking critically would reduce your working speed. And if you're facing deadlines, that may not be a luxury that you have all the time." (S6)

Prior experience with CT

"In my country, in my previous studies, there was no CT at all. So, this is my first time, first experience of applied CT. So, it's hard to do CT.… whenever I write an assessment, it becomes too descriptive." (G8)

"When I came here, and I took the first class, I was overwhelmed. This level of CT is new to me. There was no formal training for CT in the Philippines, CT was not utilized at this level. When I submitted my draft, the professor told me that everything I write is descriptive. I'm not using CT." (S3)

"The first time the lecturer asked me to think critically... I didn't have an experience about this in Korea, I had no idea what CT is at first." (S10)

OVERALL FINDINGS: LECTURERS (L) PARTICIPANT

The overall findings of the data analysis for lecturers show that language, previous educational system and prior experience with CT are factors identified as barriers toward CT capabilities for students. The sub-sections below present the specific findings for each sub-theme with examples of participant evidence.

Language barrier

The data analysis also shows that the English language barrier is a factor that lecturers also mention as a challenge that students faced for developing CT capabilities.

"The language barrier might be a problem for a lot of international students. They want to express themselves, they want to critique, they want to show their logical thinking, their reasoning. But it is hindered by the language skill." (L1)

"…international students have good CT capabilities, but they struggle with expressing it and getting the CT in written form… in academic writing." (L2)

Previous education system

"…different education system where CT has not necessarily been a focus." (L3)

Prior experience with CT

"They haven't necessarily had to do this before. The difficulty is selling it to students as something that would be beneficial to them. It is actually a critical skill you want to have." (L3)

OVERALL FINDINGS: MANAGERS (M) PARTICIPANTS

The overall findings of the data analysis for managers report cultural background and one-sided thinking as barriers toward developing CT capabilities in students. The sub-sections below present the specific findings with examples of participant evidence.

Cultural background

"The issues with international graduates mostly have to do with like cultural background. They were taught to not question authority; they were taught not to question things that their managers have told them." (M2)

One-sided opinion

"Some international students, their points of view are very solid… having this strong view disables you to think outside the box. If you have a narrow mind, a strong view, even though I keep explaining to you [my own opinion], you're so focused on your own view that you fail to understand." (M3)

THEME 2: STRATEGIES TO IMPROVE CT

This second theme presents evidence of suggestions by students, lecturers and managers to improve the development of CT capabilities

Student participants' overall findings to improve CT

The student participants presented a range of ways to improve CT capabilities reported below.

In-class discussion

In-class discussion is one approach that students think can support the development of CT capabilities.

"What I find that could be useful: brainstorming and finding relationships between one subject to another, this will help develop a better idea in writing your assessment." (G4)

"Online sessions or offline sessions in classroom give us tasks for group discussion... to provide some positive or negative features of different events, so they can encourage students to provide more critical analysis in their assignments." (S2)

"…discussions in class about all aspects… they ask us to explain something and give us time to discuss in group… more time to have more discussions." (S9)

In-depth feedback

"I really read the feedback but, in some parts, it is not really deep. Maybe provide detailed feedback, like... What do you mean about this one?... to be really helpful to students." (G3)

"Proper feedback is also important because students need to know where the fallacies are that they have made." (S6)

Personal sessions

"They can guide us more in detail, they can talk to us one on one. It's more effective, because in groups, it's harder to know the situation that the student is facing." (S5)

Active learning / debate

"Give students like a more active kind of learning… have a debate session between students and force them to take different positions. The debate is actually one (...) thing that actually forces you and trains your CT… even though you may not actually agree with what you are saying, but you're forced to think about the other opposite party's thinking." (G9)

"…more interactive… it will open up their ideas (...) and how they can counter arguments or support each other's argument." (G10)

"When the lecturers are more engaged with the students, if the lecturers open a dialogue between the students and appreciate the ideas given by the students… that's a good thing for them and for the students to grow and think critically." (S6)

Workshop

"Try to give students more opportunity to get this workshop before they actually join the programme. So, in a way that should help them, prepare them better for doing the course." (G4)

"Provide more workshops... specific workshops for areas where students are having trouble with CT." (G6)

Experiential learning

"…maybe some other skills to support the CT. So, it's not only on a classroom basis, but also experience basis……outbound, and learn some new skills, like teamwork, leadership, ...get extra lessons, like LinkedIn learning." (G2)

Qualified mentor

"…provide professionals and qualified mentors… make sure that whoever is helping is actually qualified enough to help... guidance with the help of proper mentors." (G1)

"…provide high calibre lecturers that would really benefit the students." (G7)

Preparatory course

"…they need to create, maybe incorporate in one of the early courses or subjects [something] on how to do CT systematically." (G3)

"…do more like a specific course on CT... if the students want to join, they can." (S5)

"They could make an extra class to practice it. Maybe students will be interested in it if they help to develop it. They could take the class and then have a chance to like speak and discuss with each other." (S10)

Promote awareness of CT

"…give them information on CT, do it upfront, tell them the very first day that you're supposed to think critically, and this is how CT is [done]." (G1)

"…informing about the importance of this and providing maybe more opportunities for practice… to see how CT is actually part of a successful career." (S9)

LECTURERS' OVERALL FINDINGS TO IMPROVE CT CAPABILITIES

Networking

"I would encourage (...) the university to work with industry, bringing guest lecturers and working on projects. I think that would give a variety of approaches. Otherwise, students will get bored..." (L1)

Academic writing support

"… only challenge that we are having is, how to express their CT when they are writing a report, because we assist them with only that part, (...) academic writing. So, I think that the academic writing part has to be supported, which we are doing through our student success team." *(L2)*

Lecturer participants - internal collaboration

"…we have a peer review, we have lecturers coming to our class at the lecture to give us feedback in terms of how we teach, in terms of how we engage in discussion." *(L1)*

"It would probably be a good idea to talk to all the lecturers and get their opinions (...) on what they're doing around CT. Because if we do that, and we've got an understanding of who's doing what, (...) we can probably better scaffold the skills." *(L3)*

MANAGER PARTICIPANTS: OVERALL FINDINGS TO IMPROVE CT CAPABILITIES

The findings below present the managers' perspectives and strategies to improve CT capabilities.

Task assignment

"Give them a task or a challenge that they need to tackle themselves first. So, try to make them think their way out of it first, before (...) questioning us who've already done it before. Because that forces them to use their CT skills to solve these problems." *(M1)*

"I generally kind of throw them into the deep end to get them to pull out as many insights that you think are relevant. (...) I also give them a set amount of time, I say, just deliver what you can in the next hour or two. And the reason why I do that is because what I want to see is, not only what they can do, but also the questions that they come to me with, say, I saw this, I think this but I'm not sure if that's correct or not... It's trial by fire." *(M2)*

Practical CT exercise

"I sit down with them, and I take them through my thought process. I take them through my account, and I take them through why I think this or why I think that." *(M2)*

Job role research

"They need to first know that it's an important skill to have, especially for the later years of their careers. So, they might as well start to develop their CT skills… do a quick study on the exact role that you're applying for and see what type of problems you will face." *(M1)*

CV update

"I would recommend updating your CV. Specifically, if CT is an important part of the process, or the job that you're applying for. What we're looking for is how you tackle the problem, something that you did to overcome a business challenge. It doesn't necessarily have to be in a business context. It could even be at university, it could be something that happened within your community. What we're looking for a lot of the time from graduates is how did you overcome that problem or that issue? What the problem was and what kind of attitude you brought to the table as well." *(M2)*

Case study learning

Managers supported the adoption of case study learning that would improve the development of CT capabilities.

"If students have case studies, [they can] try to identify the issues (...) and write a brief summary of possible solutions. Then look at the answers and see if they're on the right track or not. I think that will help them a lot with CT. One of the examples was a food brand taking their products to China. Chinese people don't use forks and knifes. They use chopsticks, so we need to change the brands. We have to do something with the brand, [make changes] from a different perspective and to the point. Very basic, but very important." *(M3)*

DISCUSSION AND RECOMMENDATIONS

This section presents discussion of the findings relating to the barriers to CT and recommendations to improve CT for international learners.

BARRIERS TO CT

Overall summary

The findings show several factors contributing to challenges international postgraduate learners encounter for the development of CT capabilities. In this section, we frame the findings in the context of the wider contemporary literature.

Language barrier

Language is one explanation as to why international learners possess weak CT capabilities. Rashid and Qaisar (2016) report that when English is taught as a second language, learners face challenges in breaking down complex information into simpler elements and developing logical reasoning. This study goes on to suggest that if these learners were given an opportunity to write in their own language, they might do better at presenting logical thought for a similar task. (Rashid & Qaisar, 2016). Thus, contemporary literature supports our findings. When English is a second language for learners, it presents a challenging context for learners in which to apply CT in their learning tasks.

Cultural background

The previous experiences of international learners within their own cultural contexts makes it more challenging for these learners to transition to a more open and flexible learning or working environment (Blank, 2020). Thus, cultural contexts provide an explanation for international learners' attitudes towards avoidance of questioning and expressing their own views (Fell & Lukianova, 2015), as reported in our study. For example, cultural contexts favour deference and respect for elders and being vocal with opinions is perceived as disrespect towards them. Hence these cultural norms and backgrounds may discourage learners from thinking critically and voicing their own arguments (Kawashima, 2003; Mangena & Chabeli, 2005; Jenkins, 2011; Chan, 2013; Shaheen, 2016).

Previous education system

When the previous education systems present traits such as lack of questioning, didactic teaching, and where learners are busy taking notes, this creates a passive learning environment (Chan, 2013; Guo, 2013; Fell & Lukianova,2015). The participants in our study provide concurring evidence that the previous educational systems of international learners do not proactively support CT capabilities (Shaheen, 2016).

Time management

Our findings show learners cite lack of time when working on assessments as a challenge to the development of CT capabilities. One study suggests that tasks, activities and processes in undertaking CT are complex and time-consuming, especially when analysing large amounts of data and information (McLean, 2005; Torff & Sessions, 2006). Hence, underestimating time for the required tasks puts pressure to produce work with criticality (Jackson, 2015; Sedlak, Doheny, Panthofer & Anaya, 2003). From a lecturer's viewpoint, when there is an overemphasis on delivering content in the classroom, this leaves less time to incorporate CT activities (Kowalczyk, Hackworth, & Case-Smith, 2012).

Prior experience with CT

Our findings reveal learners were unaware of CT concepts, and that they heard of these concepts for the first time when arriving in New Zealand. It may well be that prior learning experiences of international learners may not have given them opportunities to think critically in the classroom (Peter, 2012). So, the unfamiliarity with learning demands in a self-directed student-centred learning process presents an uncomfortable learning context (Plush & Kehrwald, 2014).

One-sided opinion

Based on the findings, managers reported that some international graduates have narrow perspectives which do not enable learners to think outside the box and create barriers for critical analysis. Studies have reported that educational approaches that do not support open-mindedness, curiosity, and the questioning of issues, present roadblocks to the development of criticality in thought processes (Bar-Tal, Vered & Fuxman, 2020; Kang & Ho-wren, 2004; Peter, 2012).

Strategies to improve CT

This discussion relates to the findings for research question 2 and provides action-oriented recommendations aimed at enhancing the development of CT capabilities of international postgraduate learners. We proposed three overall approaches to improve CT, categorised as pre-course strategies, in-course strategies, and post-course strategies.

PRE-COURSE STRATEGIES

The following strategies are recommended for implementation before the start of the study programme for international postgraduate learners as a cue to develop CT capabilities at an early stage of the study programme.

Promoting awareness of CT

Providing learners with course requirements and expectations early on can help learners become aware of what is expected of them academically and prepare them in advance to focus more explicitly on CT capabilities. Simply raising awareness of CT capabilities can support learners to better relate to skills that are relevant for their study programme as skills that are valued by employers after graduation (Mills et al., 2012; Cai & Sankaran, 2015).

Preparatory course in CT

According to Brookfield (2011), a preparatory course on CT can support international learners to clarify the expectations of the education system and the tasks they undertake in the context of CT capabilities development. The CT preparatory course may comprise elements such as reading, questioning, reasoning and writing as a starting point for CT capability enhancement (Mehta, 2015).

Provide professional and qualified mentors

One study indicated that highly qualified mentors can assist the development of learners' CT and analytical and reasoning skills (Callahan, 2016). The role of a teacher as a 'facilitator' in class who supports alternative views and also challenges these views through open-ended questions would scaffold the learners' understanding of CT (Wass, Harland, & Mercer, 2011; Murris, 2014).

IN-COURSE STRATEGIES

In-class discussion

It is asserted that in-classroom discussion is more effective than lecturing when it comes to fostering learners' CT skills as learners are encouraged to ask questions and verbally debate their ideas with one another, which usually helps learners to comprehend and retain ideas (Lennon, 2014). Thus, it is recommended to have more in-class discussion since it would support fostering an appreciation for the diversity of opinions and a capacity for self-critique and reflections (Hajhosseini, Zandi, Shabanan & Madani, 2016).

In-depth feedback

The purpose of feedback is to help learners learn how to correct faulty thinking and contribute to learning from past mistakes which is one way of improving CT capabilities (Sendag & Odabasi, 2009). In-depth feedback can offer some direction on how to improve their performance (Heft & Scharff, 2017).

Active learning / debate

The curriculum that incorporates active learning is claimed to encourage student engagement and foster and sustain positive habits such as open-mindedness, maturity of judgment, and confidence of reasoning that support the development of CT capabilities (Cone, et al., 2016). To enhance the development of CT capabilities such as being open to different perspectives, reasoning logically and accepting criticism, active learning approaches are recommended (Zare & Othman, 2015; Węgrzecka-Kowalewski, 2018).

Networking & Experiential learning

One additional suggestion is the adoption of experiential learning through organised service experiences by providing opportunities for practical, on-site experience in the learners' chosen field of interest (Arter, Wallace, & Shaffer, 2016; Sedlak, Doheny, Panthofer, & Anaya, 2003). These opportunities can stimulate the development of CT capabilities through the acquisition of specific knowledge from actual practitioners, enabling students to reinforce, challenge, and explicate concepts presented in a formal academic environment (Arter, Wallace, & Shaffer, 2016).

Workshop / academic writing support

An appropriate workshop approach is one that begins with an introduction to the foundations of CT that systematically contextualises these foundations through relevant curricular areas and incorporates CT practices into academic writing (Elder, 2004; Lennon, 2014). Therefore, the workshop for academic writing support should be embedded into the course to help learners in cultivating learners' CT abilities.

Post-course strategies

The following strategies are recommended for implementation at the end of the course programme, since this will support the development of CT capabilities after students graduate.

Practical CT exercise for graduates

CT skills play a significant role not only in academic achievement but also in the workplace (Masduqi, 2011). It is recommended for international postgraduate learners to continue the development of CT beyond graduation. Tertiary institutions can offer ongoing practical CT training that would help build up and strengthen the CT skills of graduates (Petty, 2019). Professional development training such as case study learning can support the development of CT capabilities. Case studies enable learners to "experience" real clients and stimulate graduates to make decisions in a simulated environment reflecting real life contexts (Popil, 2011; Shivakumar, 2012).

CT certification

One further suggestion is that tertiary institutions may consider having CT tests/surveys at the beginning and at the end of the programme to determine the CT development of learners over time. It may serve as a measure for colleges to reflect on the learners' development of CT capabilities throughout their study period. In addition to official academic performance certification, tertiary institutions could provide certification of the CT capabilities which would improve employability opportunities for learners (Mehta, 2015).

Limitations

As with all research, the small size of this study limits the generalisation of findings reported. The findings provide an indication of the challenges international students encounter in developing their CT capabilities. We suggest that a broader range of participants from multiple tertiary institutions as well as from different study programmes would provide more diverse samples in future studies.

CONCLUSION

The development of CT capabilities is necessary to ensure learners can perform their roles in education, work and society (Peach and Clare, 2017) and the issue of CT is becoming more important with the growth of international tertiary education (Pham, Hoang et al., 2024). To ensure consistency in the quality of international graduates prepared for employment markets, tertiary institutions must heed the call of prospective employers to place high priority on the development of CT capabilities for international learners to become global citizens (Peach and Clare, 2017). The findings from our study show international postgraduate learners encounter challenges in six specific areas for the development of CT capabilities. It is suggested that tertiary institutions adopt pre-course, in-course, and post-course strategies to improve levels of CT capabilities among international learners.

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Conceptual Article

THE IMPLICATIONS OF AI FOR VOCATIONAL EDUCATION – IT'S COMPLICATED!

Bruno Balducci

OTAGO POLYTECHNIC AUCKLAND INTERNATIONAL CAMPUS

INTRODUCTION

It is barely two years since ChatGPT was launched, followed by a whole gamut of new chatbots (Rudolph et al., 2023), and already a great deal has changed, not only in the education sector but throughout industry and the world at large. How artificial intelligence (AI) will impact vocational education and training (VET), as well as job opportunities for graduates and the nature of work in the future can only be guessed at. But while specific consequences of generative and other forms of AI cannot be predicted with any degree of certainty, it is still possible for us to anticipate the conceptual shift that may come about through its rapid development, and to prepare ourselves intellectually for tackling the new challenges facing us in the coming decades.

To begin with, it is important to distinguish between the implications of the AI revolution from its actual effects on our working lives. Although we can expect things to be different in the way that education will function, it is the significance of such changes that are of interest in this article. When we talk about how teachers and students might be affected by AI today, we usually refer to "technology that (i) leverages deep learning models to (ii) generate human-like content (e.g., images, words) in response to (iii) complex and varied prompts" (Lim et al., 2023, p. 2). In education, this technology has started to be used as a learning tool, but it has also undermined the validity and reliability of assessments, albeit to a limited extent. While these issues are being dealt with, on the surface at least, through academic integrity policies and procedures, the real danger remains that the exponential growth of AI will pose a major threat to our assessment practices. The implication of this growth may very well be that assessment as we know it will become impossible. Or to put it differently, its meaning will have undergone a serious and far-reaching transformation.

The aim of this article is to explore the likely consequences of future AI on how assessment is to be defined and viewed if the current goals, outcomes and structures of vocational education remain what they are today. The key questions to be considered are:

- Who, or what, will be assessed?
- By whom?
- For what reason(s) will this assessment take place?
- Above all, what will be its perceived value in a world of work that is itself transformed by the new technology?
- In short, what would be the meaning of vocational assessment in such a world?

Giving answers to these questions may seem like science fiction. The social phenomenon of AI use, however, is now a reality. Claims are made about the detection of AI-generated material in student work, yet nobody can say how much of this material remains undetected (Weber-Wulff et al., 2023). Nor is anyone able to deny that "this is only the beginning of an era where generative models will play an instrumental role in content creation" (Martínez et al., 2024, p.2). There is a need to look at the problem of AI in educational assessment squarely and directly, without waiting for it to become overwhelming. The central problem that seems to be avoided in the literature and that should be addressed, therefore, is how the development of AI may impact the conceptual categories on which all our existing assessment practices are built.

WHAT IS ASSESSMENT?

Before turning to the implications of future AI for those who are assessed, those who assess them, and those who make use of recognised and quality-assured qualifications, what is currently meant by assessment needs to be established. The New Zealand Qualifications Authority (NZQA) focuses on "assessment for learning", that is to say "the skills and knowledge acquired by students and ākonga" in order to "provide them with accurate, fair, and valid judgments that can be used to inform their further learning" (NZQA, 2022, p.5). Meanwhile, the fuller definition of assessment given by NZQA rests on the following summary of its characteristics by the Center for Curriculum Redesign:

- A coordinated system

- Collections of demonstrated evidence

- Evidence collections supporting inferences and claims

- Claims about how well students are learning

- Claims about learners' developed and progressing competencies

- Useful and actionable feedback

- Feedback that guides individual and collective learning

- Feedback that supports integrated educational improvement

(Bialik et al., 2016, p.4)

The advantage of having such a broad and detailed definition is that it reveals how much is at stake once the origin of material submitted for assessment is in doubt. All the evidence, inferences and claims of students' learning, as well as all the feedback aimed at educational improvement, in a word an entire system is impacted. Since, according to NZQA, the judgements that are made through assessment may be useful in relation to further learning, the value of these judgements is necessarily compromised if they do not accurately reflect the skills and knowledge of the learners themselves.

WHO IS ASSESSED?

This leads to the first key concept to be analysed - that of the assessee. Once it is officially acknowledged that the work on which the judgements of assessment are based may not be entirely generated by the learner being assessed, but may also contain the work of AI, the implication is that our understanding of what constitutes an assessee has become drastically different. In accordance with the aim in this study of conceptualising future AI in relation to the vocational education structures of today, it can be observed that assessed learners in such a world would be taken as something more than separate individuals. As a system, assessment is no longer able to assess the skills and knowledge of people as independent entities. While it is obvious that students remain learners, they are changed nevertheless for the purposes of assessment into a sort of hybrid, part human and part AI. The equivalent transformation at a physical level would be to have radically-altered humans, or cyborg-athletes competing in the Olympic Games (Lopez Frias, 2016). This is not to say that such a thing can never happen; but if it does, it will be more than individual athletes that are changed as a consequence.

The strongest objection to this view must be that even the most sophisticated AI will amount to nothing more than a tool, like language and mathematics, and thus would not be assimilated to human intelligence (HI). A tool that helps us to think or create or solve problems does not, by definition, automatically become a thinker or creator or problem-solver. However, AI is different from a tool; it is more comparable to a machine that can operate itself, as well as perform tasks for an individual user. Unless the assessor is equipped with criteria that are sufficiently precise and effective, and able to monitor the conditions in which an assessment product is generated, it will become impossible to differentiate between the work of AI and HI (at least without time-consuming verification procedures). Unless we see radical changes in many different disciplines (including vocational ones), assessment processes will no longer be able to identify the evidence required for inferences, claims and feedback on an individual's own progress. It will either have to be accepted that the AI/HI distinction is no longer important in the accreditation of individual learning, or new modes of assessment will need to be devised.

A further problem arising from the advent of AI will be that, as with cyborg-athletes, the transformational nature of the new technology could have an adverse effect on the fairness of the system as a whole. While academic reflection on AI's impact in tertiary education stresses the importance of inclusiveness (Lodge et al., 2023), the acceptance of AI-enhanced performance might still create an affordability gap in relation to assessment. To put it simply, there is no guarantee that some learners will not be disadvantaged. As with all large-scale technology transformation, there is the risk of existing inequalities being reinforced and social disparity increasing through education as a result.

WHO ASSESSES?

If the concept of an assessee is no longer stable in the face of future AI, then neither is that of the assessor, whose role it is to make inferences and claims about what has been learned on the basis of the evidence available. When challenged, assessors should be able to explain how their judgements are supported by the relevant assessment rubrics. Some of this work is undoubtedly linguistic, requiring that the wording of criteria is interpreted in order to be applied, but for the most part learner performance is assessed in relation to epistemological constructs and standard practices that constitute the reality of the discipline(s) involved. The implication of AI for this process may be twofold:

• In a world where AI is set to become as ubiquitous as the internet, the assessor's initial task must be to differentiate between appropriate and illegitimate AI use (after which, all appropriate uses of the technology may be evaluated).

• The introduction of AI in assessment roles for which it can be trained undermines the function of the assessor as a reliable judge of non-symbolic, non-linguistic knowledge and skills.

To focus on the first of these, it might help to imagine there is an assessment product ready to be assessed at this moment. Whether it be written or visual, digital or physical need not be a concern in this context. It is now the assessor's own expertise in assessing whether (and how) AI has been used by the assessee that should be taken into account. To make matters worse, there are numerous factors involved in assessment design (timeframe, format, learner independence, etc) which could make such decisions extremely difficult to make. The issue may be raised as to whether in future an assessor in this situation will be capable of deciding not only whether but also how AI might have been used, a question that transcends the current debate on detection and integrity. With the likely development of AI for specialised purposes in most (if not all) employment sectors (Dwivedi et al., 2021), it can be assumed that assessors in vocational education will pass judgement on the use of AI by individual students. But will they be in a position to determine the legitimacy of this use? Will they be qualified to evaluate its effectiveness? There can be little doubt that the professional assessment of AI use must be carried out by experienced practitioners. As anticipated by Lodge et al. (2023, p.7) "There will be a widespread need to build academic and professional staff capabilities for working with AI."

Whereas the first implication is about our ability to adapt to AI, the second is about AI's ability to adapt to our practices. Training AI to assess human performance is not the same as enabling it to make informed and principled judgements in the way that assessors can be trained to do. Unless AI is to evolve into a real intelligence of its own, the best it can offer must remain a simulacrum of HI (no matter how advanced or even superior it may be) and there is a world of difference in that regard between human-like and human. The behaviour that AI can imitate is essentially of a formal nature, more or less equivalent to following protocols, solving maths problems or writing to impress. It is true, of course, there is a place in vocational education for learning routines and procedures. There are many other educational outcomes, however, especially at tertiary level, where the aim is also to assess other kinds of knowledge and skills. The behaviours through which this kind of learning is applied require new objectives in new contexts in order to be observable. Human assessors with experience of achieving similar objectives have the ability to gain an understanding of what an assessee has done, or at least attempted. AI, on the other hand, has no such understanding. All it can "observe" is the form, the appearance of things, without any way of judging the content. But the appeal of technology-assisted practices being what it is, there is now the temptation of adapting assessment to AI's capabilities. Instead of AI adapting to our ways, it could end up encouraging us to adapt our practices to what it can do, thereby devaluing the role of assessors and their work.

WHY ASSESS?

According to Meyer (2009, p.7), the purpose of assessment in tertiary education is three-fold (my italics):

"*a. feedback on learning (students and teachers)*

b. selection and progression decisions (students, teachers and institutions)

c. quality assurance and accountability (institution-wide responsibilities)."

The function of feedback, as already indicated, is to guide learning and support educational improvement, both of which are impaired if evidence of the students' knowledge and skills on which assessment is based becomes unreliable. This in turn will have a knock-on effect on progression and quality.

But as well as problems of reliability, AI raises questions about the validity of assessments, i.e. whether they are "actually measuring what they are intended to measure" (Meyer (2009, p.7). In vocational programmes, this involves the measurement of "functioning knowledge", where students are required "to exercise active control over problems and decisions in the appropriate content domains" (Biggs and Tang, 2011, pp.120-121). Now whether, first of all, a student can be said to have achieved learning outcomes by means of their own actions and intentions when they have used AI becomes a moot point. The learner's dependence on its capabilities may limit their own so profoundly as to make it debatable that they are able to have "active control". The only way for assessment to remain valid in such conditions would be to accept the human-AI

synergy of assessees. The purpose of assessment would likewise have a dual aspect: human-focused assessment would be about student learning, whereas AI-focused evaluation would be about technological efficiency.

Secondly, "appropriate content domains" in the world of future AI will, by necessity, have to include the appropriate use of AI technology in accordance with current professional practice in the relevant fields. VET would cease to be vocational if this were not the case. This could entail i) not assessing tasks that can be performed as well (or even better) by AI as they are by humans, and ii) assessing tasks that cannot be performed as well by AI (preferably with the widest possible margin). Educators already need to ensure that they do not teach their students how to perform human tasks that either have been or are in the process of being replaced by AI activity. As employers adapt their operations to take advantage of the opportunities offered by AI, or perhaps to resist the intrusion of AI into their industry, vocational programmes may have to be aligned to both approaches in order that their graduates are given the best possible chances of employment. This would have to be underpinned by a robust understanding of how AI is affecting the labour market, whether as a substitute for, complement to, or creator of new jobs (Cazzaniga et al., 2024).

Recently proposed measurements of AI exposure (Felten et al., 2021) and AI complementarity (Pizzinelli et al., 2023) could help to foster such an understanding. The first provides an index of the overlap between AI's capabilities and the tasks ordinarily performed in a given type of job. The second is an extension of the first that includes "a broad set of factors beyond tasks, related to the social and physical context in which work is performed" (Pizzinelli et al., 2023, p.5). No doubt these definitions will be further elaborated or refined as AI continues to displace, enhance and develop professional practice.

THE FUTURE ROLE OF VOCATIONAL ASSESSMENT

Having looked at the potential impact of AI on our understanding of what constitutes an assessee, an assessor and the purposes of assessment, the next point to be considered is how tertiary qualifications might be viewed in future. To recap, these are the fundamental changes to assessment that have been envisaged so far in this article:

- assessees being able to make use of AI's capabilities
- assessors having the capacity to judge how AI has been used
- assessment that is (partly) focused on AI complementarity skills

What would be the value in the workplace of education and training based on assessment practices of this kind? Employers, it must be remembered, are not uncritical of the vocational qualifications that job applicants include in their CVs. Nor are students going to be satisfied with vocational courses that do not adequately prepare them for the real world of work. For the qualifications of tomorrow to be fit for purpose, they will need to accurately reflect the ways in which human intelligence and skills may be affected by AI.

The initial requirement for any vocational qualification to gain acceptance in the labour market must be that it gives a true indication, not of AI's capabilities, but of an applicant's knowledge and skills. Hence, if the evidence, inferences and claims of assessment about someone's ability to make use of AI are not reliable, the qualification to which they relate will be deemed, at best, irrelevant. This places the onus on assessment writers to ensure that their designs are effective instruments not only for allowing the use of AI, but also for identifying and judging the application of complementarity skills.

In addition, the learning outcomes of VET programmes that such assessments would be aiming to assess must enable students to develop their technical, creative and critical skills through their own interaction with AI technology. As well as social and physical factors in occupations, the concept of AI exposure can be extended to vocational qualifications and learner competencies (Mandala Partners and Future Skills Organisation, 2023). The degree to which qualifications are exposed to AI will play a significant part in determining their relative value in the eyes of employers. It seems highly likely that, in the future, VET will be required to demonstrate appropriate AI exposure in student learning, together with valid assessment processes that are able to discriminate between different kinds of AI use by assessees.

Finally, the knowledge and skills that vocational graduates may bring to the workplace will undoubtedly be judged in the wider context of their adaptability to the "fourth industrial revolution." This socio-economic transformation that began at the turn of the century is "not only about smart and connected machines and systems. (...) Occurring simultaneously are waves of further breakthroughs in areas ranging from gene sequencing to nanotechnology, from renewables to quantum computing. It is the fusion of these technologies and their interaction across the physical, digital and biological domains that make the fourth industrial revolution fundamentally different from previous revolutions." (Schwab, 2016, p.12). The extent to which vocational education can adequately prepare students for these new work environments will be crucial to its future role. The implication for the way students will be assessed, and for learning and teaching in general, is that the use of AI in VET programmes will be combined with other major technological innovations appropriate to the different vocational fields.

CONCLUSION

This article has sought to articulate the basic concepts of assessment in education and training in light of the disruptions likely to be caused by future AI. From this perspective, it is the whole system of assessment that would appear in danger of being subverted. The autonomy of learners, competence of assessors and validity of assessments are all called into question. But the assumption throughout has been that vocational education itself would not undergo any radical alterations to mitigate and even overcome these problems. In fact, deep structural changes over time, perhaps in direct response to the issues raised by early incarnations of AI, must also be considered and anticipated for a better picture of the shape of things to come.

Consequently, to say that we need more research into the possible impact of future AI on the VET sector would be something of an understatement. From the perspective of this study, however, the following areas of enquiry stand out as important in the effort to mitigate and counteract the negative implications of the technological revolution that is already underway:

- how to ensure reliability and validity in vocational assessments
- how to develop staff capabilities in the appropriate use of AI in assessment tasks
- how to design assessments focused on AI complementarity skills

The best starting point for this research work is most probably to conduct a rigorous study of AI use in all the economic sectors that are relevant to our programmes. Reliable data is needed from which information on the use of AI by professionals can be extracted, and the specific types of knowledge and skills which they apply can be identified. It would be on the basis of such findings that secure vocational assessments could be modelled and designed, as well as professional development for academic staff and policies for the integration of AI complementarity into student programmes.

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