Assessing the Feasibility of a Microfabrication Cluster in New Zealand

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Abstract

This project assessed the feasibility of establishing a microfabrication cluster in New Zealand for Callaghan Innovation and provided them recommendations for the establishment and success of this proposed cluster. We conducted 35 interviews and found that 94% of interviewees were interested in a cluster. The perceived barriers to the formation of the cluster included: a lack of communication within the industry, internal competition, and funding. Despite these barriers we concluded that this industry cluster was feasible. We recommended that Callaghan Innovation hold central meetings where potential cluster members can discuss the cluster's operation and move forward, focusing on solving industry weaknesses, improving communication, and addressing the needs of cluster members.

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Disclaimer

This Interactive Qualifying Project was written as a requirement for the completion of a Bachelor of Science degree from Worcester Polytechnic Institute. The authors are not experts or professionals on microfabrication or industry clustering. This document was written for Callaghan Innovation. This document does not represent the opinion of Callaghan Innovation or Worcester Polytechnic Institute.

Executive Summary

In industries throughout the world, companies and institutions band together to form clusters, or groups of interconnected organizations associated with a particular field or industry. These organizations include companies and firms, specialized suppliers, associated research institutions, universities, and service providers (MassTech, 2015). An industry cluster can potentially strengthen the success of individual high-tech organizations and catalyze industry growth. Our team assessed the feasibility of establishing a microfabrication cluster in New Zealand for our sponsor Callaghan Innovation, a government organization focused on assisting New Zealand business through technology (Callaghan Innovation, 2015).

Microfabrication is the creation of devices and structures that contain features on the scale of 1 micron to 1 millimeter, as well as the processes involved in the creation of these devices and structures. People around the world use products of microfabrication, sometimes referred to as microelectromechanical systems or MEMS, in our everyday lives. MEMS devices consist of structures, actuators, electronics, or sensors inside cell phones, computers, and other devices (MEMS & Nanotechnology Exchange). Many people may not be aware of its impact, but without microfabrication, technology would not have evolved to the point that it has today.

Microfabrication has applications in many industries and a variety of settings and this is crucial for the growth of the industry in New Zealand. Many New Zealanders are involved in primary industry, including agriculture and fishing, rather than technology based fields such as microfabrication. There are many applications of microfabrication that can contribute to primary industry and the growth of the New Zealand economy as a whole. Integrating microfabricated devices into already established New Zealand industries to improve processes is an important concept for the future of all the industries involved. Some examples of these industries that have potential to be involved with microfabrication include the agricultural industry, the medical industry, and the environmental industry.

The dairy industry accounts for 39.1% of agriculture in New Zealand and farmers can apply MEMS heavily in this area (Treasury, 2012). Devices created using microfabrication can help ensure the quality of milk and overall health of the herd by detecting pathogens in milk which can indicate a diseased cow. (Smith & Gottfried, 2015). In addition, there are medical applications such as using devices for applications like monitoring blood glucose levels in real-time for diabetics (Huang, 2014). Microfabricated devices can also be a lab-on-a-chip where researchers can analyze samples in the field rather than take them to an off-site lab which could take days. The University of Cincinnati has microfabricated a disposable device for sensing heavy-metal ions in soil and water that researchers can use as a lab-on-a-chip, thus greatly increasing their efficiency (Zou, Z. et al., 2007).

The goal of this project was to assist Callaghan Innovation in assessing the feasibility of establishing a microfabrication cluster in New Zealand. The three objectives of the project were to evaluate the current state of the microfabrication industry in New Zealand and the needs of the organizations, to determine the willingness of New Zealand organizations to join a cluster initiative and to determine the potential barriers hindering the formation of the cluster, and to identify the perceptions of industry members with respect to the environmental concerns of their work and with respect to New Zealand culture as it pertains to the microfabrication industry in New Zealand.

We accomplished the goals of our project by conducting semi-structured interviews with a variety of stakeholders including researchers, manufacturers, suppliers, and students in the microfabrication field. Throughout the project, we interviewed 32 representatives from these four stakeholder groups as well as the CEO of Callaghan Innovation and two Maori: the Maori Business and Relationship Manager at Callaghan Innovation and a Principle Advisor of the Maori Economy at the Treasury Department, for a total of 35 interviews. The team conducted these interviews in Auckland, Christchurch, Wellington, and through a digital questionnaire if a face-to-face meeting wasn't possible. The digital questionnaire asked the same questions as the interviews that the team conducted and both included 26 questions inclusive to every stakeholder group and five to nine questions specific to the different stakeholder groups.

In order to prepare the information gathered from these interviews for both qualitative and quantitative data analyses, the team used a form of data processing called coding. We used a coding method that included a total of ten categories, derived from the project's goals and 46 individual codes. These codes consisted of recurring themes and ideas that the team found in the interviews. To perform the quantitative data analysis, the team tallied how many interviewees responded with each code and created tables and graphs to represent the responses from each stakeholder group. We then compared the quantitative data from the different stakeholder groups in order to identify any similarities and differences between the groups. We also generated numbers from our overall interviewee pool in order to determine the views of the industry as a whole related to our three objectives.

The team only used qualitative analysis when there were not enough interviewees who mentioned a certain topic. This occurred in only one situation where the two Maori interviewees commented on cultural attitudes toward high tech industries. In this instance, we compared the opinions from both of these interviewees and synthesized this information into general views for both interviewees.

After completing the data processing and analysis, the team generated results concerning the project's three objectives. The interview responses indicated that the major strengths of the current industry are the collaborative atmosphere within New Zealand, the variety and quality of specialists within each sector, and the mobility and adaptability of the industry and its products. The team determined the major weaknesses of the industry to be the small population size of New Zealand and scale of production, the absence of a developed industry, the competition with other countries, and the limited amount of government funding for high-tech industries including microfabrication. The interview responses also suggested that the major barriers to the microfabrication cluster formation in New Zealand are the lack of communication within and between industry sectors, funding for the cluster, and competition within sectors. As far as the perceived environmental impacts were concerned, the interviewees revealed that they believe there are some possible environmental hazards due to the chemicals used in microfabrication processes; however, some also believe that these chemicals pose little concern when properly handled. As far as the perceived societal impacts were concerned, a good number of the interview respondents believe that the social impact of microfabrication in New Zealand is very similar to the changes that occurred globally, but also believed that the public awareness of microfabricated technology is very low. The two Maori who we interviewed both explained that from their perspectives, there were not significant cultural concerns regarding microfabrication. However, this cannot represent the entire Maori population or their belief system and only represents the ideas and opinions of these two individuals who we interviewed.

Based on the data collected, the team believes that the microfabrication industry cluster initiative in New Zealand is feasible due to the pre-existing collaborative atmosphere and high percentage of interviewees (94%) who said that they are willing to join a microfabrication cluster in New Zealand. To form a successful microfabrication cluster in New Zealand, the project team generated five recommendations for Callaghan Innovation:

- In order to facilitate communication between sectors, Callaghan Innovation should hold large central meetings where all potential cluster members can openly discuss the way the cluster should run and move forward, while also helping to raise awareness of involved organizations within and between the industry sectors.
- Potential cluster members should discuss the suggestions proposed by various interviewees within the industry about how to make the cluster successful, such as the

use of a mediator, having a common vision for the cluster, obtaining funding external to the cluster, keeping the cluster applicable to the individuals' work, and representing all cluster members equally.

- The organizations interested in becoming part of this cluster should prioritize finding solutions to the main weaknesses we identified: competition, scale of production, funding, and industry visibility and existence.
- The proposed future industry cluster should exploit the advantage of having small products that can be shipped cheaply.
- The potential cluster should make efforts to make other industries and individual consumers more aware of microfabricated technology and its benefits. Integrating microfabrication into primary industries, such as agriculture or forestry, may help to create a larger domestic market for microfabrication.

We hope this project has provided valuable information for Callaghan Innovation in their efforts to assess the feasibility of a microfabrication cluster in New Zealand. We believe this cluster initiative is feasible and Callaghan Innovation can use the recommendations from this report to determine what they need to focus on in order to establish the proposed cluster.

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1 Introduction

All over the world, technological industries are developing as a result of innovative progress made in scientific fields of study. The growth of these technological industries has created a great deal of societal change, especially considering the miniaturization of technology over the last decade, and these changes continue as high-tech industries flourish. As society adapts to technology, high-tech industries need to expand to meet the demand for products. Connections formed through links between supply firms, manufacturers, research organizations, and educational facilities, also known as an industry cluster, can potentially strengthen the success of high-tech industries and catalyze industry growth.

In New Zealand, the focus is mainly on primary industries, and high-tech secondary industries such as microfabrication are not as prevalent (A., Best, personal communication, 14/1/2016). Callaghan Innovation, a government organization focusing on using technology to promote New Zealand business, wants to establish a microfabrication cluster in New Zealand thus strengthening the technological industry presence. Creating a microfabrication cluster, connected through technology and geographic nodes, has the opportunity to strengthen the industry in New Zealand.

In order to establish a microfabrication cluster, the different organizations and sectors involved must establish a community of trust, sharing, and communication. To discover which of these elements already exist, we interviewed companies, research institutions, and other related organizations within the microfabrication industry in New Zealand. If these organizations collaborate with each other, they have the potential to form a successful industry cluster in New Zealand. Figure 1.1 shows the companies and institutions that have the potential to become part of a microfabrication cluster that the team interviewed. The business culture in New Zealand has shown itself to be receptive to clusters as evidenced by successful industry clusters that currently exist, like the Marine Export Group (MAREX) boat-building cluster (Valerie, 2005).

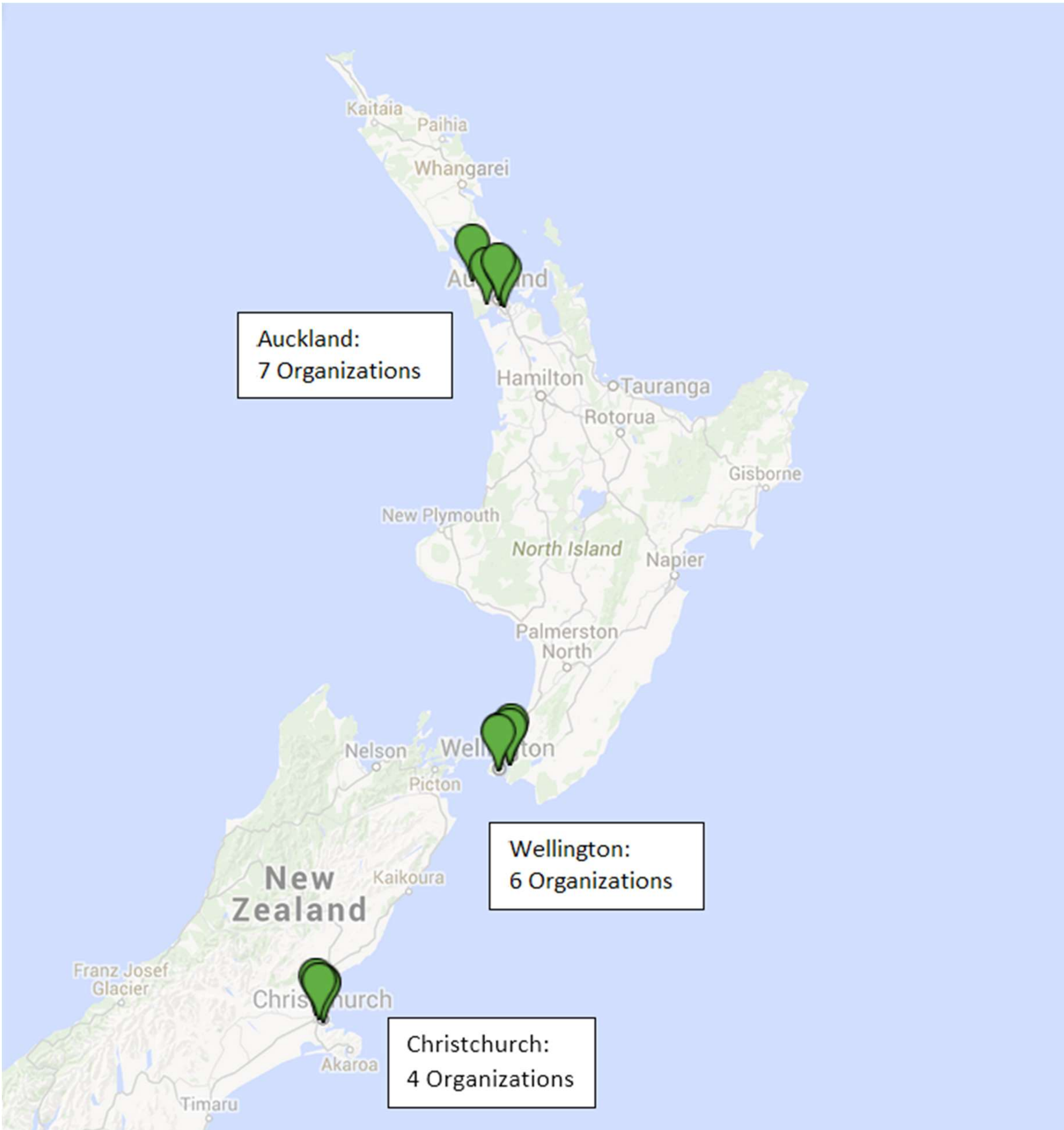


Figure 1.1: Map of Organizations

In order to facilitate the emergence of a successful microfabrication cluster, we evaluated the views and opinions of New Zealand experts in the field, as these were the people who make up and support the industry. Understanding the technical aspects of creating a cluster, as well as understanding the interviewees' perceptions of the effects such a cluster will have on New Zealand's environment and culture, was key to accomplishing the goals of this project. We achieved our three objectives by evaluating opinions and needs of the key stakeholders – suppliers, manufacturers, researchers, students, and other experts involved with microfabrication – through interviews. Some major concerns that we addressed in the interview questions were weaknesses of the industry, barriers to cluster formation, willingness of the company or institution to join a cluster, awareness of other sectors, and the perceived environmental and cultural concerns with the microfabrication industry in New Zealand.

The team coded the interview transcripts, a process that involves highlighting key points and sentences in order to quantify the raw data, to generate data for analysis. From our analysis, we found that the major strengths of the industry in New Zealand are its collaborative atmosphere and specialization. We also determined that 94% of our interviewees had some level of interest to join a microfabrication cluster initiative. Finally, the perceptions of the industry members are such that they believe that there are environmental concerns with microfabrication, but many of them believed that their organizations are handling them properly. These do not reflect the reality of the environmental impacts of microfabrication, but rather the perceptions of industry members. These current strengths and apparent willingness of organizations to join the cluster initiative are key aspects for the foundation of a successful cluster; however, the environmental concerns arising from microfabrication, if not properly dealt with, can inhibit the potential success of the cluster. Therefore, we believe that the establishment of a microfabrication cluster in New Zealand is feasible, but some organizations may need to address environmental concerns. We used these results to create recommendations for Callaghan Innovation regarding the best methods for the success of the potential microfabrication cluster in New Zealand.

2 Background

The first part of the background lays out the foundations of microfabrication in order to familiarize the reader with the field. The next section discusses the theory behind the formation and sustainment of a cluster and this section gives a brief background of an already existing cluster initiative in New Zealand and lays out the typical characteristics of currently successful clusters. The background then focuses on primary industry in New Zealand such as agriculture and explains how this industry is thriving, as well as what the microfabrication industry needs to do in order to move forward from its current state if it is to succeed. Microfabrication has applications to other existing New Zealand industries, which Section 2.5 elaborates on. The following section explains the foundation that New Zealand already has to support a microfabrication cluster initiative. Finally, the background explains some environmental hazards that the industry may produce and the government regulations that organizations in this industry must follow.

2.1 Microfabrication

Microfabrication is the creation of devices and structures that contain features on the scale of 1 micron to 1 millimeter, as well as the processes involved in the creation of these devices and structures. The products of microfabrication are sometimes referred to as microelectromechanical systems, or MEMS. These systems consist of structures, actuators, electronics, and sensors and there are a variety of applications, including chemical etching and high-aspect-ratio lithography (MEMS & Nanotechnology Exchange). High-aspect-ratio lithography is a process in which researchers shine UV light through a photoresist, a material designed to act similarly to a camera film negative, to create a pattern on a silicon wafer (MicroChem, 2015).

One overarching institute that supports the microfabrication industry in New Zealand is the MacDiarmid Institute for Advanced Materials and Nanotechnology in Wellington. This institute is a research center that works closely with suppliers, industrial companies, and other research institutions in order to make advancements in this technology (Callaghan & Blaikie, 2009). This chain of companies and institutions has the opportunity to work with other microfabrication organizations in New Zealand to form a cluster which would be beneficial for the New Zealand economy and for the future of the industry in the country. One government organization that is actively trying to develop this microfabrication cluster in New Zealand is Callaghan Innovation.

2.2 Industrial Cluster Theory

Clusters are groups of interconnected organizations associated with a particular field or industry. These organizations include companies and firms, specialized suppliers, associated research institutions, universities, and service providers (MassTech, 2015). Alongside the geographic proximity that typically characterizes clusters is the sharing of common resources. The different organizations that constitute a cluster all implicitly and explicitly share certain commonalities such as knowledge, infrastructure, growth opportunities, and barriers to growth. As one firm succeeds, another will copy them and reap the benefits. However, if one company fails, there is a strong chance that more will follow.

2.2.1 Formation and Sustainment of Hotspots

Valerie Lindsay, from the School of Marketing and International Business, in the Victoria University of Wellington, uses the Marine Export Group (MAREX), an export-based New Zealand boat building cluster, as an instructive example for exploring the formation and evolution of high-performing industries. The study she performed on MAREX suggests that the reason for the formation of industry clusters is the belief that the benefit of being in a cluster increases as more organizations enter (Valerie, 2005). There is one specific type of cluster categorized as a "hotspot." Rapid economic growth exists inside these hotspots, often with a focus on technology. The firms comprising these clusters are competitive and highly innovative with distinct identities. However, with this rapid growth of clusters comes a trend of decline in the absorptive capacity of the individual firms and of the cluster (Valerie, 2005).

The absorptive capacity of a firm is the measure by which it gathers and uses knowledge from outside the firm. It is this attribute of hotspots that ultimately leads to the failure of the cluster. Access to and application of new information fosters the innovation and adaptation potential that a firm needs to survive. In declining hotspots, there is an encompassing reduction in a firm's adaptive capacity. The adaptive capacity of a firm gauges how the firm reacts to unexpected situations and new technology, as opposed to absorptive capacity which represents how a firm gathers and uses new information. This reduced adaptive capacity results in limited new knowledge, which in turn hinders the innovative processes that sustains firms in these high-growth industries (Valerie, 2005).

In order for firms in these hotspot clusters to sustain themselves, the individual firms need to prevent themselves from falling into a competency trap. This happens when a firm tends to plateau in terms of innovation and growth. When companies rely too much on internal processes and ignore external input, the firm cannot recognize new opportunities. This contrasts with the co-evolutionary view which is using both inside and outside sources for expansion of the individual firms and the cluster as a whole (Valerie, 2005).

2.2.2 MAREX: A New Zealand Hotspot

In the late 20th century, New Zealand's boat-building industry, similar to today's microfabrication industry, was an emerging industry. As an industry, there was high demand for its products, with 50% of New Zealanders enjoying boating and 30% fishing, but the core components of a strong industry, such as business strategies and supporting industries, were lacking. Several factors that shaped the growth of the industry include an extensive coastline, favorable climate, university research, and international competition (Valerie, 2005).

The boat-building industry in New Zealand employs 8000 people in over 1300 companies. MAREX consists of about 175 of those companies, specializing in the construction of superyachts and racing yachts. As of 2005, MAREX experienced a growth of 25% per year for five years, classifying it as a hotspot. Even with the small percentage of New Zealand firms within the boat-building industry, MAREX sales account for a large portion of New Zealand's marine industry's annual sales (Valerie, 2005).

The problem with hotspots is that a trend of high growth leads to individual firms entering competency traps ultimately leading to market decline of the individual firms and the industry. MAREX avoids this problem by using both internal and external sources of information. This diversity is the reason behind the constant stream of new knowledge. MAREX includes firms who specialize in clothing, cabinet making, communication, engines, sails, and spars, in addition to the core boat-building firms (Valerie, 2005).

The microfabrication industry can learn from the MAREX cluster. For the boat-building industry, the University of Auckland has a Yacht Research Unit, and for the microfabrication industry, the MacDiarmid Institute for Advanced Materials and Nanotechnology. Similarly to the demand for boats in New Zealand, the demand for microfabrication is rising with the demand for smaller technologies in New Zealand and around the world. To help stimulate the growth of the microfabrication industry, there is also an international market within the microfabrication field.

2.3 Primary Industry in New Zealand

2.3.1 Economic Overview of New Zealand

The New Zealand economy has been through dramatic changes in the past three decades including changes in its government regulations, recent disasters including the devastating Canterbury earthquakes from 2010 to 2011 (McSeveney, 2014), and the effects of the global financial crisis in 2008. However, New Zealand has managed to maintain a steady recovery in response to its most recent struggles. The New Zealand Treasury released an economic and financial overview in 2015 discussing their recovery and their economic outlook (The Treasury, 2015).

Through reductions in government regulations, in the OECD (Organisation for Economic Co-operation and Development), New Zealand has evolved from one of the most regulated national economies to one of the least regulated countries. However, the government has put into place policies that support firms and companies and allow them to make more independent decisions about how they want to proceed. This will allow the microfabrication industry to grow and adapt to any changes more easily (The Treasury, 2015).

In response to the global financial crisis, the government tried to restore the lost confidence in the economy by helping the banking sector, individuals, and businesses. To help the banking sector, the government set in place retail and wholesale bank guarantees. They also incorporated cuts in the income tax as well as relief packages for small and medium-sized companies to assist individuals and businesses. The Canterbury earthquakes of February 2011 slowed this recovery. However, the recovery is acting as a source of growth through residential, commercial, and infrastructure investments.

2.3.2 Manufacturing in New Zealand's Economy

A major problem facing the manufacturing sector in New Zealand is the exchange rate of the New Zealand dollar. The IMF (International Monetary Fund) suggested in 2012 that the New Zealand dollar was 10-20 percent overvalued (Wheeler, 2013). Governor Graeme Wheeler stated in a speech addressing the New Zealand Manufacturers and Exporters Association in Auckland that along with the issue of overvaluing the New Zealand dollar, there were other components such as globalization, outsourcing, international supply chains, and the competition between low cost producers that were hurting the state of New Zealand industries like microfabrication (Wheeler, 2013).

The lack of skilled labor and the current architecture of the manufacturing sector makes the creation of a sustainable microfabrication cluster in New Zealand difficult. In order to shed light on the situation, Castalia, an advising company, created a report for BusinessNZ on the dynamics and competitiveness of New Zealand and its manufacturing sector (Castalia, 2014). In their report, Castalia conducted a study involving 15 New Zealand manufacturing companies showing high growth to ascertain the factors determining strong growth in the future. A couple of the main issues that Castalia highlights in this study are the architecture of the industry and the shortage in skilled labor.

2.3.3 Manufacturing Sector Architecture

The focus of the manufacturing industry in New Zealand has shifted from manufacturing to a mix of manufacturing and services including research, design, and marketing. This shift has caused some misunderstandings about the sector's composition and, consequently, its strategies for sustainable growth. Using official government statistics, Castalia concluded that there were misconceptions on the classification of specific units (Castalia, 2014). In particular, many products and services that New Zealanders classify as in the services sector are in fact a part of a vertically integrated business in the manufacturing sector. In other words, the firms that are manufacturing these services are also the ones who distribute the services. Instead of having a separate company handle the service, the firm handles it internally. This adds to the labor shortage problem due to added confusion about the role of manufacturing in New Zealand. Castalia determined that the common factors that make firms in a cluster successful are talent-driven innovation instead of a cost-minimization approach and a vertically-integrated architecture. The success of these individual firms then in turn would make a successful and competitive manufacturing sector in New Zealand.

2.3.4 Primary Industry Sectors

Primary industry in New Zealand consists of agriculture, fishing, and forestry. This is most likely due to New Zealand's geographic factors. New Zealand is an island nation, making fishing a highly accessible industry, and has 14.3 million hectares designated as farming land (Beef+lamb New Zealand, 2015). The labor force is abundant in these booming industries because generations of New Zealanders integrated farming, gardening, and forestry into their lifestyles. These areas account for about 16% of the nation's labor force. In 2012, there were 60,562 farmers and farm managers in New Zealand compared to 5,388 Information and Communications Technology (ICT) professionals and this disparity was even worse in 2002 (Grimmond, 2014). The agricultural industry is directly responsible for 5.0% of GDP (Treasury, 2012) and approximately 50% of total income from exports comes from meat, dairy, and wool products (Productsfromnz.com, 2015). In New Zealand, 44% of farms are "mainly sheep and beef farming" and another 21% are "mainly dairy farming" (Beef+lamb New Zealand, 2015) making sheep and cattle the most relevant elements of the agriculture industry in the country. As a whole, New Zealand is highly agriculturally and environmentally focused and less targeted toward high-tech fields such as microfabrication.

2.3.5 Skilled Labor Supply

The lack of skilled labor in the manufacturing sector is a problem hiding in the shadows of the economic success of the industry in New Zealand, but it will become more of an issue the longer companies and institutions ignore it (Castalia, 2014). Castalia stated that the manufacturing industry provided 191,000 jobs by the middle of 2013 and was supplying 14.6% of the country's GDP in 2012. This makes it one of the four largest sources of jobs and income in New Zealand, establishing New Zealand as more manufacturing-heavy than its neighbor, Australia. However, the survey conducted by Castalia targeting high-growth manufacturing firms determined that the lack of skilled labor is the highest concern in the industry (Castalia, 2014). Culturally, this is an issue, as many citizens do not view themselves as a nation that relies on manufacturing. This may lead to many people not choosing a manufacturing career path, thus contributing to the lack of skilled labor.

2.4 Microfabrication Applications in other New Zealand Industries

It is important for the microfabrication industry in New Zealand to make connections with already established industries in the country in order to grow and expand. Many New Zealanders have been involved in primary industry, including agriculture and fishing, rather than technology based fields such as microfabrication. What these primary industry workers may not know however, is that there are many applications of microfabrication that can contribute to primary industry and the growth of the New Zealand economy as a whole. Integrating microfabricated devices into already established New Zealand industries to improve processes is an important concept for the future of all of the involved industries. Some examples of these industries include the agricultural industry, the medical industry, and the environmental industry.

2.4.1 Agricultural Applications

As previously mentioned, agriculture is one of the largest industries in New Zealand. Consequently, for the microfabrication industry in New Zealand to be successful, it must make efforts to connect these two industries.

The dairy industry accounts for 39.1% of agriculture in New Zealand and farmers can apply MEMS heavily in this area (Treasury, 2012). One such application is a device, seen in Figure 2.1 that can detect and immobilize pathogens including E.coli, Streptococcus, and Staphylococcus in milk in real time (Smith & Gottfried, 2015). This is incredibly useful, not only to ensure the quality of milk, but also because it can lead to early detection of diseases such as mastitis in dairy cows. Mastitis is an inflammation in mammary tissue and is a financial issue in dairy industries worldwide, costing the U.S. one billion dollars annually (Smith & Gottfried, 2015).

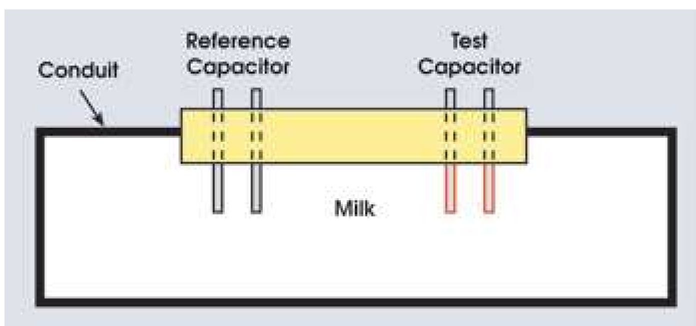


Figure 2.1: Sensor in milk conduit (Smith, 2012)

Additionally, SpectralSight Inc. developed a microfabricated device that is applicable in the agricultural industry. This device utilizes hyper-spectral imaging to detect problems in crops and food. By tuning the device to specific light frequencies, users can detect fungal infections and needs for irrigation (Smith & Gottfried, 2015). Users can also utilize this type of device for food that is already packaged and on store shelves (Smith & Gottfried, 2015). Detecting these issues increases both production and quality of the food.

2.4.2 Medical Applications

There are numerous areas that microfabrication technology applies to the medical field, one of which being biosensors. Two specific biosensors that could be important to New Zealand healthcare are continuous glucose monitoring sensors (Huang, 2014) and heart-failure-monitoring sensors (Sjm.com, 2015).

Diabetes is the fastest growing health problem in New Zealand with over 240,000 people diagnosed with the disease (Ministry of Health NZ, 2015). Glucose-monitoring sensors are the main tool diabetics employ to keep track of and control their blood sugar. The Department of Mechanical Engineering at Columbia University has developed a fully implantable MEMS dielectric affinity glucose biosensor. This biosensor monitors blood glucose concentrations in real time so that the user doesn't have to take blood samples throughout the day (Huang, 2014).

Heart disease is the leading cause of death in New Zealand, resulting in 30% of deaths annually (Heartfoundation.org.nz, 2015). Devices applicable to this area of the medical field are helpful to the general health of New Zealand. St. Jude Medical, in Tennessee, has developed the CardioMEMS™ HF System which is a tool for early detection of heart failure. The device monitors the pulmonary artery pressure with an implanted sensor. This device, as seen in Figure 2.2, has reduced heart-failure-related hospitalizations by 43% in clinical trials throughout the US (Sjm.com, 2015).

Figure 2.2: Heart Failure Monitor System (CardioMEMS HF, 2015)

Another medical application of microfabrication is in research. Technicians currently use micropatterning methods, a form of microfabrication, to fabricate the extracellular environment for cancer cells to grow in (Yang et al., 2015). This aids in arrangement, proliferation, and cell behavior research which is important to understanding how cancers form and respond in the body (Yang et al., 2015).

2.4.3 Environmental Protection Applications

While environmental protection is not a typical industry, it does have many microfabrication applications and is fundamentally important as it deals with the safety of the environment. There are several sources citing the potential use of micro-sensors to monitor environmental conditions to detect pollutants (Suzuki, 2000) (Zou, Z. et al., 2007) (Feeney & Kounaves, 2000). The environmental protection industry can reduce manufacturing costs by switching over to microfabricated devices instead of using their macro counterparts. This is due to batch fabrication, which allows lab personnel to make more sensors at once, and multi-analyte detection which means that one device can detect and analyze several different molecules or pollutants (Feeney, 2000).

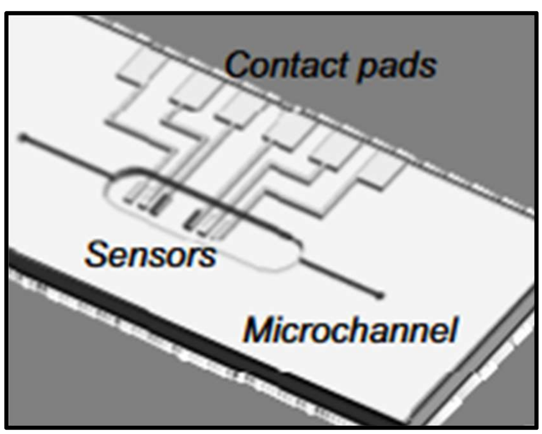


Figure 2.3: Heavy-metal ion sensor (Bishop, 2007)

The University of Cincinnati has microfabricated a disposable heavy-metal ion sensor as seen in Figure 2.3. Researchers can use this sensor at the site they are analyzing (Zou, Z. et al.,

2007) meaning they do not need to take samples off-site to a lab. This is not only more convenient, but also much more efficient. The device is able to accurately detect harmful materials such as lead ions in the soil and in water sources without producing toxic chemicals in the process (Zou, Z. et al., 2007). This is important because the ultimate goal of using these sensors is to decrease the amounts of pollutants in the environment.

2.5 Existing Foundations for a Microfabrication Cluster in New Zealand

The MacDiarmid Institute for Advanced Materials and Nanotechnology is a partnership between several main research institutes for microfabrication in New Zealand; it is a public institute surrounded by branching institutions and companies known as Crown Entities. There are seven current entities, consisting of five universities and two Crown Research Institutes, in which the MacDiarmid Institute oversees microfabrication research. This institute propelled the research on microfluidics and nanotechnology so that other companies such as Callaghan Innovation could carry on with specific research to fulfill a desired purpose (Yewdall, 2015).

2.5.1 Crown Entities of the MacDiarmid Institute

Callaghan Innovation works together with organizations affiliated with the MacDiarmid Institute on nanotechnology research as well as industrial applications of this research. The University of Auckland and the University of Canterbury are crucial contributors to this effort as well. The latter played a role in the creation and commercialization of self-assembling nanowires, working heavily with the MacDiarmid Institute (Callaghan & Blaikie, 2009).

Callaghan Innovation is a technology oriented company which pledges to take the ideas of researchers and commercialize them. This is one of the most prominent New Zealand companies containing researchers in the field of microfabrication. These researchers have made great progress in recent years in trying to improve the microfabrication industry in New Zealand; Callaghan Innovation is currently at the forefront of the industry in this country (Callaghan & Blaikie, 2009).

An article in the journal Smart Materials and Structures contains a step-by-step process in which Andrea Bubendorfer and two other researchers from Callaghan Innovation used microfluidic devices to fabricate microchannels and seal them to a substrate. Demonstrating the ability to produce microstructures and make use of them is the first step for companies trying to break into the microfabrication industry. The second step is figuring out how to lower the cost of production and manage changing technologies, something Callaghan Innovation is focusing on now (Bubendorfer, 2007).

Another Crown Entity that works closely with the MacDiarmid Institute is the University of Auckland. It has an entire facility dedicated to research on microfabrication for both academia and industry. The students at the University of Auckland Microfabrication Facility complete projects dealing with single cell microfluidics, drug delivery and biosensing actuators, gas sensors, and sensors for sound waves. These projects are important because they allow University of Auckland students to become proficient in a variety of microfabrication processes and this prepares them to begin working in the microfabrication industry once they've finished university. In fact, microfabrication consulting is an integral part of the academia-industry relationship that the University of Auckland tries to keep intact (University of Auckland).

This research is not simply for the university itself, however. It is also helpful for the growing microfabrication industry in New Zealand. For example, companies in this industry have already used the University of Auckland's facilities "to improve processing conditions for biomedical and industrial polymers, for the design of flowcells for dairy waste stream sensors, and to explore new concepts in gas sensor design" (University of Auckland). The University of Auckland Microfabrication Facility and similar facilities will be important as the microfabrication industry in New Zealand grows because they are institutions crucial for researching efficiency and conditions for various microfabrication processes and products.

2.5.2 MacDiarmid Institute Strategic Plan

Not only is the MacDiarmid Institute making technological progress, it is striding towards social and cultural progress in terms of increasing public acceptance of technical industries. One way it is accomplishing this feat is by conducting social research with the general public about their opinions on nanotechnology and related fields. This research found “that the New Zealand public generally views nanotechnology favourably, but that there is some aversion to products where people can be directly exposed to nanoparticles” (Callaghan & Blaikie, 2009). If the institute knows that the public is averse to certain technologies, it can determine whether these technologies are actually a concern, make efforts to mitigate these concerns if necessary, and ultimately increase public acceptance of the industry.

In the next six years, the MacDiarmid Institute expects to make significant progress in three areas: increasing the potential for technological advancement and human capital, positively influencing New Zealand’s economy, and generating changes in social attitudes that increase favorability of microfabrication and the desire to explore a career in such a field (Yewdall, 2015). One of the techniques to inspire change in New Zealand society is interacting with specific groups of people who may not be initially interested in microfabrication. The MacDiarmid Institute has identified these groups of people as the Maori and Pasifika, and a crucial part of the aforementioned six-year plan deals with attempting to integrate these groups into the industry. The plan is to “Develop, grow and formalise relationships with Māori communities founded on mutual exploration of education and business opportunities supported by a science foundation” (Yewdall, 2015: 4). The institute recognizes that some Maori are not necessarily going to be interested in the microfabrication industry due to their culture; however, Yewdall believes it is essential that the institute educates the Maori and Pasifika about career opportunities and reasons why the microfabrication industry is beneficial. To achieve this, the MacDiarmid Institute will introduce scientific development programs in predominantly Māori and Pasifika schools (Yewdall, 2015).

2.5.3 University of Auckland

Figure 2.4: University of Auckland (Grafton Campus, 2008)

Young innovators collaborating with the MacDiarmid Institute and related organizations in the microfabrication field could be beneficial to the industry. One way to facilitate young innovation would be to promote enrollment in microfabrication programs in universities such as the University of Auckland, shown in Figure 2.4. This university is the largest educational institution in New Zealand that deals with microfabrication, consisting of 41,953 total students (University of Auckland, 2014). It is the largest and highest-ranked university in New Zealand, rated as 82nd in the world according to Quacquarelli Symonds (QS) World University Rankings (University of Auckland, 2014). Proof of this university's importance also comes in the form of its research prowess. "The University of Auckland is New Zealand's largest research organisation with more than 13,000 staff and postgraduate students involved in fundamental and applied research. It generates around $230 million in annual research revenue" (University of Auckland, 2014). This university has the potential to supply the industry with new graduates who may have a fresh perspective on microfabrication.

2.6 Environmental Concerns

The microfabrication industry, like many high-tech industries, uses chemicals that have the potential to be harmful. Some New Zealanders may not support the industry if these processes have harmful environmental effects. In a country with high environmental standards, this has the potential of hindering the cluster's success.

2.6.1 Environmental Hazards of Microfabrication Industry

One of the most harmful practices related to this industry is etching. During etching, a technician develops and installs a photoresist on a wafer. This wafer's silicon dioxide layer is then stripped using a chemical solution, but the photoresist remains on the wafer. Etching is important because it is the best technique for securing a photoresist to a wafer to perform a desired function. There are two types of etching: wet etching and dry etching. Wet etching uses chemicals such as hydrofluoric acid, sulfuric acid, nitric acid, and hydrogen peroxide to strip the silicon dioxide layer off the wafer at room temperature or warmer environments. Researchers developed dry etching in order to strip certain layers that wet etching cannot handle. There are even more chemicals used in dry etching, such as chlorine, hydrogen bromide, fluorocarbons, and fluorine (Manufacture of Semiconductors, Pages 30-31).

All of these chemicals have the potential to harm the environment if not properly handled. The United States Environmental Protection Agency drafted a report about the semiconductor industry which explains, *[These] physical and chemical processing steps occur at four process operation areas … A variety of pollutants may be emitted at these stations. These include acid fumes and organic solvent emissions from cleaning, rinsing, resist drying, developing, and resist stripping; hydrogen chloride emissions from etching; and other various emissions from spent etching solutions … In addition to process related emissions, air emissions may also result from onsite treatment of industrial wastewater (Manufacture of Semiconductors, Pages 35-36).*

In the semiconductor portion of the industry especially, companies must consider the effects of the many different pollutants produced.

2.6.2 Progress on Reducing Pollutants

Many people recognize that unregulated microfabrication processes can be harmful to the environment, so the United States put into place procedures to reduce hazardous air pollutants (HAP). Between 1987 and 1994, technological advances reduced HAP releases per area of silicon substrate from nearly 0.08 to 0.01 pounds per square inch. This is a significant improvement, which is exactly what the Semiconductor Industry Association (SIA) hoped to achieve for the industry. A study by the SIA found that "HAP usage in the semiconductor industry is declining due to regulatory, worker safety, and cost pressures, and the trend is likely to continue. Many HAP materials used in semiconductor manufacture have been replaced by HAP-free materials" (Manufacture of Semiconductors, Pages 37-38). If the microfabrication industry continues to grow in New Zealand and becomes as widespread as it is in the United States, the New Zealand Environmental Protection Authority can put regulations in place to lower HAP levels.

2.7 New Zealand Legislation

There are several potential barriers to the formation of a microfabrication cluster in New Zealand regarding the government regulations associated with microfabrication. Some issues that companies and institutions have to worry about when creating devices and running processes are laws related to environment, health, and safety. These regulations are the reason that these microfabrication facilities have a safe environment in which to thrive and expand.

2.7.1 Environmental Act 1986

In 1986, New Zealand Government passed the Environmental Act which called for the Commissioner to hold in high regard “any land, water, sites, fishing grounds, or physical or cultural resources, or interests associated with such areas” (Environment Act 1986, 2014). Therefore, the New Zealand Government must monitor all areas that facilities could harm by pollution or chemical waste. This consists of investigating organizations in order to limit practices that “result in or increase pollution; or result in the occurrence, or increase the chances of occurrence, of natural hazards or hazardous substances” (Environment Act 1986, 2014).

2.7.2 Health and Safety in Employment Act 1992

The New Zealand Government enacted the Health and Safety in Employment Act in 1992 to limit workplace hazards and incidents. These limitations ensure that workers in microfabrication and related fields in New Zealand act safely and responsibly. Regarding workplace regulations, this act specifies “where there is a significant hazard to employees at work, the employer shall take all practicable steps to eliminate it” (Health and Safety in Employment Act 1992, 2013). This means that the employer is responsible for the health and safety of the employees. It is important to have these regulations in place because otherwise a facility dealing with microfabrication or other dangerous technical processes would become a hazardous workplace. If a facility becomes too dangerous, the New Zealand Government can close it, having a negative impact on a potential cluster.

2.7.3 Hazardous Substances and New Organisms Act 1996

Another potential problem confronting a microfabrication cluster in New Zealand is the Hazardous Substances and New Organisms Act enacted in 1996. While this act does protect the environment, it also greatly reduces the variety of substances and organisms that organizations can import into New Zealand, as well as the number of exported materials. The act states, "No—(a) hazardous substance shall be imported, or manufactured: (b) new organism shall be imported, developed, field tested, or released—otherwise than in accordance with an approval issued under this Act" (Hazardous Substances and New Organisms Act 1996, 2015). If regulations allowed organizations to import, export, or create whatever they wanted, then hazardous substances might become more widespread. This would hurt the industry because an increase in dangerous chemicals or organisms is bound to increase the amount of hazards and incidents involving these substances. Microfabrication companies and institutions must keep this set of regulations in mind when considering expansion and collaboration with other organizations. Throughout this project, the team gathered information about what other factors are important when organizations attempt to come together to form a cluster.

3 Methods

This project assisted Callaghan Innovation in assessing the feasibility of establishing a microfabrication cluster in New Zealand. The team accomplished this by conducting interviews with a variety of stakeholders in the microfabrication industry. The stakeholders consisted of individuals from organizations from the supply, research, manufacturing, and education sectors within the microfabrication industry in New Zealand. We used coding to process the data gathered from the interviews and then analyzed the coded data between the stakeholders quantitatively and qualitatively. The project's objectives were:

1. To evaluate the current state of the microfabrication industry in New Zealand and the needs of the organizations.
2. To determine the willingness of New Zealand organizations to join a cluster initiative and to determine the potential barriers hindering the formation of the cluster.
3. To identify the perceptions of industry members concerning potential environmental and cultural impacts the microfabrication industry may have in New Zealand.

3.1 Interview Process

The team chose to use semi-structured interviews as the sole method to achieve our project's three objectives. A semi-structured interview, also called an open-ended interview, allows the interviewer to remain flexible and responsive to the answers of the interviewee and add additional relevant questions to the conversation (Hamill, 2014). We chose the semi-structured interview type because of its flexible nature. Since our project involves interviews with interviewees with varying degrees of technical and managerial background, we made adjustments in phrasing and probing questions on the fly when needed. A completely structured interview would not have allowed our team to adjust to each interviewee in the same way as the semi-structured interview.

3.1.1 Interview Strategy

In order to collect all of the necessary information for each of the project's three objectives, the team conducted semi-structured interviews in three major areas in New Zealand: Wellington, Auckland, and Christchurch. The team's base of operations was in Wellington, and this is where we held most of the interviews. The team flew out to both Auckland and Christchurch to hold the interviews in those locations. If the location of the interviewee was in any other city, or if the interviewee was too busy to schedule a face-to-face interview but still wanted to participate in the project, we sent him/her a digital questionnaire. This digital questionnaire contained the same questions, presented in the same manner as the face-to-face interviews, designed to get the same responses as we would in a face-to-face interview. After the team distributed the digital questionnaire, we gave the option of having a phone call to answer any follow-up questions that the respondent had.

For each of the different stakeholders, the team asked the interviewees different types of questions after asking a set of general questions which applied to all the stakeholders. The different stakeholder groups that we focused on were: suppliers, manufacturers, researchers, and students. Table 3.1 shows the list of all interviews that we held, along with the company that the representative belonged to, the location of the interview, as well as a date and time stamp when the interview took place. The table is organized chronologically.

Key:	Research	Manufacturing	Supplier	Student	Other

Name	Organization	Location	Role	Date/ Time
Andrew Best	Callaghan Innovation	Wellington	Research	1/14/16 14:30
Mike Arnold	Callaghan Innovation	Wellington	Research	1/14/16 15:30
Richard Templar	Callaghan Innovation	Wellington	Research	1/18/16 10:00
Andrew Dawson	Callaghan Innovation	Wellington	Supplier	1/18/16 12:00
Paul Mather	Callaghan Innovation	Wellington	Manufacturing	1/18/16 13:30
Frederic LeCarpentier	Spark Transducers	Wellington	Research	1/18/16 15:00
Hamish McGowan	Callaghan Innovation	Wellington	Research	1/19/16 12:00
Jerome Levener	GNS	Wellington	Research	1/19/16 14:30
Leo Browning	Victoria University	Wellington	Student	1/20/16 11:30
Anonymous A	Victoria University	Wellington	Research	1/20/16 12:00
Anonymous B	Victoria University	Wellington	Research	1/20/16 12:00
Gideon Gouws	Victoria University	Wellington	Research	1/20/16 14:30
Brendan O’Connell	Tru-Test Ltd.	Digital	Research	1/20/16 16:30
Eva Weatherall	Victoria University	Wellington	Student	1/21/16 10:30

Atawhai Tibble	Ministry of Finance	Wellington	Other	1/22/16 11:00
Vincent Campbell	Callaghan Innovation	Wellington	Other	1/22/16 11:30
John Newton	Pure Depth	Auckland	Research	1/26/16 10:00
Iain Hosie	Revolution Fibres	Auckland	Manufacturing	1/26/16 10:30
Bryon Wright	MacDiarmid Institute	Digital	Research	1/26/16 13:30
Benjamin O'Brien	Stretchsense	Auckland	Manufacturing	1/26/16 14:30
Cather Simpson	Photon Factory	Auckland	Manufacturing	1/26/16 15:00
Michael McILroy	Rakon Limited	Auckland	Research	1/27/16 10:00
David Grant	Rakon Limited	Auckland	Manufacturing	1/27/16 10:00
Alan Coulson	Callaghan Innovation	Wellington	Research	1/28/16 9:30
Anonymous F	Spark Transducers	Digital	Research	1/29/16 12:00
Mary Quin	Callaghan Innovation	Wellington	Other	1/29/16 14:00
Bart Ludbrook	MacDiarmid Institute	Digital	Research	2/1/16 11:00
Anonymous C	Shamrock Industries	Christchurch	Supplier	2/3/16 11:30
Volker Nock	University of Canterbury	Christchurch	Research	2/3/16 15:00
Anonymous G	Not Disclosed	Christchurch	Manufacturer	2/3/16 13:00
Maan Alkaisi	University of Canterbury	Christchurch	Research	2/4/16 11:00

Paul Garrett	Photoetch Industries Limited	Christchurch	Manufacturer	2/4/16 13:00
Anonymous D	Victoria University of Wellington	Digital	Student	2/11/16 17:00
Anonymous E	MacDiarmid Institute	Digital	Student	2/12/16 16:00
Helen Morris	Victoria University of Wellington	Digital	Student	2/12/16 17:00

Table 3.1: Interviews Held

We used three methods to procure interviews. Our first set of interviews were with industry representatives contacted by our sponsor liaison Andrea Bubendorfer, at Callaghan Innovation. She set up the interviews directly with no involvement from the team. We conducted most of these interviews during the first week of the project. The second method we used to procure interviews was through connections from Callaghan Innovation. The sponsor shared with the team a Google Sheet consisting of different organizations involved within the microfabrication industry, representatives from those organizations, and contact information for the representatives. The team contacted each of the representatives primarily through email. If no email was available, we contacted the representatives by phone. This method provided the most interview opportunities. The third and final method we used to set up interviews was through connections disclosed by previous interviewees. These interviews contributed the least to the total number of interviews and they were set up in the same manner as the ones set up with the second method. A list of organizations that we could not interview is in Appendix C. We could not interview these organizations, either because they did not respond to our interview requests or because we did not have time to interview them; however, these organizations could still be part of a potential cluster for microfabrication in New Zealand.

Throughout the project, we used two different team configurations to conduct interviews. For the first few interviews in the beginning of the project, all four members participated. In this configuration, there was one interviewer, one backup interviewer, and two note-takers. The purpose of these interviews was to practice our interviewing skills and learn the strengths and weaknesses of each team member. We conducted the majority of the remaining interviews in groups of two, which consisted of one interviewer and one note-taker.

The interviewer was in charge of asking all questions during the interviews, including probing questions based on the responses from the interviewees. The note-taker's primary function was to audio record the interviews, with a secondary function of taking notes. We only used these notes as a backup if the audio recording was incomprehensible, or if the interviewee wished for the team to not record the interview.

3.1.2 Interview Questions

Throughout the first week of the project, the team edited and revised the questions used during the interviews for each stakeholder. Bubendorfer reviewed our initial set of questions and made suggestions on how to change them to better procure the information we needed from each stakeholder. After making these adjustments, the team conducted two practice interviews with Mike Arnold and Andrew Best. With the comments and suggestions from Bubendorfer, who sat in on the previously mentioned interviews of Arnold and Best, we rephrased unclear or over-generalized questions, omitted redundant questions, and added missing questions that the team felt were necessary. These questions are in Appendix A.

Introduction and Confidentiality Prompt

There were three goals of the introduction and confidentiality prompt. The first goal was to introduce the team as third year engineering students from the United States studying at Worcester Polytechnic Institute in Massachusetts. The second goal was to formally introduce the project to the interviewee. The third goal was to inform the interviewee that they had the option to stay anonymous and that they had the choice to withhold any information that they provided during their interview. The prompt is as follows:

"Hello, we are third year engineering students from the US studying at Worcester Polytechnic Institute in Massachusetts. We are carrying out this project assessing the feasibility of creating a microfabrication (by which we mean miniaturized structures or devices with features that may be smaller than a millimeter) cluster in New Zealand as part of our degree program. We will be using this interview in a report that will be published and made available in the public domain. You can remain anonymous and please tell us at the end if there is any information that you do not want published. We hope our report will also be of interest to you."

General Questions for all stakeholders

1. May we audio record this interview?
2. What is your name?
3. What is the name of your organization?
4. Would you like to remain anonymous?
5. Which part of the microfabrication industry are you personally involved in? (Please select the part you are involved in the strongest.)
   a) Supplier
   b) Manufacturing
   c) Research
   d) Student
6. What part of the microfabrication industry is your organization involved in?
   a) Supplier
   b) Manufacturing
   c) Research
   d) Student

7. What is your job title?
8. What is your job description?
9. What does the word microfabrication mean to you?
10. How does microfabrication play a role in your organization?
11. How has miniaturization changed technology in New Zealand?
12. What do you imagine microfabrication in New Zealand to be like in 5-10 years?
13. How do you see ongoing miniaturization affecting the future in 5-10 years?
14. How do you think miniaturized technology impacts society in New Zealand?
15. What are the strengths of the microfabrication industry in New Zealand?
16. What are the weaknesses of the microfabrication industry in New Zealand?
17. How do you feel about collaboration with other organizations?
18. What do you know about industry clusters and how do you see a cluster operating?
19. `How aware are you of the microfabrication facilities in New Zealand?
20. How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field? Why or why not?
21. Are there any environmental concerns with microfabrication and if so, what are they and how are they dealt with?
22. What types of government regulations affect your work?

<u>Questions 1 and 4:</u> Since we published this report in the public domain, we needed to give the interviewees the options of not being audio recorded and to remain anonymous so that they could feel free to speak openly.

<u>Questions 2 and 3:</u> These questions were purely for the audio recording so that when a team member listened to the recording it would be clear which interviewee they were transcribing.

Questions 5 and 6: The team asked these questions to identify what type of stakeholder the interviewee and their organization represented and to gain a better understanding of the interviewee's background and helped the team look for potential bias We also used question 5 to determine which set of specialized stakeholder questions we would ask the interviewee.

Questions 7 and 8: The answers to these questions provide more information about the interviewee’s personal role in their organization and how involved they are with microfabrication.

Questions 9 and 10: The team asked these questions to gauge how much understanding of microfabrication the interviewee had because not all of the people interviewed had the same familiarity or background in the field. Knowing their level of familiarity allowed us to adjust our phrasing and probing questions throughout the interview. The team also used these questions to gauge the importance of microfabrication to the interviewee and their organization. These questions addressed objective 1.

Questions 11, 12, and 13: These questions provided an understanding of how the interviewee sees the microfabrication industry currently, as well as what the interviewee expects or desires for the microfabrication industry moving forward into the future. This was important because if an individual does not have a positive outlook about the current or future microfabrication industry, then they are less likely to have a vested interest in the cluster. These questions addressed objective 1.

Question 14: The team used this question to evaluate the perceptions of the interviewees in regard to the impact microfabrication/miniaturized technology has had on New Zealand and how it has affected New Zealand society. This question addressed objective 3.

Question 15 and 16: These questions helped to identify the current assets and the disadvantages of the current microfabrication industry that could aid or hinder cluster formation and success. These questions addressed objective 1.

Questions 17, 18, 19, and 20: The team asked these questions to assess the general knowledge of the interviewee about clusters, their awareness of other related organizations, and their willingness to join a cluster. These questions addressed objective 2.

Question 21: This question revealed the interviewee's thoughts about environmental hazards caused by microfabrication processes and how they believed their organizations handled the potential hazards. This question addressed objective 3.

Question 22: The team asked this question to discover if there were any potential government regulations that affect the current and future microfabrication industry in New Zealand. This question addressed objective 1.

Supplier Questions

23. How do international trends shape the future of New Zealand microfabrication?
24. Is your company looking to hire more staff?
25. What products do your company provide for the microfabrication industry?
26. What country do you do the most business with?
27. What factors make it difficult to compete in a global market?
28. What companies do you supply in New Zealand?

Questions 23, 26, and 27: These questions gauged the scope of importance of international markets, how they affect the interviewee's organization, and how they play a role in the microfabrication industry in New Zealand. These questions addressed objective 1.

Question 24: This question gauged the growth of supplier organizations and provided the team with information about how fast the supply sector is growing in New Zealand. This question addressed objective 1.

Questions 25 and 28: The team asked these questions to gauge the range and type of business in the microfabrication industry where supplies interact with other organizations. These questions addressed objective 1.

Manufacturing Questions

29. What are the main applications of your work?
30. What is your current approach to stay relevant in this rapidly expanding field?

31. How much money does your organization spend yearly on Research and Development?
32. How much money does your organization spend yearly on microfabrication in particular?
33. How many people does your organization have on staff?
34. How many people does your organization have on staff for microfabrication in particular?
35. Is your company looking to hire more staff?
36. How do international trends shape the future of New Zealand microfabrication?
37. What factors make it difficult to compete in a global market?

Question 29: This question provided information about which fields the microfabrication industry is currently affecting, as well as the different applications that New Zealand manufacturers are providing, to gain an understanding of the progress individuals are making in this field and the applications that could contribute to the knowledge pool for a cluster. This question addressed objective 1.

Question 30: This question determined the different methods that representatives in the manufacturing sector in New Zealand are using to stay relevant. Staying relevant in the microfabrication industry is very important to the formation of a cluster as the cluster itself would have to remain relevant on an international scale. This question addressed objective 1.

Questions 31 and 32: Originally, these questions were meant to gauge the role that microfabrication plays in the individual organizations within the manufacturing sector in New Zealand to help the team determine the organizations' priorities. However, the team decided that these questions did not provide the information we were looking for and the data obtained by these questions was never used.

Questions 33, 34, and 35: These questions gauged the growth of manufacturing organizations in the microfabrication field and provided the team with information about how the manufacturing sector is growing, if at all, in New Zealand. These questions addressed objective 1.

Questions 36 and 37: The team asked these questions to determine the impact of foreign markets on the microfabrication industry in New Zealand, as well as to gauge the importance and difficulty of entering the international market for the purpose of bettering the industry. These questions addressed objective 1.

Research Questions

38. What is your current approach to stay relevant in this rapidly expanding field?
39. Is your organization looking to hire more staff?
40. What factors make it difficult to compete in a global market?
41. What are the main and potential applications of your work?
42. How much money does your organization spend yearly on Research and Development?
43. How much money does your organization spend yearly on microfabrication in particular?
44. How many people does your organization have on staff?
45. How many people does your organization have on staff for microfabrication in particular?

Question 38: This question determined the different methods that representatives in the research sector in New Zealand are using to stay relevant. Staying relevant in the microfabrication industry is very important to the formation of a cluster as the cluster itself would have to remain relevant on an international scale. This question addressed objective 1.

Questions 39, 44, and 45: These questions gauged the growth of research organizations in the microfabrication field and provided the team with information about how the research sector is growing, if at all, in New Zealand. These questions addressed objective 1.

Question 40: This question gauged the importance and difficulty of entering the international market for the purpose of bettering the industry. This question also gave the team information about the different factors that make it difficult, and provided insight into why these factors hurt the industry, and a potential cluster, on a global scale. This question addressed objective 1.

Question 41: This question provided information about which fields the microfabrication industry is currently researching, as well as the different applications that New Zealand researchers are providing. This question addressed objective 1.

Questions 42 and 43: Originally, these questions were meant to gauge the role that microfabrication plays in the individual organizations within the researching sector in New Zealand to help the team determine the organizations' priorities. However, the team decided that these questions did not provide the information we were looking for and the data obtained by these questions was never used.

Student Questions

46. Are you doing any research in microfabrication? If so, what are the applications of your research?
47. What degree(s) are you pursuing?
48. Are you looking to get a job in New Zealand or somewhere else?
49. If you are looking to get a job in another country, why?
50. If you are looking to get a job in New Zealand, why?

Question 46: The team asked this question to determine the level of involvement with microfabrication of the interviewee, as well as the specific applications that could add to the knowledge pool of a potential cluster. This question addressed objective 1.

Question 47: This question provided the team with information about what degrees students are pursuing, their relation to microfabrication, and their current research interests. This question addressed objective 1.

Questions 48, 49, and 50: The team asked these questions to ascertain the places where students are looking to get jobs, providing the team with a sense of how willing students are to stay in New Zealand, and the reasons why or why not. These questions addressed objective 1.

Concluding Questions

51. If you consider yourself Maori, do you see any major cultural conflicts with microfabrication/high-tech fields?

52. Do you have any additional comments?
53. Do you know of other companies or research groups in New Zealand that have interest in microfabrication? Who can we contact and what are your connections with these people?
54. Is there any information that you provided that you do not want published?

Question 51: The team targeted this question to the interviewees who were Maori in order to determine their perceptions on whether or not Maori had any cultural concerns with practices in the microfabrication industry in New Zealand. This question addressed objective 3.

Questions 52, 53, and 54: The team asked these questions to all interviewees at the end of the interviews to gather additional information from the interviewees via one broad, open question and allow them to strike anything they said off the record. These questions also allowed us to use snowballing techniques to obtain more contacts and interviews.

3.1.3 Trip to Auckland

For the team's trip to Auckland, due to limited time between interviews and great distances between interview locations, the team split into two separate groups: Group A and Group B, to tackle the interviews in the most efficient manner possible. In each group there was one interviewer and one notetaker. There was a total of six face-to-face interviews. Figure 3.1, displayed below, shows the locations of these interviews. To determine which group would conduct which interviews, the team took into consideration distance between locations to reduce the cost of the taxi rides between interviews and the time of the interviews to make sure that the travel was as efficient possible.

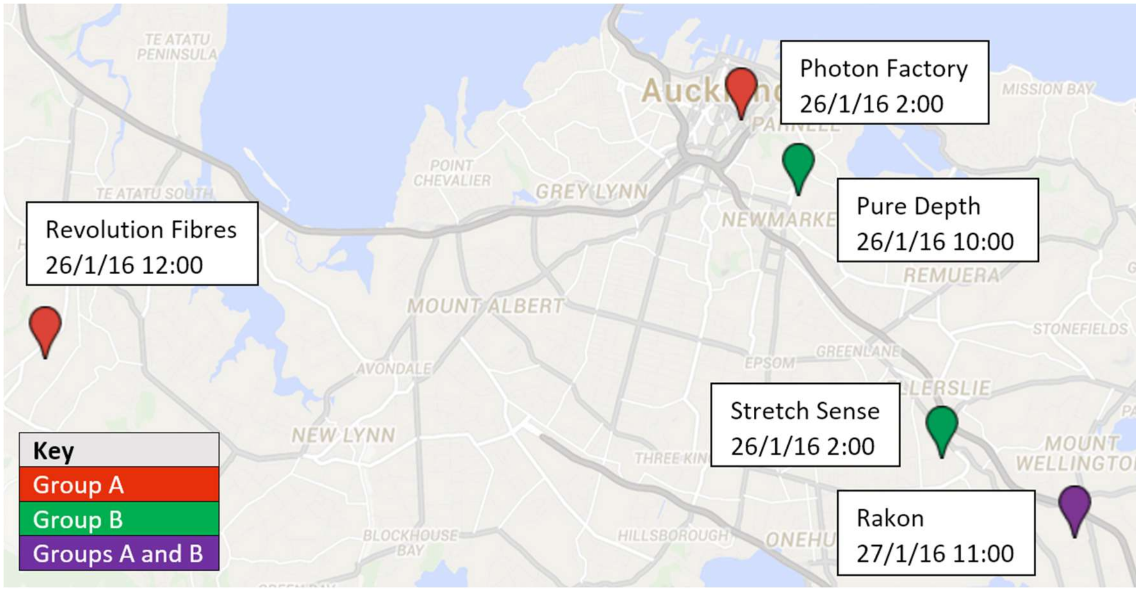


Figure 3.1: Interview Map of Auckland

3.1.4 Trip to Christchurch

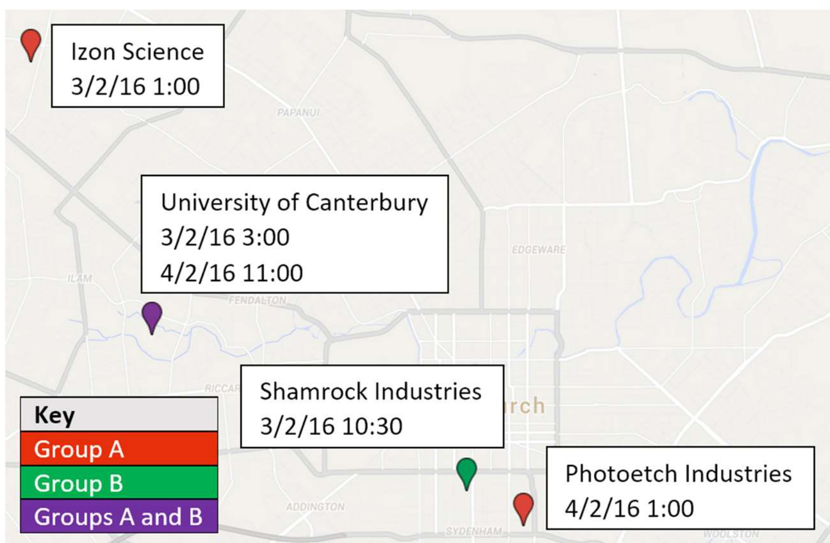


Figure 3.2: Interview Map of Christchurch

The trip to Christchurch was similar to the Auckland trip in that there was limited time between interviews and great distances between interview locations. Hence, the team again split into two separate groups: Group A and Group B, to maximize efficiency in conducting the interviews. There was a total of five face-to-face interviews. Figure 3.2 shows the locations of these interviews. To determine which group would conduct which interviews, the team again took into consideration distance between locations and the interview times in order to maximize efficiency of travel.

3.2 Data Processing

In order to analyze the information gathered from the interviews, we first needed to transcribe the interviews. The team details this process in section 3.2.1. Transcribing was a crucial step to data processing because it provided us with all the information in each interview, clearly written out. This allowed us to easily code the data later, as well as equipped us with the ability to quote something directly from an interview into our final report. The team decided upon coding versus another data processing method due to its properties as a heuristic, “an exploratory problem-solving technique without specific formulas or algorithms to follow,” in linking together the data collected to the idea (Saldaña, 2012). The team decided to use the grounded theory method to prepare the textual data from the interviews with all stakeholder groups for a quantitative analysis. The grounded theory allows for hypothesis-generating research, as opposed to hypothesis-testing research. Hypothesis-generating research allows research to begin without a hypothesis to test. It allows for the generation of the hypothesis or hypotheses after the collection of the data (Auerbach & Silverstein, 2003). This was crucial to our project, as we did not know what the outcomes of the interviews would be until we had actually conducted the interviews.

3.2.1 Transcribing

Interviewee: Iain Hosie
Interviewer: Rachel Ooyama-Searls
Organization: Revolution Fibres Ltd
Location: Auckland
Date and Time: 26/1/2016 12:00:00

Rachel: For our records can you please state your name?
Iain: Iain Hosie.
R: And the name of your organization?
I: Revolution Fibres Limited. I'm the managing director.
R: Which part of the microfabrication industry are you personally involved in: supplier, manufacturer, research or student?
I: We are manufacturers and research as well so we run essentially manufacture of nanofiber but more often than not there's a huge amount of product development that has to go on before the manufacture and so we offer that as a customization service as well. So it's paid research and we're sort of recognized in New Zealand as advanced materials specialists. Our speciality is nanofiber but we have quite a broad understanding of all chemistries.
R: What part of the microfabrication industry is your organization involved in? Again the same four options. Manufacturing and research?
I: Yes.
R: Can you state your job title?
I: Managing Director and Founder.
R: In your own words can you give us a job description?

Figure 3.3: Sample of Transcribed Interview

We began the transcribing process by uploading our recordings to our computers. At the start of the process, all four group members listened separately to recordings, typing out the recordings word for word into a Google Document. Each team member used a slightly different software to playback the audio recordings. Some software was able to filter out some of the background noise which made it easier to hear the interviewee. Other software slowed down the audio recording to provide a more continuous approach to transcribing without the need to pause frequently. Both of these methods sped up the transcription process, allowing the team to transcribe more interviews in a shorter period of time. Further along in the project, the team realized that the transcription process was taking a long time, and that the coding process would also be very time-consuming. Consequently, we divided into two teams: one team of the fastest transcribers to finish transcribing the interviews and one team to start the coding process of the already transcribed interviews. Figure 3.3 shows a sample of a transcription.

3.2.2 Bias Study

Before the team could start the coding process, a bias study needed to be held to ascertain any potential biases between the different team members. Due to the splitting off into two separate teams for transcribing and coding, only two members initially performed the study. The study consisted of two separate parts: the individual coding of the same transcript and the discussion of any differences in the results. The team drew two conclusions from this bias study:

1. There was a difference between the two team members in how they highlighted certain sections of the transcript. There were times when both members used different codes, classifying the highlighted section in different objectives. With this bias toward certain codes and objectives, the team decided to discuss each code and decide on a single meaning. The team wrote down these meanings so that for future coding, it would be clear to the coder what each code meant. As another result of these differences, the team decided to have the ability to assign multiple codes to the same idea. This means that if one section of a transcript fits more than one code, given the updated meanings, the coder could assign all applicable codes to the section of the transcript.
2. The second conclusion that the team drew from the bias study was about the differences between the words society and culture. The team nullified this confusion by combining the two previously separate categories: “New Zealand Culture” and “New Zealand Society” into “New Zealand Culture and Society.”

After the team identified these differences, we adjusted and defined the coding process through discussion of the codes and decided how we would code moving forward with the project. After the first two team members completed the short study, the other two members repeated the same process with the same transcript. With similar discussions, all four of the team members were arriving at same results. With this study finished, all four members of the team could start coding the transcripts individually and with minimized bias.

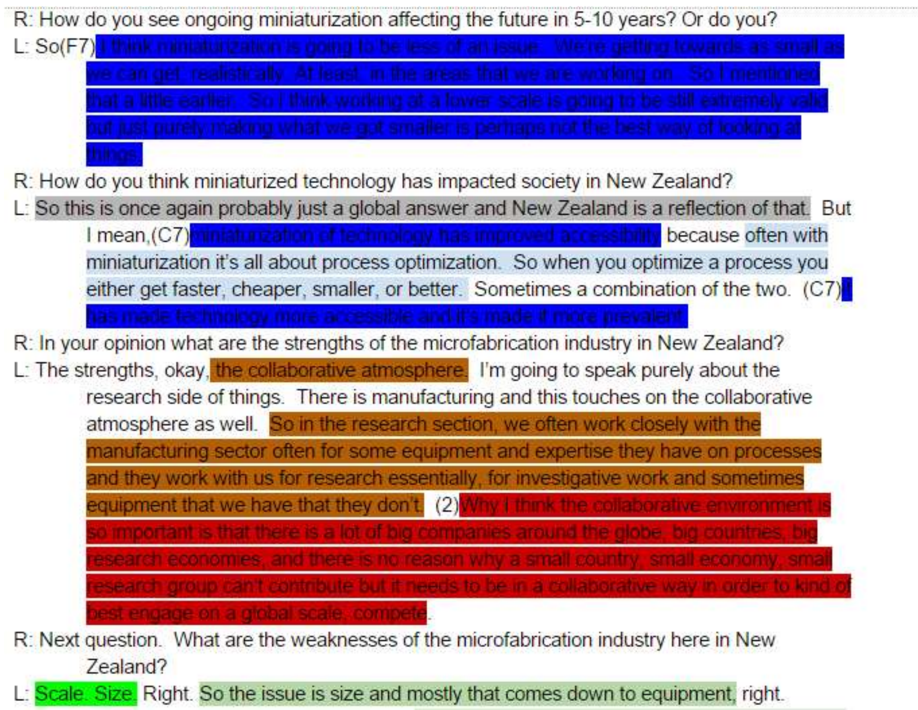
3.2.3 Coding

Codifying is “a process that permits data to be ‘segregated, grouped, regrouped, and relinked in order to consolidate meaning and explanation’” (Saldaña, 2012). The team decided to use a four-layered approach to coding: objectives, categories, codes, and subcodes. The broadest layer of this approach were the objectives, which were our project's three objectives. These objectives lay out what we aimed to achieve through the project, so they were a good starting point for determining our codes. We then separated the project's three main objectives and narrowed them down into different categories. For example, our objective pertaining to the perceived environmental and cultural concerns with the microfabrication industry split into two categories: one for the perceived environmental concerns and one for cultural concerns. The team broke the first objective into five different categories, the second objective into three, and the third into two, for a total of ten categories. We further divided each category into smaller codes that applied to the responses that the interviewees gave. Within the ten categories, there were 46 different codes pertaining to various concepts relevant to the project.

The first step in the coding process for any given transcript was to highlight the different sections of the transcripts that applied to a specific code using the color scheme that the team determined prior to coding. Throughout the process, there were two predominant methods for highlighting the transcripts. The team used the first method early in the coding process, before knowing the individual codes well. This method required the coder to pick one category, read the entire transcript, and highlight any portion where the interviewee mentioned the topic of the code. After the team became familiar with the codes, we used the second method. This method was to read through the transcript one sentence at a time, deciding which code was most relevant for each portion of the transcript. This allowed the coder to code each transcript more efficiently.

Due to the large number of codes used in the coding process that we agreed upon, we could not assign every code a unique color. To address this problem, we made sure that every code in the first two objectives, for which there were enough colors, had a unique color. For the third objective, the team used repeat colors if needed. While highlighting, the coder would mark those sections that required codes from the project's third objective with the letter E in parentheses: (E). The "E" is shorthand for Environment, which is a large part of the project's third objective. To address the existence of subcodes, the highlighted portion included a number signifying which number subcode the highlighted portion fell under in parenthesis. Additionally, for the category "Current and Future Outlook," the highlighted portion included a "C" or an "F" placed before it in order to specify "current" or "future" respectively. This was to identify whether the idea was referring to the future or present times. For our coding purposes, the team had a Google Document that identified each of the colors as well as the numbers for each of the subcodes. Appendix B has all of the information on the colors chosen for the codes and the numbers used for each of the subcodes.

Due to the nature of our coding methodology, if there was a portion of the interview that did not satisfy any current codes, the coder would discuss with the team if there should be a code and, if it was deemed necessary, add it to the list of codes. Due to the communication between coders and the discussion of any possible new codes, there was little chance that any newly added code had already appeared in previous transcripts. This cut away the need for a second complete cycle of coding transcripts, something the team initially planned on doing. However, after discussing the new code in question, if it was deemed necessary, the team would indeed continue on to perform a second cycle of coding. This second cycle would only focus on the new code or codes, and would use the coded transcripts from the first cycle. For the subcodes, as they are more specific answers to the general ideas represented by the codes, the team decided that a discussion was not necessary beyond the relevancy of the new subcode, as the exclusion of a specific subcode would not change the highlighting of previous transcripts. This is due to the fact that the coders were looking for the codes and not the subcodes during the highlighting process. The section "Organization of Codes" below represents the different codes. Detailed below are the objectives, categories, codes, and subcodes. The codes and subcodes are also found in Appendix B. Below in Figure 3.4 is a sample of a coded transcript.



R: How do you see ongoing miniaturization affecting the future in 5-10 years? Or do you?

L: So(F7) I think miniaturization is going to be less of an issue. We're getting towards as small as we can get, realistically. At least, in the areas that we are working on. So I mentioned that a little earlier. So I think working at a lower scale is going to be still extremely valid but just purely making what we got smaller is perhaps not the best way of looking at things.

R: How do you think miniaturized technology has impacted society in New Zealand?

L: So this is once again probably just a global answer and New Zealand is a reflection of that. But I mean,(C7) miniaturization of technology has improved accessibility because often with miniaturization it's all about process optimization. So when you optimize a process you either get faster, cheaper, smaller, or better. Sometimes a combination of the two. (C7) it has made technology more accessible and it's made it more prevalent.

R: In your opinion what are the strengths of the microfabrication industry in New Zealand?

L: The strengths, okay, the collaborative atmosphere. I'm going to speak purely about the research side of things. There is manufacturing and this touches on the collaborative atmosphere as well. So in the research section, we often work closely with the manufacturing sector often for some equipment and expertise they have on processes and they work with us for research essentially, for investigative work and sometimes equipment that we have that they don't. (2) Why I think the collaborative environment is so important is that there is a lot of big companies around the globe, big countries, big research economies, and there is no reason why a small country, small economy, small research group can't contribute but it needs to be in a collaborative way in order to kind of best engage on a global scale, compete.

R: Next question. What are the weaknesses of the microfabrication industry here in New Zealand?

L: Scale. Size. Right. So the issue is size and mostly that comes down to equipment, right.

Figure 3.4: Sample of Coded Transcript

Organization of codes

Objective 1

To evaluate the current state of the microfabrication industry in New Zealand and the needs of the organizations.

1. Current and Future Outlook
    a. Technology and Applications: The team designed this code to group information on the current and future technologies created with the use of microfabrication. The team split this code into seven subcodes: “Sensors,” “Actuators,” “Textiles,”

"Lab on a chip," "Electrical," "Other," and "Impact or effect of microfabrication." The team used the first six subcodes to differentiate how different industries use microfabrication within New Zealand. The subcodes "Biomedical," "Communication," "Environment," "Primary industries", and "Other" represent these industries. The team created the last subcode to differentiate between specific applications of microfabrication and specific information about how microfabrication has impacted technology in New Zealand. The sub-subcodes for this last subcode are "Global interaction," "Business," "No effect," and "Disruptive vs. incremental".

b. International Influences: This code grouped information on the influences of other countries on the technology in New Zealand.

c. Efficiency: This code grouped information about the increased efficiency of devices as a result of microfabrication in different fields, or the potential increase.

d. International: The team designed this code to group information about the current and future international involvement and effect on the microfabrication industry in New Zealand. The team split this code into five subcodes: "Trends," "Markets," "Difficulty," "Collaborating internationally," and "Influences of technology".

e. Awareness of Personal Involvement: This code grouped information related to how aware the interviewee is of their company's involvement within the microfabrication industry in New Zealand. The team split this code into five subcodes: "Unaware that they do microfabrication," "Aware that they do some microfabrication," "Only does microfabrication," "Does not do microfabrication," and "Indirectly involved with microfabrication."

f. Industry Future: The team designed this code to group information on the outlook of the future of the microfabrication industry from the eyes of stakeholders. The team split this code into seven subcodes: “Uncertain,” “Positive outlook,” “More collaboration,” "Move away from primary industry," "Incorporate into primary industry," "Increase in manufacturing abilities," and “Negative outlook”.

2. Strengths
    a. Specialists/Specialization: The team grouped responses talking about the specialists that work in the microfabrication industry in New Zealand.
    b. Mobility/Adaptability: The team grouped information about the mobility and adaptability of the microfabrication industry in New Zealand, meaning ease of transportation, ease of shipping, and flexibility in terms of switching research industry focus to better align with local and global markets. The team broke this code into three subcodes: “Shipping,” “Schedules,” and “Flexibility.”
    c. Facilities: The team grouped responses citing the different microfabrication facilities in New Zealand as a strength of the industry.
    d. Research Sector: The team grouped responses citing the research sector and research facilities in New Zealand as a strength of the microfabrication industry.
    e. Innovation: The team grouped responses citing the level of innovation present within the microfabrication industry in New Zealand as a strength of the industry.
    f. Improvisation: The team grouped responses pertaining to the ability of New Zealanders to improvise solutions with limited resources.
    g. None: The team grouped responses indicating that there were no real strengths in the microfabrication industry in New Zealand.
    h. Communication / Proximity: The team grouped responses about the ability to communicate, through a phone call or otherwise, with other national or international industry representatives.

i. Collaborative Atmosphere: The team grouped responses about the collaborative atmosphere in New Zealand between stakeholder groups or within a stakeholder group, including responses mentioning current clusters in New Zealand that add to the collaboration.

3. Weaknesses:

   a. Government Regulations: The team grouped responses citing government regulations that might inhibit the formation of the microfabrication cluster in New Zealand due to the extra efforts needed to comply. The team split this code into three subcodes to differentiate the regulations each stakeholder identified: “Health and safety,” “Customs/Importing and exporting,” and “Environment.”

   b. Size/Scale: The team grouped responses citing New Zealand's population size or production quantity as a hindrance to the microfabrication industry in the country. The team split this code into two subcodes: “Size of country” and “Scale of production.”

   c. Funding: The team grouped responses citing that the levels of funding within their company or within the microfabrication industry in New Zealand are too low. To differentiate between lack of government funding, lack of internal funding, and competition for funding with other industries, the team split this code into three subcodes: “In general,” “Due to government,” and “Competition for funding.”

   d. Facilities/Equipment: The team grouped responses saying that the microfabrication facilities and the equipment in those facilities in New Zealand are not as good as they are in other countries, or subpar.

   e. Industry Existence/Visibility: The team grouped responses addressing the visibility of the microfabrication industry in New Zealand from the eyes of the general public and from other industry representatives, as well as the lack of key sectors, such as suppliers or manufacturers. The team split this code into four subcodes: “Lack of complete industry,” “Public visibility,” “Underestimated/Not taken seriously,” and “Global visibility.”

f. Lack of Communication: The team grouped responses stating that there is a lack of communication in the microfabrication industry in New Zealand and the rest of the world. The team split this code into three subcodes: “Between sectors,” “Within sector,” and “With the rest of the world.”

g. Global Competition: The team grouped responses addressing the difficulty of competing with other companies and organizations, as well as what countries the competition comes from. The team split this code into two subcodes: “Against China” and “Against other countries.”

h. Need for Immediate Globalization/No Market in New Zealand: The team grouped responses talking about the lack of a market for microfabrication in New Zealand, and the need for immediate globalization.

i. Distance: The team grouped responses citing the distances between the different microfabrication facilities and the distances from other countries as a weakness of the microfabrication industry in New Zealand. The team split this code into two subcodes: “Between New Zealand facilities,” and “From other countries.”

j. Lack of People: The team grouped responses stating that the lack of people, including production staff and principal researchers, is a weakness in the microfabrication industry in New Zealand. The team split this code into two subcodes: “Skilled labor,” and “Specialists.”

k. Lack of Supply/Resources: The team grouped responses about the lack of suppliers and resources in the microfabrication industry.

4. Education:
    a. Degrees: The team grouped responses pertaining to what degrees students are pursuing. The team split this code into five subcodes: “Electrical Engineering,” “Mechanical Engineering,” “Physics,” “Chemistry,” and “Other/Not specified.” The team used the “Other/Not specified” subcode only in the one digital questionnaire, where we were unable to clarify the student's degree in person.
    b. Jobs in New Zealand: The team grouped responses about students wanting to stay in New Zealand for their career in microfabrication. The team split this code into four subcodes: “Family/Significant other,” “Home,” “The environment,” and “Culture.”
    c. Jobs outside of New Zealand: The team grouped responses about students wanting to leave New Zealand in search for a career in microfabrication. The team split this code into six subcodes in order to determine their reasons for wanting to leave: “No jobs,” Poor facilities,” “Not competitive globally,” “From a different country,” “Family/Significant other,” and “Desire to travel.”

Objective 2

To determine the willingness of New Zealand organizations to join a cluster initiative and to determine the potential barriers hindering the formation of the cluster.

1. Willingness:
    a. Conditions to Join: The team grouped responses about the idea that something else needs to be present before the representative would join a cluster initiative for microfabrication in New Zealand. The team split this code into four subcodes based on what the interviewees wanted to see in a cluster initiative: “Mediator,” “Common goal,” “External funding,” “All parties equally represented,” “Applicable to Personal Work.”

b. Not Interested: The team grouped responses about the idea that there is no interest for some industry representatives in joining a cluster initiative in microfabrication. The team split this code into two subcodes based on the interviewees' reasons for not wanting to join a cluster: "Academia" and "Think it cannot work."

c. Interested: The team grouped responses about why industry representatives might be interested in joining a cluster initiative for microfabrication. The team split this code into seven subcodes to gauge the scale of interest and skepticism about the cluster: "Benefits to organization," "Benefits to New Zealand," "Benefits to all organizations," "Skeptical of success," "Decreases national competition," "Personal gain separate from organizational gain," and "Trading staff."

2. Barriers:

a. Funding for Cluster: The team grouped responses citing the lack of funding for the sustainment of the microfabrication cluster as a barrier to the formation of the cluster.

b. Common Vision: The team grouped responses about the existence of a common vision for the cluster. When this common vision is lacking, it is a barrier to the formation of a microfabrication cluster in New Zealand. The team split this code into two subcodes: "Between sectors" and "For the cluster as a whole."

c. Internal Competition: The team grouped responses relating to the idea of competition between other organizations or other countries being a barrier to the formation of a microfabrication cluster in New Zealand.

d. Relevancy Methods: The team grouped responses about the various methods that the industry representatives use to stay relevant with current processes and technologies. The team split this code into six subcodes: "Reports," "Academic journals," "Conferences," "Trading Staff," "Not enough time to stay up to date," and "Clusters/Relationships with other organizations."

e. <u>Lack of Communication</u>: The team grouped responses about the various relationships, within sectors or between sectors, which are not present in the microfabrication industry, acting as a barrier to the formation of the cluster. The team split this code into two subcodes: "Between sectors" and "Within sectors."

f. <u>Awareness of Industry</u>: The team grouped responses about the individual's awareness of other organizations within the microfabrication industry in New Zealand. The team split this code into three subcodes: "Very aware," "Partially aware," and "Not aware." The team then split each of these subcodes into three additional sub-subcodes to identify which connections between sectors are not present: "Research/Universities," "Manufacturers," and "Suppliers."

g. <u>Growth of Company</u>: The team grouped responses about the growth of the companies of the interviewees based on whether the company had hired more staff recently, or if they will be hiring in the future. The team split this code into three subcodes: "Staying the same," "Growing," and "Declining."

3. Knowledge of Clusters:

    a. <u>Knowledge of Clusters</u>: The team grouped responses to ascertain the level of knowledge of clusters among industry representatives. The team split this code into four subcodes: "Current clusters," "Clusters they are/have been involved in," "Little to no knowledge," and "Familiar with just the concept."

<u>Objective 3</u>

To identify the perceptions of industry members concerning potential environmental and cultural impacts that the microfabrication industry may have in New Zealand.

1. Environmental Concerns:
    a. Concerns to Environment: The team grouped responses pertaining to the various perceived environmental concerns facing the microfabrication industry in the form of chemicals, solvents, or nanotechnology. The team split this code into six subcodes: “Heavy metals,” “Nanotechnology,” “Solvents,” “Chemicals,” “Other,” and “Hazardous waste handled properly.”
    b. No Concerns to Environment**:** The team grouped responses saying that there were no perceived concerns to the wellbeing of the environment. The team split this code into three subcodes: “Too small a scale to produce harm,” “Chemicals properly handled,” and “Nothing harmful is produced at all.”
2. New Zealand Culture and Society:
    a. Maori: The team grouped responses concerning the perceived impact of microfabrication on Maori culture. The team split this code, used primarily for the two Maori interviews, into nine subcodes: “Ability to adapt,” “Open to technology,” “Conservative Views,” “Economic Growth,” “Primary Industry,” “Education/ Involvement,” “Cultural conflicts,” “Exposure to S.T.E.M.,” and “Clusters.”
    b. Open to the Idea of Clusters: The team grouped responses about the openness and awareness of New Zealand culture to the idea of clusters.
    c. Openness to and Awareness of Technology and Microfabrication: The team grouped responses about the usage of high-tech devices in New Zealand, as well as the awareness of the usage of high-tech devices. The team split this code into two subcodes: “Openness” and “Awareness.”
    d. Primary Industries: The team grouped responses about the different primary industries and their importance in the New Zealand society.

e. Ease of Life: The team grouped responses about the increase to the ease of life in New Zealand that microfabrication brings, such as through the impact of devices like cell phones.

f. Change Similar to Global Change: The team grouped responses about the idea that microfabrication has impacted New Zealand society in the same way that it has affected the rest of the world.

3.3 Data Analysis

The data analysis procedure consisted of three steps: analyzing the demographical data acquired from the interviews, quantitatively comparing the similarities and differences between stakeholder groups by objective, and qualitatively analyzing the data pertaining to the perceived Maori cultural concerns. Section 3.3.1 details the demographical analysis that the team used and section 3.3.2 details the quantitative and qualitative analyses by objective. The team used the combination of these analysis steps and the conclusions drawn from them to create our final recommendations for the establishment of a microfabrication cluster in New Zealand.

3.3.1 Demographical Data Analysis

The team created pie charts to represent the demographic data that we collected from our interviews. The demographic data included how many interviewees and organizations the team interviewed from each of the stakeholder groups. In addition to the key stakeholder groups of researchers, manufacturers, suppliers, and students, the team included an “other experts” classification to include all other interviewees that did not associate with any of the key stakeholder groups.

3.3.2 Analyses by Objective

For the quantitative analysis, the team picked out key, countable categories related to our objectives that were prevalent in all of the interviews and tallied the number of interviewees that responded with ideas that we were able to code using specific codes within the categories in order to display them graphically. Once the team finished going through all the transcripts, we counted the tallies within a stakeholder group and compared those tallies in the tables which are located in Chapter 4. This allowed the team to draw conclusions concerning the relationship between each stakeholder group and the project's three objectives. Where appropriate, the team also created graphs to display the views and opinions of the entire interviewee pool. Analysis of these graphs led to conclusions about the microfabrication industry as a whole. Each table or graph is accompanied by an analysis about the importance of the similarities and differences to the formation of a potential microfabrication cluster in New Zealand.

For the qualitative analysis, the team analyzed the responses from the two different Maori interviewees. To do this, we coded their transcripts and compared the similarities and differences in their statements. This gave us some ideas about their opinions, but didn't necessarily allow us to make decisive statements about their responses due to the small sample size.

Based on the mixture of quantitative and qualitative data analysis, the team was able to draw conclusions about how the views of the different interviewees and stakeholders influenced the cluster initiative. These conclusions helped the team determine the feasibility of establishing a microfabrication cluster in New Zealand and resulted in the creation of final recommendations about how to establish a microfabrication cluster.

4 Results and Analysis

As a note to the reader, this chapter uses the generic terms: researcher, manufacturer, student, or supplier to specifically refer to the individuals that we interviewed who are working in those sectors within, or relating to, the microfabrication industry in New Zealand. The team also interviewed three other experts who did not identify with any of the four major stakeholder groups. These interviews were with the CEO of Callaghan Innovation and two Maori: the Maori Business and Relationship Manager at Callaghan Innovation and a Principle Advisor of the Maori Economy at the Treasury Department. We incorporated the data collected from these individuals in the combined analysis of the data where applicable. The team drew these results specifically from the interviewed population and we cannot generalize these results with confidence to the whole microfabrication industry or the specific sectors of the microfabrication industry in New Zealand.

4.1 Demographical Data Analysis

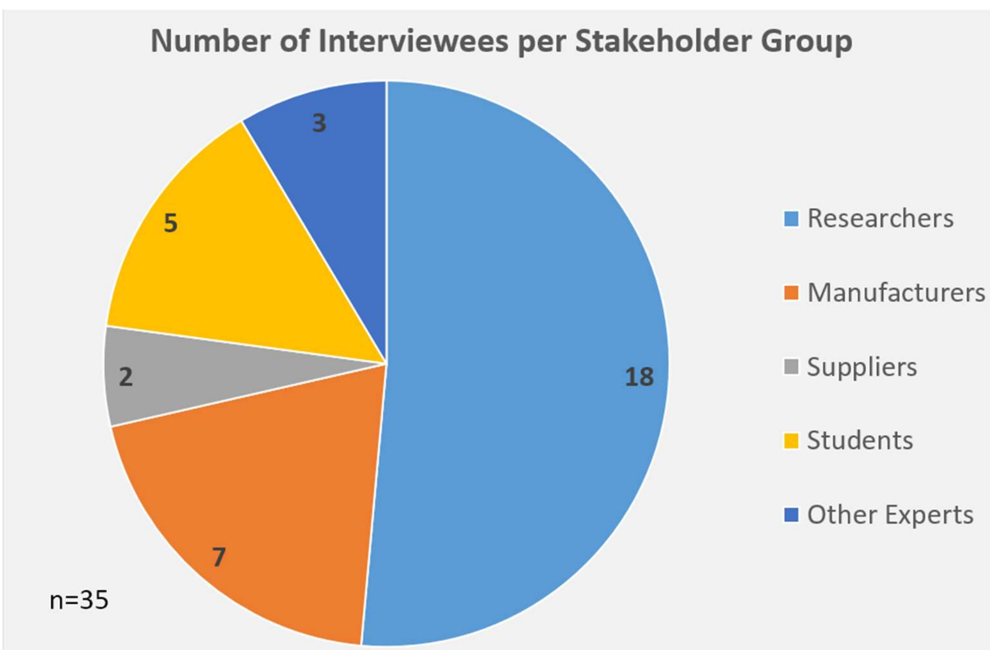


Figure 4.1: Number of Interviewees per Stakeholder Group

Figure 4.1 displays the number of interviewees who identified themselves in one specific stakeholder group. The majority of the interviews we conducted were with researchers. The possibility that researchers were more willing to talk about the potential for a cluster initiative can explain the difference in the number of interviews conducted, but it is more likely to be the result of the dominant number of researchers within the current microfabrication industry in New Zealand. The fact that researchers make up more than half of our interviewees may indicate that the research sector for microfabrication in New Zealand is more prevalent than the other sectors of the microfabrication industry in New Zealand. The team struggled to find suppliers to interview and as a result only interviewed two. This may possibly indicate a lack of actual suppliers of microfabrication products in New Zealand.

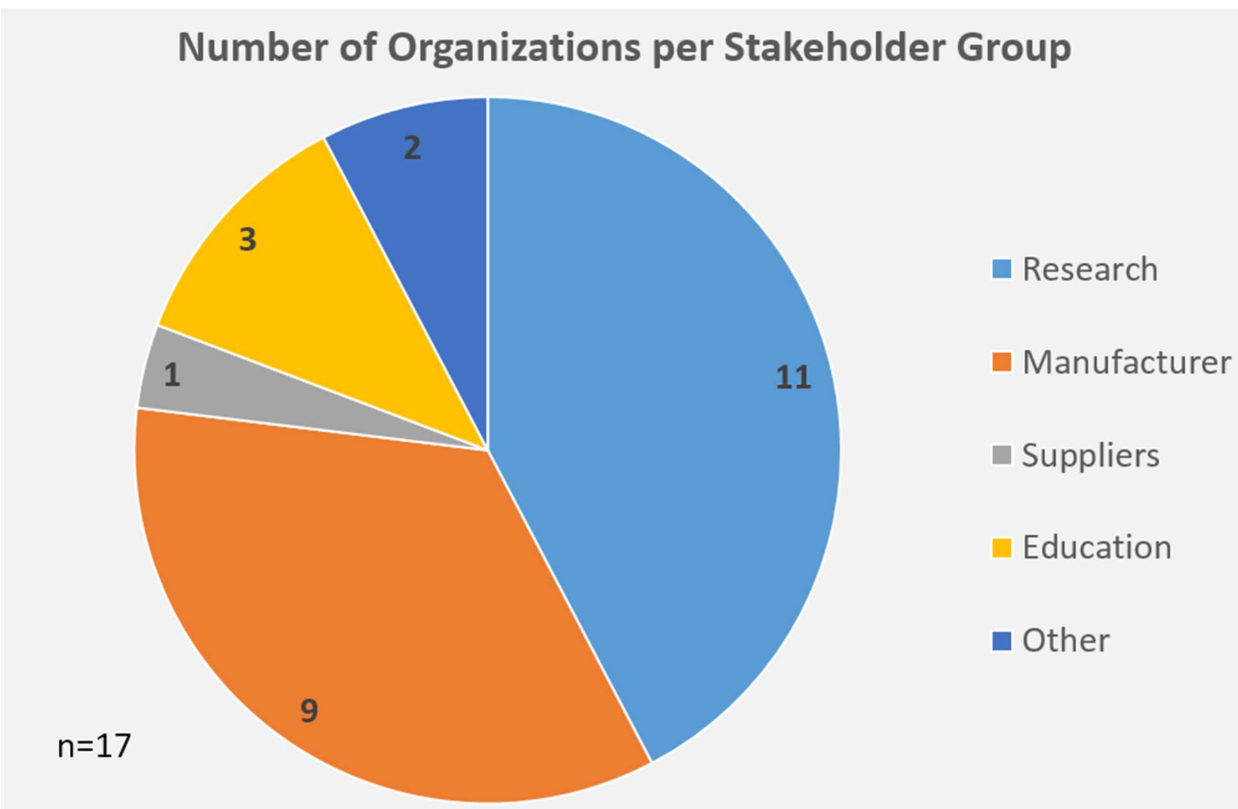


Figure 4.2: Number of Organizations per Stakeholder Group

Figure 4.2 displays the number of organizations per specific stakeholder group based on the responses from the interviewees. We asked each interviewee to also categorize their organization into a sector or sectors of the industry (research, manufacturing, supplier, and education). The organization the interviewee belonged to could be different from the interviewee's personal involvement. Some interviewees identified their organization as being in multiple sectors, which accounts for the fact that there were 17 organizations, but there are 26 responses in the pie chart.

4.2 Objective 1

The project's first objective was to evaluate the current state of the microfabrication industry in New Zealand and the needs of the organizations. From the semi-structured interviews the team conducted with members from each of the stakeholder groups, the team identified five key themes to concisely represent the data that we collected that is germane to our first objective. These are: “Strengths of the Microfabrication Industry in New Zealand,” “Weaknesses of the Microfabrication Industry in New Zealand,” “Efficiency,” “Future Outlook of the Microfabrication Industry in New Zealand,” “Plans after Graduation.” Sections 4.2.1 to 4.2.5 display the data that the team gathered from the interviews and the analysis of this data.

4.2.1 Strengths of the Microfabrication Industry in New Zealand

The team evaluated the perceived strengths of the current microfabrication industry in New Zealand based on responses to Question 15: **“What are the strengths of the microfabrication industry in New Zealand?”** and represented the responses in Table 4.1 and Figure 4.3. It is important to note that the team did not specifically prompt for any of the specific strengths of the industry and that we based all specific strengths on the interviewees’ responses. It is also important to note that interviewees were able to give as many or as few strengths as they wished in the interviews and the total count of strengths does not necessarily match the number of interviewees.

Strengths Mentioned	**Researcher**		**Manufacturer**		**Student**		**Supplier**		**Other**		**Total**	
Specialists	7	39%	4	57%	0	0%	0	0%	0	0%	11	31%
Mobility	4	22%	3	43%	0	0%	2	100%	0	0%	9	26%
Facilities	1	6%	0	0%	1	20%	1	50%	0	0%	3	9%
Research Sector	1	6%	3	43%	1	20%	2	100%	0	0%	7	20%
Innovation	0	0%	2	29%	0	0%	1	50%	1	33%	4	11%
Improvisation	3	17%	3	43%	0	0%	0	0%	0	0%	6	17%
Communication / Proximity	1	6%	0	0%	0	0%	0	0%	0	0%	1	3%
Collaborative Atmosphere	6	33%	3	43%	1	20%	2	100%	0	0%	12	34%
None	2	11%	0	0%	0	0%	0	0%	0	0%	2	6%
Number of Responses	18		7		5		2		3		35	

Table 4.1: Interviewee Identified Strengths of the Microfabrication Industry in New Zealand

Table 4.1 shows that 39% of researchers said that specialists and specialization in the microfabrication industry in New Zealand are a strength whereas 57% of manufacturers said the same and no students or suppliers identified it as a strength. This data may suggest that manufacturers consider specialists and specialization to be more important to the success of the microfabrication industry in New Zealand or that they are more aware of the specialists compared to the other three stakeholders groups. Table 4.1 also reveals that only 1 out of 18 researchers and 1 out of 5 students, two groups mainly involved with research, identified the research sector as a strength of the microfabrication industry in New Zealand. However, the data for manufacturers and suppliers shows that 43% of manufacturers and 100% of suppliers identified the researching sector to be a strength. This suggests that the stakeholder groups who are not directly and wholly involved with research believe that the researching sector is important whereas the individuals working directly in research may undervalue their role.

Knowing the current strengths of the microfabrication industry is important because these strengths will help form the foundation of the potential microfabrication cluster in New Zealand. Knowing the strengths is also important as these strengths help the industry recognize which areas do not need as much attention. Essentially, knowing the strengths helps to prioritize where energy and resources should go when trying to improve the industry as a whole.

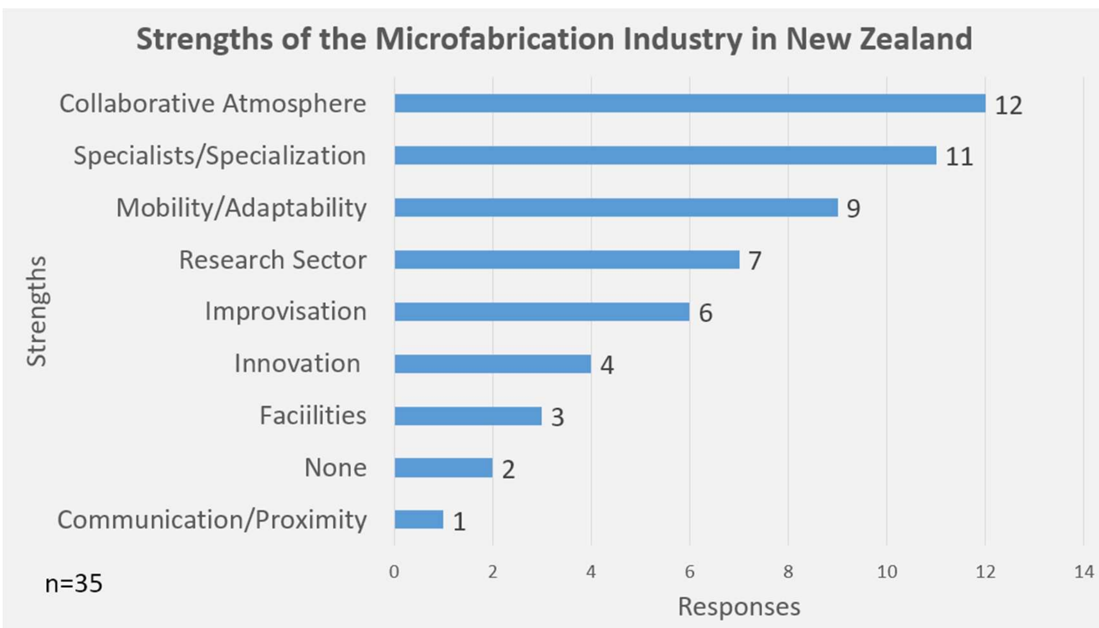


Figure 4.3: Interviewee Identified Strengths of the Microfabrication Industry in New Zealand

Figure 4.3 displays the perceived main strengths of the current microfabrication industry ordered by the number of the interviewees who identified them. The three main strengths identified were having a collaborative atmosphere, having a variety of quality specialists and areas of specialization, and having the advantage of mobility and flexibility.

As Figure 4.3 depicts, the collaborative atmosphere is the largest perceived strength of the current microfabrication industry based on the number of the interviewees that identified it. While this is only 34% of the total number of interviewees, this is still a significant percentage since the team's questions never asked about collaboration in the microfabrication industry. Having a good collaborative environment is essential to cluster success and if that already exists in New Zealand, as this data suggests, it will greatly increase the chance of forming a successful cluster. Leo Browning, a PhD student from Victoria University of Wellington, highlighted the importance of collaboration to a small country like New Zealand.

> *Why I think the collaborative environment is so important is that there [are] a lot of big companies around the globe, big countries, big research economies, and there is no reason why a small country, small economy, small research group can't contribute but it needs to be in a collaborative way in order to kind of best engage on a global scale. (L. Browning, personal communication, January 20th, 2016)*

When asked about the current strengths of the microfabrication industry, 31% of the interviewees said that they considered specialists and specialization to be a strength of the microfabrication industry in New Zealand. Again this is significant because the team did not specifically ask about specialization or specialists. Having numerous specialists in various different areas of specialization can potentially help a cluster by giving the cluster a wider breadth of knowledge and lower the chances of falling into a competency trap.

Figure 4.3 illustrates that the third largest strength that the interviewees identified is mobility/adaptability. Mobility refers to the microfabrication industry's ability to easily ship products due to the small size of microfabricated elements. Adaptability refers to the ability of this industry to switch specializations and focuses quickly and adapt to changing trends. Mobility was a strength that the team did not think of when we initially created our interview questions. Being able to ship microfabrication products easily and cheaply due to their weight and size could give the microfabrication industry in New Zealand an advantage over other New Zealand industries.

4.2.2 Weaknesses of the Microfabrication Industry in New Zealand

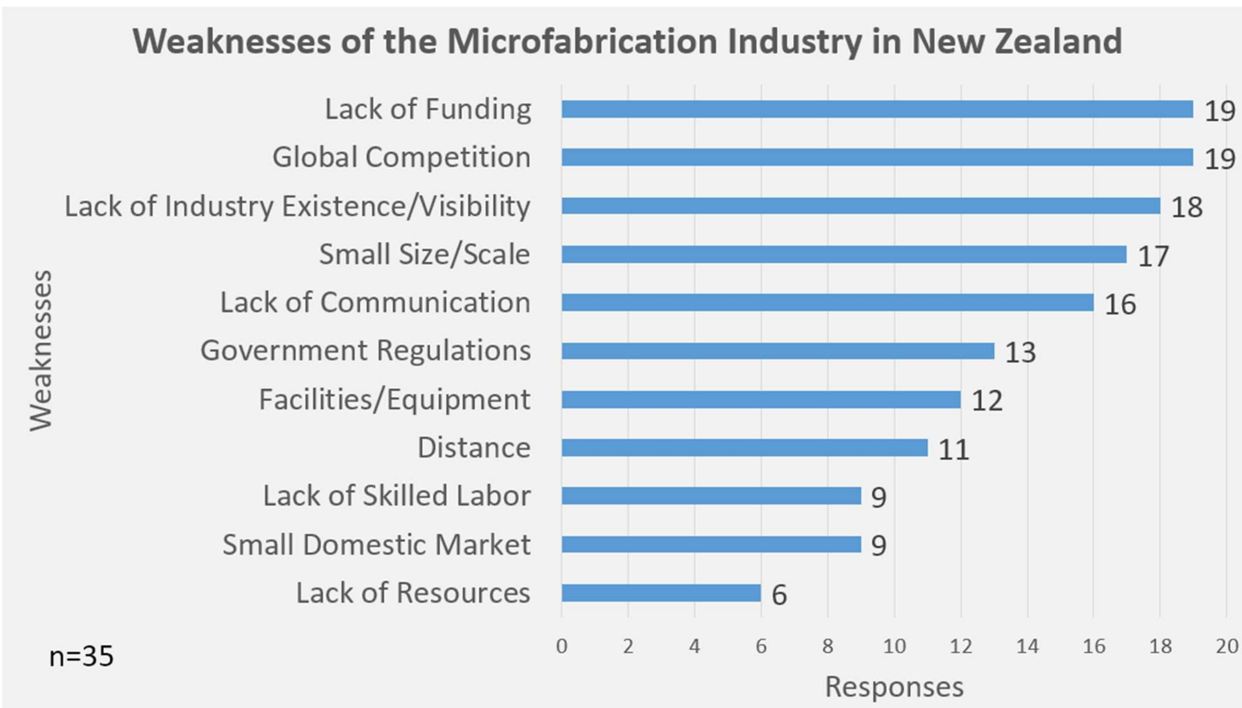


Figure 4.4: Interviewee Identified Weaknesses of the Microfabrication Industry in New Zealand

Weaknesses Mentioned	**Researcher**		**Manufacturer**		**Student**		**Supplier**		**Other**		**Total**	
Small Size / Scale	11	61%	4	57%	1	20%	1	50%	0	0%	17	49%
Lack of Funding	11	61%	2	29%	2	40%	2	100%	2	66%	19	54%
Facilities / Equipment	8	44%	3	43%	1	20%	0	0%	0	0%	12	34%
Existence	12	66%	4	57%	2	40%	0	0%	0	0%	18	51%
Lack of Communication	7	39%	3	43%	0	0%	1	50%	0	0%	11	31%
Competition	8	44%	7	100%	1	20%	2	100%	1	33%	19	53%
Need for Globalization / No Market in NZ	6	33%	3	43%	0	0%	0	0%	0	0%	9	26%
Distance	5	28%	3	43%	1	20%	2	100%	0	0%	11	31%
Lack of Skilled Labor	4	22%	3	43%	1	20%	1	50%	0	0%	9	26%
Lack of Resources	3	17%	1	14%	1	20%	1	50%	0	0%	6	17%
Government Regulations	7	39%	4	57%	0	0%	1	50%	1	33%	13	37%
Number of Respondents	18		7		5		2		3		35	

Table 4.2: Interviewee Identified Weaknesses of the Microfabrication Industry in New Zealand

The team evaluated the perceived weaknesses of the current microfabrication industry in New Zealand based on responses to Question 16: **“What are the weaknesses of the microfabrication industry in New Zealand?”** and represented the responses in Table 4.2 and Figure 4.4. It is important to note that the team did not prompt for any of the specific weaknesses of the industry and that we based all weaknesses on the interviewees’ responses. Additionally, note that interviewees were able to give as many or as few weaknesses as they wished in the interviews and the total count of weaknesses does not necessarily match the number of interviewees.

Figure 4.4 provides the weaknesses of the current microfabrication industry based on the number of the interviewees who identified them. The four main weaknesses are lack of funding, industry existence, global competition, and the small population size of the country and scale of production.

Figure 4.4 shows that 54% of the interviewees considered lack of funding to be a weakness of the current microfabrication industry in New Zealand. Table 4.2 reveals that 61% of researchers, 29% of manufacturers, 40% of students, and 100% of suppliers said that lack of funding is a weakness of the current microfabrication industry in New Zealand. This data suggests that this is a major problem for the industry. Lack of funding could hinder the formation of a cluster but it could also give individual organizations a reason to join a cluster initiative. It may be the right choice for some organizations to join the cluster if there is a sharing of resources such as funding.

Figure 4.4 illustrates that 49% of the total interviewees indicated that size and scale of the country and production were weaknesses of the current microfabrication industry in New Zealand. Table 4.2 reveals that 50% or more of three separate stakeholder groups identified the population size of New Zealand and scale of production as a weakness of the microfabrication industry in the country. There is no direct solution to the problem of New Zealand’s small population size as there is no way to suddenly and drastically increase the local population. There may be ways to indirectly relieve the problems associated with having such a small national population. Cather Simpson, Director of the Photon Factory in Auckland, touched on the weaknesses posed by limited funding and small size.

> *The hardest thing about New Zealand in general, and especially for high tech things like microfab, is that we're far away and we're small. So a lot of the cutting edge microfabrication stuff is quite expensive and we simply can't afford to have a lot of it, if we have it at all. (C. Simpson, personal communication, January 26, 2016)*

Limited funding for state-of-the-art equipment and small population of the country may contribute to New Zealand's lack of competitiveness with other countries. Figure 4.4 displays that 54% of the total interviewees considered global competition to be a weakness of the current microfabrication industry in New Zealand. Global competition refers to difficulties competing in foreign markets. All of the manufacturers cited global competition as a weakness of the current microfabrication industry in New Zealand. Compared to other stakeholder groups, this issue was much more prominent for the manufacturers. This is likely because manufacturers are the organizations dealing with commercialization and trying to sell their products in global markets.

Figure 4.4 shows that 51% of the total interviewees considered the lack of existence of a developed microfabrication industry in New Zealand and visibility of the industry to be a weakness of the industry. Table 4.2 reveals that both a majority of researchers and manufacturers see this as a major weakness for the industry. This implies that organizations need to do more to promote commercial businesses better. “Competing against nations that have lower cost of operation than we do makes it very challenging.” (Anonymous C, personal communication, 2016) Because it is often cheaper to produce devices in other countries like China that have more resources and more relaxed labor laws, it can be very difficult for New Zealand companies to compete globally.

4.2.3 Effect of Microfabrication on Technology

The team evaluated the perceived effects of microfabrication on technological progress, specifically the increased efficiency of technology, based on responses to Question 11: **"How has miniaturization changed technology in New Zealand?"** and represented the responses in Table 4.3 It is important to note that the team did not prompt for any specific effects of microfabrication on technology. Table 4.3 represents efficiency as a result of the number of voluntary responses about the positive effect of microfabrication on technological efficiency.

Effect of Microfabrication on Technology	**Researcher**		**Manufacturer**		**Student**		**Supplier**		**Total**	
Efficiency	8	44%	4	57%	2	40%	1	50%	15	43%
Number of Respondents	18		7		5		2		35	

Table 4.3: Interviewee Responses Pertaining to Added Efficiency

The data in Table 4.3 suggests that is no great difference between the stakeholder groups' opinions concerning the effects of microfabrication on the efficiency of technologies and devices, with roughly half of each stakeholder group commenting on the topic. CEO of Revolution Fibers, Iain Hosie gave an example of the scale of the efficiency added through microfabrication: "One kg of polymer can make a fiber that would reach the sun because it's so fine" (I. Hosie, personal communication, January 26th, 2016). Given that the team did not prompt for responses on the efficiency, it is important to note the high percentage of responses that chose to highlight this specific effect on technology. This data suggests that the added efficiency is a commonly recognized benefit of microfabrication, and that it is sufficiently important to the industry that many of the interviewees specifically mentioned it.

4.2.4 Future Outlook of the Microfabrication Industry in New Zealand

It was important to assess the interviewees' perceptions about the future outlook of the microfabrication because if these interviewees had a negative outlook for the future, they may be unwilling to join a cluster initiative. The team evaluated perceptions about the future outlook of the microfabrication industry based on responses to Question 12: **"What do you imagine microfabrication in New Zealand to be like in 5-10 years?"** and Question 13: **"How do you see ongoing miniaturization affecting the future in 5-10 years?"** and represented the responses in Figure 4.5. Because some of our interviews were digital and we did not require the interviewees to answer all the questions, 2 of the 35 interviewees did not respond to both Questions 12 and 13. Thus, Figure 4.5 represents 33 total interviewees.

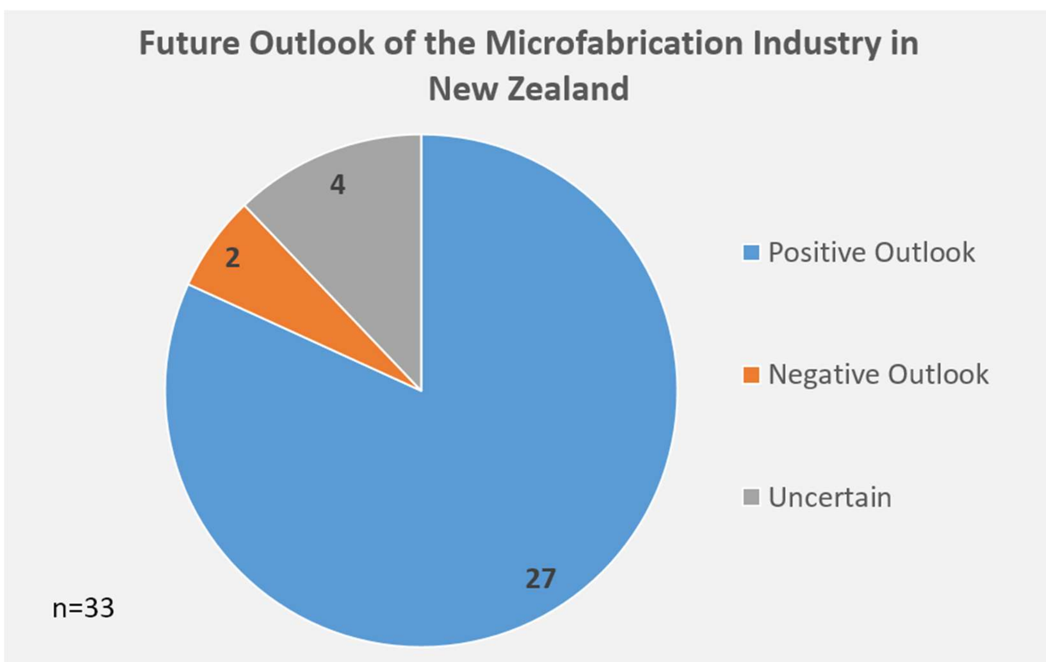


Figure 4.5: Interviewee Perception of Future Outlook of the Microfabrication Industry in New Zealand

This graph illustrates that a significant majority of the interviewees had a positive outlook on the future of the microfabrication industry in New Zealand, with only 6% of the interviewees having a negative outlook on the future of the microfabrication industry in New Zealand and 82% having a positive outlook. This suggests that many of the stakeholders currently in the industry see microfabrication either becoming stronger in the future, or having more of an impact on New Zealand. Researcher Alan Coulson reinforced this idea, stating, “obviously it’s a technology of high potential future benefit to New Zealand. It’s an area where good researchers can really push boundaries of what’s possible and therefore can really help drive business opportunities” (A. Coulson, personal communication, January 28th, 2016).

4.2.5 Plans after Graduation

The team evaluated graduate students’ future plans concerning whether or not they would continue their careers in New Zealand or in other countries based on responses to Questions 48: **“Are you looking to get a job in New Zealand or somewhere else?”** Question 49: **“If you are looking to get a job in another country, why?”** and Question 50: **“If you are looking to get a job in New Zealand, why?”** and represented the responses in Table 4.4 and Table 4.5. We only asked these questions to the student stakeholder group, and as such there were only five responses. The lack of responses reduces the confidence in a strictly quantitative sense. From the interview responses, the team generated specific reasons for each action (staying and leaving), as well as common weaknesses of the microfabrication industry here in New Zealand.

n=5	**Family / Significant Other**	**The Environment**	**The Culture**
Students	3	1	2

Table 4.4: Student Identified Reasons Why Students Want to Stay in New Zealand

Table 4.4 displays that the reasons why the students would want to stay in New Zealand relate to family and intrinsic things about New Zealand. The data suggests that people love New Zealand for both its culture and environment, as Ph.D. student Leo Browning states, “a lot of people live here and a lot of people choose to move here from other places because it’s a beautiful place. It’s got a lot of natural beauty, it’s not super crowded….” (L. Browning, personal communication, January 20th, 2016) The data also shows that the response of staying for family or a significant other was just as common.

n=5	**No Jobs**	**Poor Facilities**	**Not Competitive Globally**	**Family / Significant Other**	**Desire to Travel**
Students	1	0	0	2	1

Table 4.5: Student Identified Reasons Why Students Would Leave New Zealand

Table 4.5 indicates that the most common response to wanting to leave was the same reason for staying: to be closer to family.

4.3 Objective 2

The project’s second objective was to determine the willingness of New Zealand organizations to join a cluster initiative and to determine the potential barriers hindering the formation of the cluster. From the semi-structured interviews that the team conducted with members from each of the stakeholder groups, the team pulled out three key categories to concisely represent the data that we collected with respect to our second objective. The three categories that the team used are: “Willingness to Join a Cluster,” “Barriers to the Formation of a Microfabrication Cluster,” and “Current Knowledge of Clusters.” Sections 4.3.1 to 4.3.3 display the data that the team gathered from the interviews and the analyses of this data.

4.3.1 Willingness to Join a Cluster

The team evaluated the willingness of organizations to join a microfabrication industry cluster initiative in New Zealand based on responses to Question 20: **“How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field? Why or why not?”** and represented the responses in Figure 4.6 and

Table 4.6. We did not ask Question 20 to 1 of the 35 interviewees, who worked for the New Zealand Treasury, as he was not a potential microfabrication cluster member. Hence, Figure 4.6 and Table 4.6 indicate only 34 total respondents. It is important to note that the team did not prompt for any of the specific conditions for joining the cluster and we based the conditions represented on the interviewees' volunteered responses. It is also important to note that interviewees were able to give as many or as few conditions as they wished in the interviews, so the total count does not necessarily match the number of interviewees.

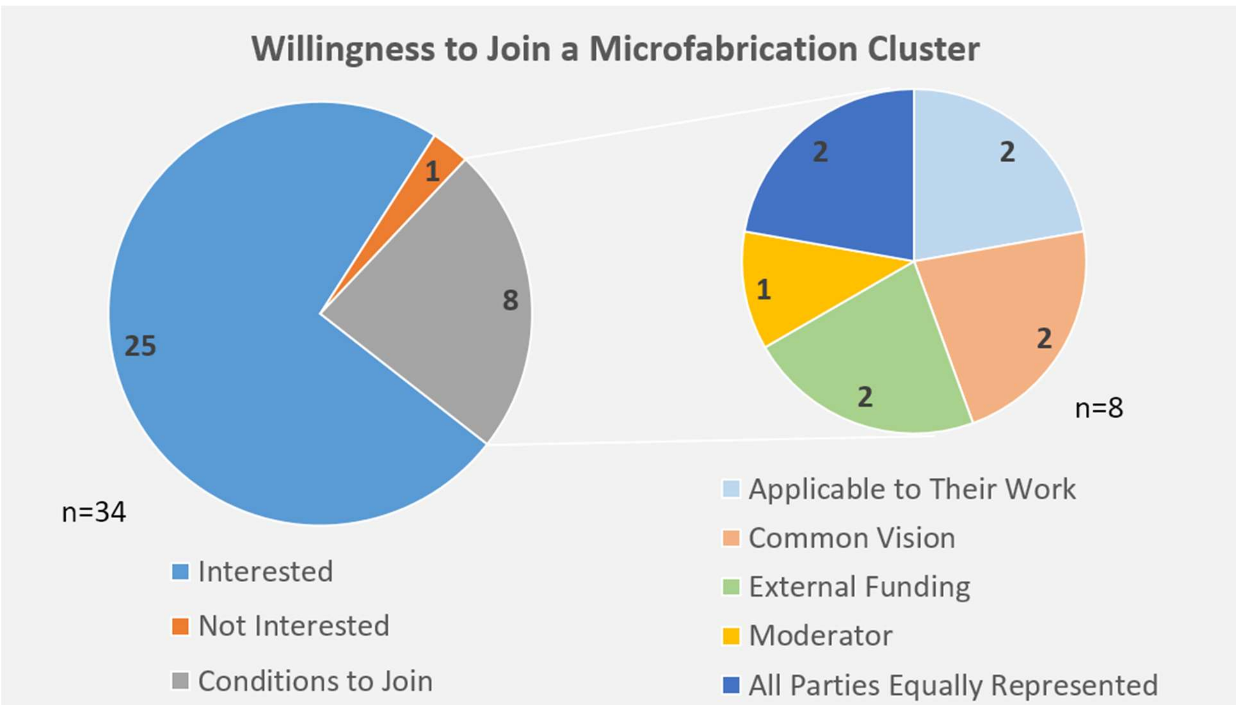


Figure 4.6: Willingness to Join a Microfabrication Cluster and Additional Needs

Interest Levels, Contingencies, and Skepticism	**Researcher**		**Manufacturer**		**Student**		**Supplier**		**Other**		**Total**	
Interested	15	83%	3	43%	4	80%	1	50%	2	66%	25	71%
Not Interested	1	6%	0	0%	0	0%	0	0%	0	0%	1	3%
Conditions to Join	2	11%	4	57%	1	20%	1	50%	0	0%	8	23%
Applicable to Their Work	2	11%	0	0%	0	0%	0	0%	0	0%	(2)	(25%)
Mediator	0	0%	1	14%	0	0%	0	0%	0	0%	(1)	(13%)
Common Vision	0	0%	2	29%	0	0%	0	0%	0	0%	(2)	(25%)
External Funding	0	0%	2	29%	0	0%	0	0%	0	0%	(2)	(25%)
All Parties Equally Represented	0	0%	0	0%	1	20%	1	50%	0	0%	(2)	(25%)
Skepticism of Cluster Success	3	9%	3	9%	0	0%	0	0%	0	0%	6	18%
Number of Respondents	18		7		5		2		3		35 (8)	

Table 4.6: Interviewee Willingness to Join a Microfabrication Cluster

In the “Total” column in Table 4.6, some figures are surrounded by parentheses. These figures represent the specific conditions mentioned by those interviewees who were interested in joining a cluster, but mentioned contingencies to joining. Because not every interviewee responded in such a manner, the total number of respondents is out of 8, and not 35. Table 4.6 depicts that 74% of interviewees said that they would be willing to join a microfabrication cluster initiative in New Zealand, but did not mention any conditions of their own on how the proposed cluster would run. An additional 24% of interviewees said that they would be willing to join the cluster if the proposed cluster has certain aspects in it. One interviewee said he was not willing to join the proposed cluster initiative because he saw his role in academia and did not see a need to join a cluster. Having such a large percentage of individuals who are willing to join the microfabrication cluster initiative is very encouraging for the feasibility of creating such a cluster.

As Table 4.6 reveals, 4 of the 7 manufacturers (57%) were in the group of 8 interviewees who wanted something more out of the cluster before committing. This means that 50% of the interviewees who wanted something more were manufacturers. This suggests that manufacturers are less flexible when it comes to terms on which they will enter a microfabrication industry cluster initiative in New Zealand. It could be detrimental for the cluster if one group has rigid terms to join, because if they are not convinced to join then the cluster will not function. Among them, these 8 interviewees specified five different conditions for the cluster initiative:

- It must be applicable to the work that they already do or plan to do.
- There must be a common vision for the cluster as a whole.
- There should be a mediator or objective third party to go between clients and the proposed cluster.
- All parties must be equally represented in the cluster.
- There should be some form of external funding for this cluster.

For the most part, interviewees mentioned these conditions in approximately the same amounts. It is important to note that 6 of the 34 interviewees were skeptical of the proposed cluster's success.

4.3.2 Barriers to the Formation of a Microfabrication Cluster

The team evaluated the barriers to the formation of a microfabrication cluster based on responses to Questions 17: **"How do you feel about collaboration with other organizations?"** Question 18: **"What do you know about industry clusters and how do you see a cluster operating?"** Question 19: **"How aware are you of the microfabrication facilities in New Zealand?"** and Question 22: **"What types of government regulations affect your work?"** and represented the responses in Table 4.7 and Table 4.8. The team compiled the list of specific barriers from the interview responses. The tallies from each of the responses do not add up to the number of responses in each stakeholder group, as one interviewee could mention more than one barrier.

Identified Barriers	**Researcher**		**Manufacturer**		**Student**		**Supplier**		**Other**		**Total**	
Lack of Funding for Cluster	3	17%	1	14%	0	0%	0	0%	1	33%	5	14%
Lack of Common Vision	0	0%	2	29%	0	0%	1	50%	0	0%	3	9%
Competition	3	17%	2	29%	0	0%	1	50%	0	0%	6	17%
Lack of Communication	7	39%	5	71%	2	0%	1	50%	1	33%	16	46%
Number of Respondents	18		7		5		2		3		35	

Table 4.7: Perceived Barriers to the Formation of the Microfabrication Cluster

Table 4.7 suggests that the largest barrier to the formation of a microfabrication cluster in New Zealand is the lack of communication between the different organizations and the different sectors, with 46% of interviewees mentioning it as a hindrance. As these responses were unprompted, this may also suggest that this barrier to the formation of a cluster is one that is most impactful to the individual organizations. With 71% of manufacturers and 39% of researchers mentioning the lack of communication, it was the most common response. The data suggests that the existence of internal competition, a lack of funding to support an industry cluster, and a lack of a common vision are less significant barriers to the formation of the microfabrication cluster in New Zealand than the lack of communication between potential cluster members. This lack of communication may arise due to the fact that the different sectors are relatively unaware of each other, as seen in Table 4.8.

Another barrier to the formation of a microfabrication cluster suggested by the data is the existence of competition on a national level. With 29% of manufacturers, 17% of researchers, 50% of suppliers, and 17% of all of the interviewees, the data suggests that this is primarily a concern within both the research and manufacturing sectors. Researchers often compete against each other for government grants, while manufacturers compete with their products. Some of the competition could also be due to intellectual property concerns and the competition for clients. One researcher who we interviewed commented on the internal competition between researchers over the available funds by saying, “if we compete on the small amount of funds that [are] available, we all lose” (M. Alkaisi, personal communication, February 4th, 2016). The data may also suggest the lack of funding for a cluster (14% of respondents) as a possible barrier to the formation of the microfabrication cluster. The data shows that the students and suppliers (0%) did not see the lack of funding as impacting the formation of a cluster in microfabrication. This data may suggest that students in the microfabrication industry in New Zealand are not yet aware of the levels of funding on a national level.

Awareness Level	**Researcher**		**Manufacturer**		**Student**		**Supplier**		**Other**		**Total**	
Aware	6	33%	0	0%	0	0%	1	50%	0	0%	7	20 %
Partially Aware	10	55%	4	57%	3	60%	0	0%	1	33%	18	51 %
Not Aware	2	11%	3	43%	2	40%	1	50%	2	66%	10	29 %
Number of Respondents	18		7		5		2		3		35	

Table 4.8: Interviewee Awareness of the Microfabrication Industry

In the context of this section, the term awareness refers to the interviewees' knowledge of the existence of other microfabrication facilities in New Zealand. As Table 4.8 indicates, a majority of the interviewees are only partially aware of the microfabrication industry in New Zealand. This classification included interviewees who had a knowledge of the research sector in New Zealand, such as the universities and government facilities like Victoria University of Wellington and Callaghan Innovation, but little to no knowledge of the manufacturing sector. Table 4.8 also reveals that 29% of the interviewees were not aware of the microfabrication industry at all, or had very limited knowledge of it. The team only classified 20% of the interviewees as aware of the industry. By aware, the team means that the interviewee knew most of the microfabrication research sector currently in New Zealand as well as various members in the microfabrication manufacturing sector. Researchers dominate the proportion of the industry that is aware, 86% of aware interviewees being from the research sector. Also the fact that only 20% of interviewees are aware of the other members of the microfabrication industry in New Zealand suggests that there is a disconnect between the different sectors of the industry in New Zealand. This is not good for the formation of the potential microfabrication cluster, as for a cluster to succeed, the different organizations need to be knowledgeable of the other organizations and what they are doing or researching. A disconnect between the different sectors of the microfabrication industry is a potential barrier to the formation of the proposed microfabrication cluster in New Zealand.

4.3.3 Current Knowledge of Clusters

The team evaluated the current knowledge of industry clusters based on responses to Question 18: **"What do you know about industry clusters and how do you see a cluster operating?"** and represented the responses in Figure 4.7. Not every interviewee gave a response to this question because the team had not asked this question in the first four interviews. As the result of editing our interview questions after some of the initial interviews to better address our second objective, the team did ask this question to the remaining 31 interviewees. This is why the number of respondents to this question does not add up to the sample size of 35.

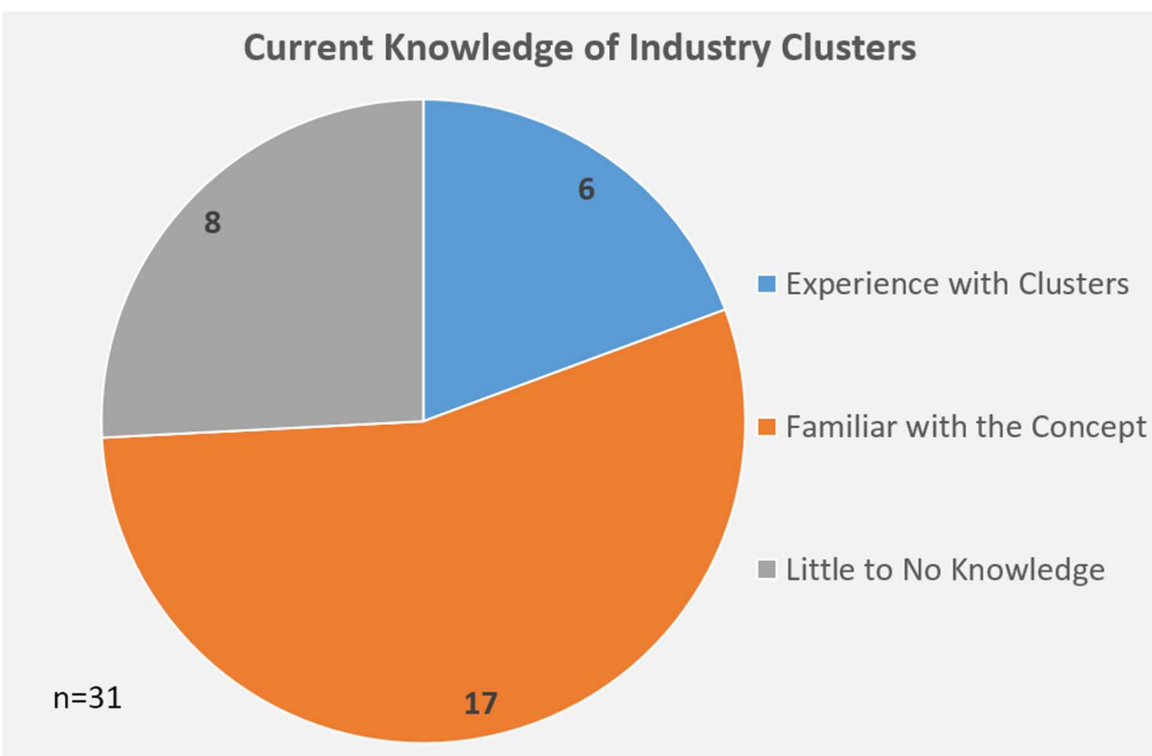


Figure 4.7: Interviewee Current Knowledge of Industry Clusters

Figure 4.7 reveals the overall knowledge of clusters of the individuals that the team interviewed. A total of 23 interviewees were at least familiar with clusters with 6 of them having personal experience with clusters. This experience could be either being a member of a cluster, or even being involved in the process for creating a cluster. Figure 4.7 also indicates that 26% of the interviewees showed or claimed to have little to no knowledge of industry clusters. This data suggests that while the interest and willingness may be there, the knowledge about clusters is lacking. This could be a problem moving forward with the formation of the cluster, because if the individuals making up the cluster do not have solid understanding of what goes into a cluster, then it could compromise the stability of the cluster.

4.4 Objective 3

The project's third objective was to identify the perceptions of industry members concerning potential environmental and cultural impacts that the microfabrication industry may have in New Zealand. From the semi-structured interviews the team conducted with members from each of the stakeholder groups, the team pulled out four key categories to concisely represent the data that we collected with respect to our third objective. The four categories that the team chose are: "Environmental Concerns with Microfabrication," "Handling of Environmental Concerns," "Openness to and Awareness of Technology and Microfabrication", and "Maori Cultural Concerns with Microfabrication". Sections 4.4.1 through 4.4.4 display the data that the team gathered from the interviews and the analyses of this data.

4.4.1 Perceived Environmental Concerns with Microfabrication

The team evaluated the perceptions of the effects of microfabrication on the environment based on responses to Question 21: **"Are there any environmental concerns with**

microfabrication and if so, what are they and how are they dealt with?" and represented the responses in Table 4.9. The team did not ask this question to two of our interviewees. The team compiled the list of perceived environmental concerns from the interview responses. The tallies from each of the responses do not add up to the number of responses in each stakeholder group, as one interviewee could mention more than one environmental concern.

	Researcher		**Manufacturer**		**Student**		**Supplier**		**Other**		**Total**	
Nanotechnology	6	38%	0	0%	0	0%	0	0%	1	33%	7	21%
Solvents	3	19%	1	14%	0	0%	0	0%	0	0%	4	12%
Chemicals	9	56%	4	57%	3	60%	2	100%	0	0%	18	54%
Other	3	19%	0	0%	1	20%	0	0%	0	0%	4	12%
Number of Respondents	16		7		5		2		3		33	

Table 4.9: Interviewee Perceived Environmental Concerns with Microfabrication

Table 4.9 shows the data collected from the interviewees about the various perceived environmental concerns from our interviewees that exist within the microfabrication industry in New Zealand. The two most reoccurring environmental concerns are nanotechnology and the various hazardous chemicals used, such as: hydrofluoric acid, fluorocarbons and sulfur hexafluoride, within the multiple processes in the microfabrication of structures and devices, followed by the use of solvents. Some interviewees discussed the potential negative effects of nanotechnology citing the dispersion and inhalation of nanoparticles. The interviewees cited these as concerns because the scientific community does not yet know the impact of such a new technology on the environment and on people. The common perceived environmental concern that had a similar response over all stakeholder groups was hazardous chemicals with 50% or more of every stakeholder group except other experts identifying this as a concern.

4.4.2 Levels of Concern about the Impact of the Microfabrication Industry on the Environment

The team evaluated the interviewees' levels of concern about the impact of the microfabrication industry on the environment based on the responses to Question 21: "**Are there any environmental concerns with microfabrication and if so, what are they and how are they dealt with?**" and represented the responses in Figure 4.8. The team did not ask this question to two of our interviewees because we edited the interview questionnaire to include this question after the first two interviews. This is the reason that the sample size for this graph is 33. It is important to note that five of the interviewees chose to not answer this question. It is also important to note that interviewees who said that they were not worried about the concerns of the microfabrication industry also gave what the potential concerns were, which were represented in Table 4.9

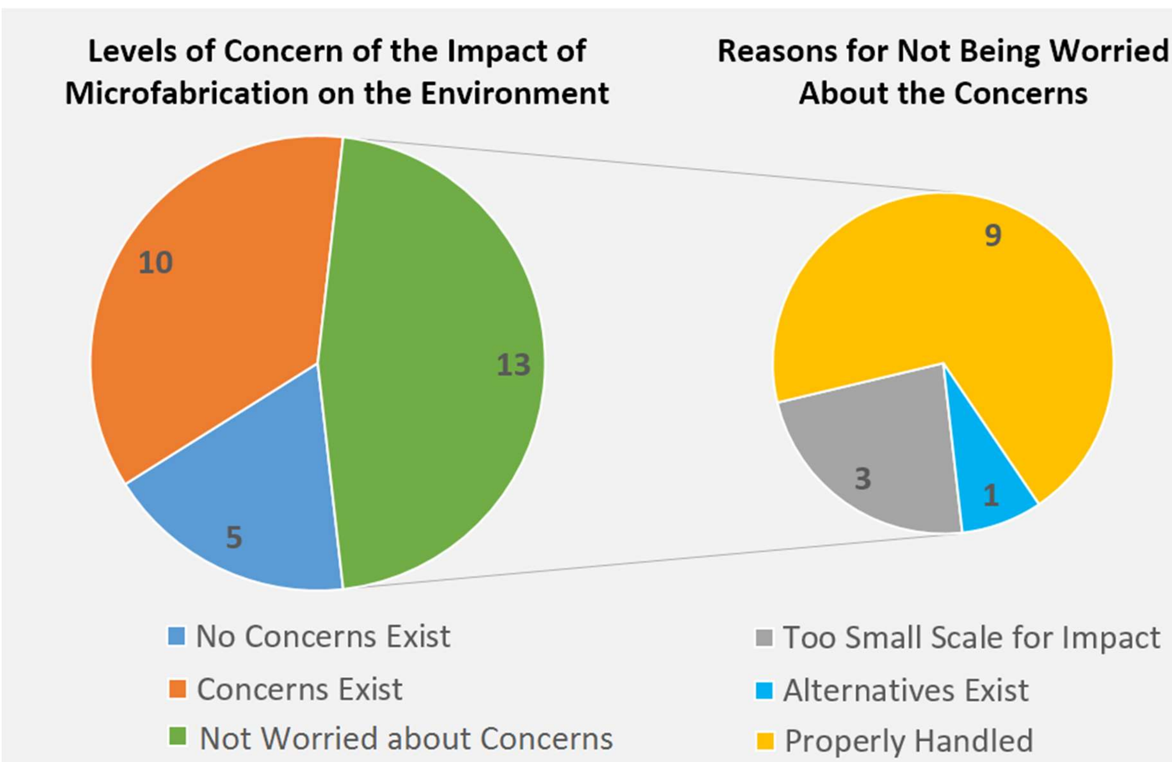


Figure 4.8: Levels of Concern of the Impact of Microfabrication on the Environment

Figure 4.8 shows the responses from the interviewees about their level of concern about the impact of the microfabrication industry on the environment. Out of the 33 interviewees that the team asked this question to, 70% said that there are concerns to the environment. These concerns include hazardous chemicals such as hydrofluoric acid, fluorocarbons and sulfur hexafluoride, solvents, the dispersion of nanoparticles into the air, and heavy metals. However, 57% of these interviewees, or 39% of all of the interviewees to whom the team asked this question, stated that they were not worried about these concerns for a variety of reasons. The largest of these reasons, at 69% of those who responded as not being worried, was that good lab practices and common sense nullifies the harmful effects that the previously mentioned concerns may have on the environment. The second largest reason, at 23%, was that due to the small scale of production in terms of microfabrication in New Zealand, the amount of waste generated was not of a large enough volume to be significantly harmful. This data suggests that many individuals in the microfabrication industry understand that there are environmental concerns, but a majority of those interviewees, who said that there were concerns to the environment, are not worried about those concerns. This data also suggests that 15% of the individuals that we interviewed either did not know of the impacts that many of the other interviewees mentioned, or that they possibly thought that the concerns to environment were not sufficient to warrant any action.

4.4.3 Perceived Societal Impacts of Microfabricated Technology in New Zealand

The team evaluated the perceived societal impacts of microfabricated technology in New Zealand based on responses to Question 14: **"How do you think miniaturized technology impacts society in New Zealand?"** and represented in Figure 4.9. It is important to note that the team did not specifically prompt for any of the specific societal impacts of the industry and that we based all specific impacts on the interviewees' responses.

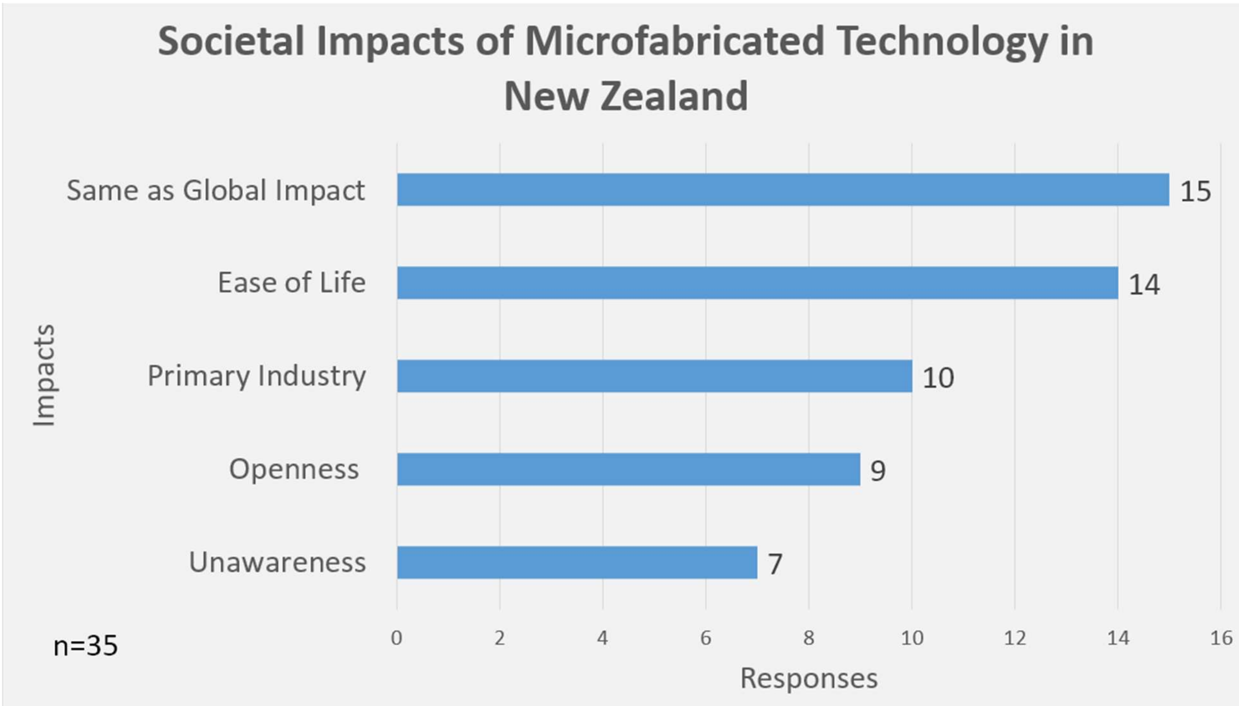


Figure 4.9: Interviewee Perceived Societal Impacts of Microfabricated Technology in New Zealand

Figure 4.9 shows 43% of interviewees believe that the impacts that microfabrication has on New Zealand are the same as the impacts microfabrication has had worldwide, such as making devices smaller and more efficient. Figure 4.9 also displays that 40% of interviewees believe that microfabricated technology is beneficial to New Zealanders and makes aspects of their lives easier. This suggests that the microfabrication is a helpful technology in New Zealand, however, Figure 4.9 also suggests that the interviewees may believe that New Zealanders may not realize the benefits with 20% of interviewees saying that the general public is unaware of microfabrication technology. While 20% is not a large percentage it is still significant as none of the responses to this question were prompted. One manufacturer echoed the views of many interviewees, stating:

I don't think most of our society is aware. But, you know, your cell phone's built basically on microfabrication and there's accelerometers in there. But the Fitbit watches that everyone's using comes about because of microfabrication facilities. (Anonymous G, personal communication, February 3, 2016)

This interviewee believes that although microfabrication has impacted many aspects of everyday life, many people are unaware of microfabrication and its effects. However, this does not mean that society is not open to new technology that microfabrication can provide. From our analysis of these responses, we discovered that 7 of the 35 interviewees observed that New Zealand society is generally unaware of how microfabrication and miniaturization of technology affects their everyday lives. In addition, 9 out of the 35 interviewees mentioned that they believed that New Zealand society is open to high-tech technology. Although these are not high percentages of the total interview pool, they are still significant because we did not prompt the interviewees to comment on the awareness and openness of society to technology.

The fact that this many interviewees commented on New Zealand society's openness to high tech without the team prompting them could indicate that much of the population is actually open to using high tech devices, such as those created through microfabrication. However, these perceptions of our interviewees could be biased based on their own involvement in the microfabrication field and may not represent the actual cultural attitude of New Zealanders to high-tech technology. This could be important for the success of the cluster initiative because support for the industry may allow it to flourish.

This data suggests that the interviewees think that much of society is not aware of how microfabrication impacts their everyday lives and may be unappreciative of microfabricated technology in general. Lack of awareness and appreciation may limit the amount of people pursuing careers in microfabrication and stunt the growth of the industry. On the other hand, a cluster may combat this lack of awareness by catalyzing more discussion of microfabrication and incorporation of this technology into other industries.

Figure 4.9 depicts that 10 out of 35 interviewees answered the question “How does microfabricated technology impact society in New Zealand?” by talking about New Zealand’s economy and its focus on primary industries such as agriculture \. This suggests that when the interviewees thought about New Zealand society they thought of New Zealand as a society that is focused more on industries like agriculture than on secondary industries like microfabrication. Ben O’Brien, CEO of Stretchsense, states, “New Zealand is still transitioning away from this agricultural thing that’s still a dominant sector of the economy” (B. O’Brien, personal communication, January 26th, 2016). This current focus on primary industries could hinder the development of the microfabrication industry in New Zealand.

4.4.4 Perceptions of Maori Cultural Concerns with Microfabrication

The team wanted to determine the perceptions of our interviewees with respect to the cultural concerns in New Zealand society with microfabrication and the processes involved in microfabrication. To do this, we looked to evaluate the opinions of specific groups that may have cultural concerns. With Maori coming from a different background than Pakeha, we believed that Maori might disapprove of high tech-tech industries due to different cultural views. The team retrieved this information based on the responses to Question 51: **“If you consider yourself Maori, do you see any major cultural conflicts with microfabrication/high-tech fields?”** The team interviewed two Maori and both perceived that there are groups of more traditional Maori who would disapprove of some microfabrication processes including processes that interfere with God’s domain, such as affecting the body in ways like injecting nanotechnology. They expressed that there are conservative, traditional views in every culture, however, which means that there will always be people who view new technologies unfavorably. In reference to Maori adapting to change, a Maori who works for the Treasury stated:

> *I think it's not a simple thing to say 'Ah technology, it's against our culture,' because we've adapted. Every time. At the same time, I'm acknowledging that there are people that will say, 'We don't do that! 75 years ago that's not how our people did it.' And lots of cultures are like that. Lots of people are like that but ... human beings are innovators, we're adapters, we don't just stay in one place forever and ever and ever (A. Tibble, personal communication, January 14, 2016).*

Tibble was saying that it is unfair to say that New Zealand is against technology or that the Maori don't like technology because this society has always adapted to change. Both Maori interviewees had perceptions that microfabrication does not present a significant cultural issue any more than similar industries in other countries. That being said, it is important to note that these are the opinions of only two Maori, both of whom work in organizations having a vested interest in the betterment of the microfabrication industry or the economy as a whole. Also, due to the extremely small sample size of only two experts, the team cannot make any conclusions based on their responses. If there are any cultural conflicts, this field may not receive much support.

5 Recommendations

We believe that the microfabrication industry cluster initiative in New Zealand is feasible because the conditions in the country are already hospitable to aid the success of the cluster. Our interviewees generally agreed that one of the major strengths of the industry is the willingness of industry members to collaborate, which is an important foundation for a successful cluster. There may be a lack of communication between potential cluster members and not everyone in the industry is aware of each other's existence, but many have the desire to collaborate. Of the interviewees we asked, a vast majority (97%) were willing or interested in joining a microfabrication industry cluster initiative in New Zealand. Our specific recommendations for Callaghan Innovation are as follows:

- To form a successful microfabrication cluster in New Zealand, the team recommends that Callaghan Innovation make contact with all of the interviewed companies and organizations and create open channels of communication between them, so as to raise awareness within and between the industry sectors. Callaghan Innovation can achieve this by holding large central meetings where all potential cluster members attend either in person or by video conference and can openly discuss the way the cluster should run and move forward. This can also help build relationships between the organizations and improve the communication gap between the different industry sectors.
- Organizations interested in the proposed cluster have suggested several things including the use of a mediator, having a common vision for the cluster, obtaining funding external to the cluster, keeping the cluster applicable to the individuals' work, and representing all cluster members equally. Our investigation suggests that these are the topics that the organizations should discuss with the other organizations in the industry.

- Our findings indicate that the key perceived strengths of the microfabrication industry in New Zealand are the variety of specialists and organization specializations, collaborative atmosphere, adaptability of the organizations, and mobility of products. Additionally, the perceived weaknesses of the industry are global competition, population size of the country and scale of production, lack of funding, and lack of a developed industry. We suggest that organizations prioritize finding solutions to these weaknesses. Such solutions could include pooling together resources; this can be achieved through the formation of a cluster.
- The microfabrication industry has a unique advantage over other industries in New Zealand in that they can export their products more cheaply due to the incredibly small size of the devices produced. This is extremely important for New Zealand specifically because so many of their products need to be exported as a result of reaching domestic market saturation so early. We believe that the future industry cluster should exploit this advantage.
- We recommend that, if formed, the cluster should make efforts to make other New Zealand industries and individual consumers more aware of the microfabricated technology that they already use and the benefits of using more microfabricated technology, possibly through the use of marketing and education. Integrating microfabrication into primary industry may help to create a larger domestic market for microfabrication.

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Appendix A: Interview Questions

Interview

Hello, we are third year engineering students from the US studying at Worcester Polytechnic Institute in Massachusetts. We are carrying out this project assessing the feasibility of creating a microfabrication (by which we mean miniaturized structures or devices with features that may be smaller than a millimeter) cluster in New Zealand as part of our degree program. We will be using this interview in a report that will be published and made available in the public domain. You can remain anonymous and please tell us at the end if there is any information that you do not want published. We hope our report will also be of interest to you.

May we audio record this interview?

- ◯ Yes
- ◯ No
- ◯ N/A

What is your name?

What is the name of your organization?

Would you like to remain anonymous?

- ◯ Yes
- ◯ No

Which part of the microfabrication industry are you personally involved in?

Please select the part you are involved in the strongest.

- ◯ Supplier
- ◯ Manufacturing
- ◯ Research
- ◯ Student

What part of the microfabrication industry is your organization involved in?

- ◯ Supplier
- ◯ Manufacturing
- ◯ Research
- ◯ Student/Education

What is your job title?

What is your job description?

What does the word microfabrication mean to you?

How does microfabrication play a role in your organization?

How has miniaturization changed technology in New Zealand?

What do you imagine microfabrication in New Zealand to be like in 5-10 years?

How do you see ongoing miniaturization affecting the future in 5-10 years?

How do you think miniaturized technology impacts society in New Zealand?

What are the strengths of the microfabrication industry in New Zealand?

What are the weaknesses of the microfabrication industry in New Zealand?

How do you feel about collaboration with other organizations?

What do you know about industry clusters and how do you see a cluster operating?

How aware are you of the microfabrication facilities in New Zealand?

How willing would you be to join a cluster initiative between suppliers, manufacturers, and researchers in the microfabrication field? Why or why not?

Are there any environmental concerns with microfabrication and if so, what are they and how are they dealt with?

What types of government regulations affect your work?

Continue »

Interview

Supplier

How do international trends shape the future of New Zealand microfabrication?

Is your company looking to hire more staff?

What companies do you supply in New Zealand?

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Interview

Manufacturing

What are the main applications of your work?

What is your current approach to stay relevant in this rapidly expanding field?

How much money does your organization spend yearly on Research and Development?

How much money does your organization spend yearly on microfabrication in particular?

How many people does your organization have on staff?

How many people does your organization have on staff for microfabrication in particular?

Is your company looking to hire more staff?

How do international trends shape the future of New Zealand microfabrication?

What factors make it difficult to compete in a global market?

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Interview

Research

What is your current approach to stay relevant in this rapidly expanding field?

Is your organization looking to hire more staff?

What factors make it difficult to compete in a global market?

What are the main and potential applications of your work?

How much money does your organization spend yearly on Research and Development?

How much money does your organization spend yearly on microfabrication in particular?

How many people does your organization have on staff?

How many people does your organization have on staff for microfabrication in particular?

« Back   Continue »

Interview

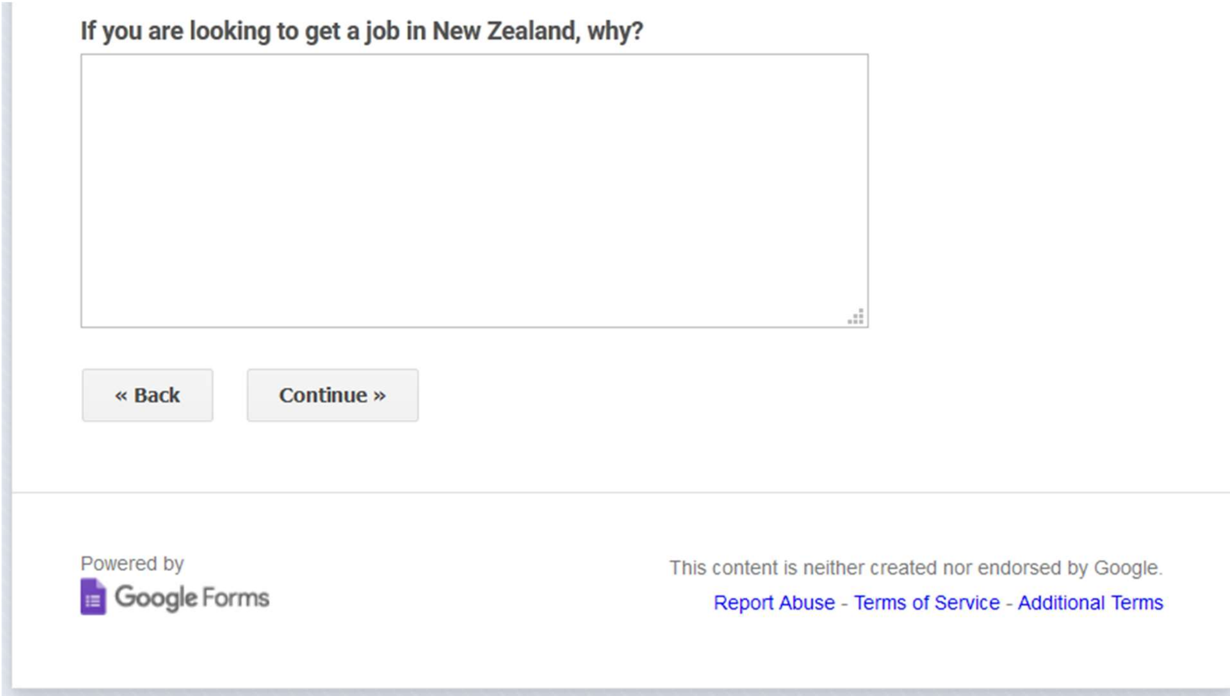
Student

Are you doing any research in microfabrication? If so, what are the applications of your research?

What degree(s) are you pursuing?

Are you looking to get a job in New Zealand or somewhere else?

If you are looking to get a job in another country, why?



If you are looking to get a job in New Zealand, why?

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Interview

Thank you!

If you consider yourself Maori, do you see any major cultural conflicts with microfabrication/high-tech fields?

Do you have any additional comments?

Do you know of other companies or research groups in New Zealand that have interest in microfabrication? Who can we contact and what are your connections with these people?

Is there any information that you provided that you do not want published?

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Appendix B: Codes

Organization structure:

- Objectives:
  - Categories
    - Codes
      1. Subcodes
         - i Sub-subcodes

Codes:

- Objective 1
  - Current and Future Outlook
    - Technology and Applications
      1. Sensors
         - i Bio-medical
         - ii Communication
         - iii Environment
         - iv Primary Industries
         - v Other
      2. Actuators
         - i Bio-medical
         - ii Communication
         - iii Environment
         - iv Primary Industries
         - v Other

3 Textiles

  i Bio-medical

  ii Communication

  iii Environment

  iv Primary Industries

  v Other

4 Lab on a chip

  i Bio-medical

  ii Communication

  iii Environment

  iv Primary Industries

  v Other

5 Electrical

  i Bio-medical

  ii Communication

  iii Environment

  iv Primary Industries

  v Other

6 Other

  i Bio-medical

  ii Communication

  iii Environment

  iv Primary Industries

  v Other

7 Impact or effect of microfabrication

  i Global interaction

ii Business

iii No effect

iv Disruptive vs. incremental

- International influences
- Efficiency
- International
  1 Trends
  2 Markets
  3 Difficulty
  4 Collaborating internationally
  5 Influences of Technology
- Awareness of involvement
  1 Unaware that they do microfabrication
  2 Aware that they do some microfabrication
  3 Only does microfabrication
  4 Does not do microfabrication
  5 Indirectly involved with microfabrication
- Industry Future
  1 Uncertain
  2 Positive outlook
  3 More collaboration
  4 Negative outlook
  5 Move away from primary industry
  6 Incorporate into primary industry
  7 Increase in manufacturing abilities

- Strengths
    - Specialists/ specialization
    - Mobility/Adaptability
    - Facilities
    - Research sector
    - Innovation
    - Improvization
    - None
    - Communication/Proximity
    - Collaborative atmosphere
- Weaknesses
    - Government regulations
        1. Health and safety
        2. Customs/importing and exporting
        3. Environment
    - Size/ scale
        1. Size of country
        2. Scale of production
    - Funding
        1. In company
        2. Due to government
        3. Competition for funding
    - Facilities/Equipment
    - Industry Existence/Visibility
        1. Lack of complete industry
        2. Public visibility

3. Underestimated/not taken seriously
4. Global visibility

- Lack of communication
  1. Between sectors
  2. Within sectors
  3. With the rest of the world
- Global Competition
  1. Against China
  2. Against other countries
- Need for immediate globalization/ no market in NZ
- Distance
  1. Between New Zealand facilities
  2. From other countries
- Lack of People
  1. Skilled labor
  2. Specialists
- Lack of Supply/ Resources

o Education

- Degrees
  1. Electrical Engineering
  2. Mechanical Engineering
  3. Physics
  4. Chemistry
  5. Other/not specified
- Jobs in New Zealand
  1. Family/significant other

2. Home
3. The environment
4. Culture

- Jobs outside of New Zealand
  1. No jobs
  2. Poor facilities
  3. Not competitive globally
  4. From a different country
  5. Family/significant other
  6. Desire to travel

- Objective 2
  - Willingness
    - Conditions to Join
      1. Mediator
      2. Common Goal
      3. External Funding
      4. All parties equally represented
      5. Applicable to Personal Work
    - Not interested
      1. Academia
      2. Think it cannot work
    - Interested
      1. Benefits to organization
      2. Benefits to New Zealand
      3. Benefits to all organizations
      4. Skeptical of success

5. Decreases nationally competition
6. Personal gain separate from organizational gain
7. Trading staff

- Barriers
  - Funding for Cluster
  - Common Vision
    1. Between sectors
    2. For the cluster as a whole
  - Internal Competition
  - Relevancy methods
    1. Reports
    2. Academic journals
    3. Conferences
    4. Trading staff
    5. Not enough time to stay up to date
    6. Clusters/relationships with other organizations
  - Lack of Communication
    1. Between sectors
    2. Within sectors
  - Awareness of industry
    1. Very aware
       - i. Research/Universities
       - ii. Manufacturers
       - iii. Suppliers
    2. Partially aware
       - i. Research/Universities

    ii Manufacturers
    iii Suppliers
  3 Not aware
    i Research/Universities
    ii Manufacturers
    iii Suppliers

- Growth of Company
  1 Staying the same
  2 Growing
  3 Declining

- Knowledge of Clusters
  - Knowledge of Clusters
    1 Current clusters
    2 Clusters, what they are/have been involved in
    3 Little to no knowledge
    4 Familiar with just concept

- Objective 3
  - Environmental concerns
    - Concerns to environment
      1 Heavy metals
      2 Nanotechnology
      3 Solvents
      4 Chemicals
      5 Other
      6 Hazardous waste handled properly
    - No concerns to environment

1. Too small a scale to produce harm
2. Chemicals properly handled
3. Nothing harmful is produced at all

- New Zealand Culture and Society
  - Maori
    1. Ability to adapt
    2. Open to technology
    3. Conservative views
    4. Economic growth
    5. Primary industry
    6. Education/involvement
    7. Cultural conflicts
    8. Exposure to S.T.E.M.
    9. Clusters
  - Open to the idea of clusters
  - Openness to and Awareness of Technology and Microfabrication
    1. Openness
    2. Awareness
  - Primary industry
  - Ease of life
  - Change similar to global change

Appendix C: Other Organizations

Contact Attempted

- MSL
- Living Cell Technologies
- Aeroqual Limited
- Kahne Limited
- Pictor Limited
- Titanium Solutions Limited
- Koti Technologies Limited
- Mars Bioimaging limited
- Perry Engineering
- Adinstruments Limited
- Precision Microcircuits
- Smart Sensing and Intelligent Systems
- Veritaxa Limited
- Goodnature Limited
- Tekron International Limited

Contact not attempted

- Product Accelerator
- Helix Industries
- ASL
- Kiwinet

- Times-7 Holdings Limited
- Magritek
- ikeGPS Limited
- Institute of Professional Engineers NZ
- FutureIn Tech
- Triontech
- CSP group
- MBIE
- Polymer Electronics Research Centre
- SGS group
- Robbinson Institute
- Kode Biotech
- University of Otago