THE KIDS ARE ALL RIGHT

Designing an Earthquake-Resilient Classroom Table

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Abstract

In the seismically active region of New Zealand, the threat of earthquakes is ever-present with potential implications for residents of all ages. As school children spend a large extent of their daily lives within the classroom, it is vital that they are provided with an effective means to protect and prepare themselves for natural disasters. Through the application of a qualitative, ethnographic, and 'research through design' methodological approaches, this research has informed the design of a classroom table that effectively promotes safety and resilience around seismic events. Through consultation with school students and teaching staff, typologies of existing furniture and the specific needs of classroom tables in contemporary primary school environments have been evaluated within a contemporary New Zealand school context. While the development of the design aims to be appropriate for everyday use, the primary objective is to investigate the role that furniture can play in mitigating the physical threat of seismic events on children. The central research question asks:

> *How might furniture effectively function to mitigate the physical threat of earthquakes and aid in facilitating education regarding earthquake preparedness within the context of New Zealand's primary schools?*

The functions of the resultant product output - the 'Earthquake-Resilient Classroom Table' - are three-fold: the design aims to provide a robust structure that physically protects children during earthquakes; enable a system that alerts students when safety procedures should be implemented; and, facilitate the education of students in earthquake safety and preparedness procedures according to established practices employed in New Zealand schools. As a pervasive means of providing immediate safety and encouraging preparedness, the proposed design outcome is a prime example in the application of alternative functions and innovative technologies in the design of contemporary furniture. The focus on earthquake safety within school environments addresses a pertinent issue that has received minimal prior investigation or addressment through design, both in New Zealand and internationally. This research aims to foster discourse within the design discipline regarding new conceptualisations of design that meet the needs of contemporary school environments, and to inspire the development of furniture designs that meet the safety needs of children in natural disasters within New Zealand and beyond.

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1 | Introduction

Earthquakes are unpredictable natural forces that can occur at any time with varying degrees of impact. In New Zealand, earthquakes are a common occurrence. Although major seismic events are not frequent, their threat is ever present and real. Earthquake preparedness, subsequently, is a primary topic of concern in New Zealand where governmental agencies regularly promote preparedness and resilience skills, and every child is taught to *Drop, Cover,* and *Hold* if an earthquake strikes. While children spend much of their lives in classrooms, however, the existing furniture in these settings often does not adequately support their protection during these events. As tables have an inherent relationship to earthquakes in affording emergency shelter, the need has been identified to pursue alternative designs that better meet the demands of disaster-related impacts, and that more effectively protect school children. The central research question asks:

> *How might furniture effectively function to mitigate the physical threat of earthquakes and aid in facilitating education regarding earthquake preparedness within the context of New Zealand's primary schools?*

Through engagement in qualitative and ethnographic research methodologies, this project proposes the development of an innovative design solution: a classroom table that effectively meets the needs of primary school children in the event of a major seismic event. As the design output of this project, the resultant prototype for the 'Earthquake-Resilient Classroom Table' encapsulates three functions: to provide increased physical protection for students during earthquakes; to include an integrated alert system that is automatically activated during seismic events; and, to facilitate the education of students about earthquake safety and preparedness according to established practices employed in New Zealand schools. Together, these functions aim to foster resilience amongst young New Zealanders around seismic events. The focus on earthquake safety as it relates to furniture, in particular within the context of primary school environments, addresses an issue that has received minimal prior investigation. In considering the larger impact of this research, the goal is to foster discourse and to inspire the development of future furniture designs that meet the safety needs of children in natural disasters within New Zealand and beyond.

2 | Literature Review

Overview of Earthquakes in New Zealand

As a hot spot for natural disasters, research and innovation around earthquakes is particularly relevant in New Zealand. Its geographical location on the Pacific 'Ring of Fire', where approximately 90% of the world's earthquakes occur, means that it is one of the most seismically active regions in the world (U.S. Geological Survey, 2016). Small earthquakes a relatively common occurrence that pose an ever-constant risk. Hundreds of seismic events occur every year and, based on the collection of scientific data, approximately 100 tremors every year are large enough to be felt (Ministry of Civil Defence & Emergency Management, n.d.). Larger quakes, while relatively few, often trigger emergency safety procedures such as taking cover or building evacuations. Such major seismic events have the potential to cause tremendous damage, injuries, and fatalities. Based on past averages, large earthquakes of magnitude 8 or greater are estimated to originate on or near the Alpine Fault or adjacent fault lines approximately every 500 years (Finnis, Standring, Johnston, & Ronan, 2004). Occasionally, New Zealand is subject to larger earthquakes that cause greater damage and injury, and even fatalities. Historically, major seismic events of note include the 1855 Wairarapa Earthquake (8.3 magnitude, 5-9 fatalities) and the 1931 Hawke's Bay Earthquake (7.8 magnitude, 258 fatalities). In recent years, earthquake awareness and anxiety has been firmly thrust into New Zealand's public consciousness in response to a series of notably large and destructive seismic events in the South Island's Canterbury region. While not everybody in the country has been directly affected, virtually all New Zealanders would know of a family member or friend that has been involved in these tragedies in some way.

On Saturday 4 September 2010 a large earthquake measuring 7.1 on the Richter scale occurred at a depth of 10 km at 4:35am. Centred on a previously unknown fault near the rural town of Darfield, it has since come to be known as the 'Darfield Earthquake'. There were approximately 100 reports of injuries, but because it occurred in the early hours of the morning when most people were asleep in their homes, there were no fatalities. The substantial amount of damage caused to the region's infrastructure and the huge number of subsequent aftershocks served to rekindle nationwide public awareness of the threat posed by earthquakes. Prior to this significant event, New Zealand had not experienced such a major seismic event for some time.

At 12:51 pm on Tuesday 22 February 2011 an extremely violent aftershock (of the Darfield Earthquake), now known as the 'Christchurch Earthquake', occurred almost directly beneath the city of Christchurch. For this reason, the magnitude 6.3 earthquake, at a depth of 5 km, caused further widespread destruction to an already damaged city and its surrounding environs, despite being nearly 10 times less powerful than the Darfield earthquake almost half a year prior. 185 people lost their lives in the tragedy, and approximately 1500 to 2000 people were injured. As it occurred at the height of a normal working day, many casualties in the CBD and the greater city area were in their workplaces or on their midday lunch break. While it occurred during a regular school day, it is extremely fortunate that no children were killed or seriously injured at any local schools. By April 2011, approximately 70,000 people, or 20% of the local population, had left the city since the earthquakes due to increased mental stress and the loss of homes and jobs (Love, 2011). This number is likely to have increased since the report was written. Furthermore, an estimated 50% of buildings in the city's CBD were designated to be demolished due to irreparable damage (Stevenson et al., 2011).

At 12:02am on Monday 14 November 2016 (during the time in which this project has been undertaken), the central South Island was again hit by one of most powerful recorded earthquakes of recent times, this time near the small rural town of Culverden. The magnitude 7.8, 15 km deep earthquake devastated the South Island's upper east coast. The seaside town of Kaikoura and surrounding rural areas were extensively damaged in the 'Kaikoura Earthquake', and were virtually isolated from all road access for days. The earthquake also triggered a small tsunami and caused hundreds of landslides as well as extensive topographical reformation, such as the rising of coastal sea beds in some areas of up to 2 metres. Two people in the region were killed, one in a building collapse, and 57 were injured. At the time of the writing of this thesis, the recovery effort following this earthquake is ongoing in Kaikoura. This particular earthquake is one of the largest to strike New Zealand in recent memory, and widespread damage of varying degrees occurred from the lower North Island to the central South Island, much of it to areas still recovering from the Canterbury earthquakes five years prior. There was even moderate damage to infrastructure as far afield as the city of Wellington, 230 km away from the epicentre.

The great extent to which these earthquakes and their aftershocks have affected the nation is undeniably profound. The crucial need for disaster resilience in all facets of everyday life has been reiterated in these events. Tierney (2014) provides a concise definition of resilience that is suitably applicable to the context of primary schools explored in this research:

> "The concept of resilience refers to the ability of social entities (for example, individuals, households, firms, communities, economies) to absorb the impacts of external and internal system shocks without losing the ability to function, and failing that, to cope, adapt, and recover from those shocks" (p. 6).

The notion of resilience is commonly used to express both strength and flexibility, the ability to adjust to anticipated levels of stress as well as to sudden shocks and extraordinary demands. In the context of hazards such as earthquakes, the concept can be understood to address pre-event, during-event, and post-event measures. These measures seek to prevent hazard-related damage and losses as well as to offer strategies designed to cope with and minimize disaster impacts (Bruneau et al., 2003). While resilience should not be confused as the opposite of vulnerability, the two concepts are related as each contributes to an understanding of disaster impacts and consequences: "the concept of vulnerability represents the potential for experiencing damage and loss; that is, vulnerability represents a condition or state that may or may not be actualized" (Tierney, 2014). The fostering and development of resilience is a fundamental theme in this project. In reflecting on the cataclysmic seismic events that have struck New Zealand, and also in speculating those that could occur in the future, there is substantial relevance in this objective. Ultimately, resilience is a process rather than an outcome. This has been an important consideration in designing a classroom table that addresses not only the immediate need to alert students and protect them from physical risks during a seismic event, but also to facilitate education of safety procedures in their day-to-day lives.

New Zealand's psyche pertaining to natural disasters is largely founded on an acute perception of earthquakes and the threat they pose to society. Relatively frequent earthquakes serve to preserve a sense of public vigilance in anticipation of large earthquakes. However, Crowley & Elliot (2015) speculate that New Zealanders in particular may face greater psychological and physical challenges when recovering from major earthquakes, as this 'everyday hazard' can take them by surprise and greatly unsettle any pre-established resilience developed around disasters. As they are unpredictable and vary greatly in magnitude, earthquakes are inherently dangerous phenomena. Mutch (2015) states that "what differentiates earthquakes from many other natural disasters … is that there is no warning, as there would be with a storm for example." The researcher also affirms the oft forgotten fact that major earthquakes are not isolated, one-off occurrences, but rather "one or more major jolts followed by aftershocks decreasing in magnitude over several years but with the constant possibility of another major tremor," as was the case in Canterbury. Although disasters such as earthquakes may not be foreshadowed, the value of engaging resilience approaches is that they acknowledge the existence of anticipated threat and assist people in preparing for the unexpected (Park, Seager, Rao, Convertino, & Linkov, 2012). For New Zealand, it is essential that resilience and preparedness skills for earthquakes are fostered and upheld as a fundamental priority in building and design practices. Although stringent building codes addressing this need are heavily enforced in the architecture and construction industries, considerably less consideration is given to the products, most notably furniture, that fill these spaces. The role of furniture design in mitigating the threat of earthquakes and promoting resilience surrounding them is central to this thesis.

New Zealand Primary Schools and Earthquakes

Typically, young New Zealanders are first exposed to strategies for earthquake preparedness in primary school, where students are aged from approximately 5 to 12 years old. Schools are an ideal facilitator for disaster education, as children spend a large extent of their daily lives within the classroom or in school facilities. In an environment where learning is inherent, education about disaster preparedness and safety can be more easily assimilated and retained by children. As such, schools can act as a conduit in the education of the community at large. The Canterbury earthquakes damaged and disrupted a great number of schools nationwide. While no children were killed or seriously injured at schools, the potential for such a tragedy to occur is a real and ever-present possibility in any major seismic event. To inform future preparedness, Mutch (2015) recommends deeper examination of earthquake procedures and pre-existing infrastructure in schools based on their effectiveness in the Canterbury earthquakes. Based on research, the author also surmises that 'there is … a lack of a comprehensive high level approach that integrates school building design and construction and the inclusion of schools into national and local disaster planning.' In terms of potential disasters and emergencies that can befall New Zealand schools, earthquakes arguably pose one of the most significant and likely perceived risks. Finnis et al. (2004) found this in the responses of 10-12 year old Christchurch children (Note: study conducted prior to the earthquakes of 2010/2011) in a questionnaire about awareness of potential hazards and natural disasters in their city. Earthquakes were believed to be the second most likely hazard to occur (with 48.6% of students endorsing likeliness, behind storms with high winds with 54.4% endorsing likeliness) and the second most likely to cause injury (with 46.6%, behind tornadoes at 51.5%). Almost half of the students believed that a large earthquake was likely to occur in the future. Two thirds affirmed that they believed the Alpine Fault could cause an earthquake that would affect Christchurch, regardless of their prior knowledge of its existence. Interestingly, at the time of the study – six years prior to the Darfield Earthquake - a large seismic event originating on or near the fault is speculated to be 50 years overdue. Following the Canterbury earthquakes, it can be safely surmised that these figures will have drastically changed. Awareness of the risk of earthquakes on or near the Alpine Fault will be greatly increased in schoolchildren, along with a much more extensive common belief that large and potentially destructive earthquakes could indeed occur in the future not only in Christchurch, but nationwide.

Earthquake Education

It is of utmost importance that earthquake preparedness and resilience is fostered and maintained in New Zealand school environments at all times. This is necessitated by the unpredictable nature of earthquakes, and the fact that major seismic events often herald heightened dangers for extended periods of time, such as those from constant aftershocks. Research has found that regular disaster drills aid greatly in children's retention of knowledge of proper actions in such events (Ronan & Johnston, 2005). National schools are required to develop and maintain comprehensive plans for disaster response and evacuation that address a range of potential emergencies, including earthquakes (Johnston et al., 2011). This is primarily facilitated by the Ministry of Education in conjunction with the Ministry of Civil Defence and Emergency Management (MCDEM). However, while fire drills are compulsory in schools (Finnis et al., 2004) there is currently no requirement for schools to conduct earthquake drills in accordance with the procedures they develop, despite the obvious risk that they must operate in spite of (Johnson, 2011). However, virtually all schools will carry out at least one earthquake drill per year (Johnson, Ronan, Johnston, & Peace, 2014). Educating students about what actions to take if they experience an earthquake while in the classroom is perhaps the most important and relevant aspect of emergency preparedness in New Zealand primary schools. This education component needs to be supplemented with regular disaster response drills and exercises to reinforce this preparedness (Johnston et al., 2011).

A number of government ministries, city and regional councils, community initiatives and private companies in New Zealand are constantly working towards a common goal of improving earthquake resilience nationwide. Some city and regional councils have developed ways of communicating earthquake preparedness information in local schools. For example, the Christchurch City Council has developed an education programme called 'Stan's Got a Plan' to supplement the delivery of Civil Defence education in the classroom (Christchurch City Council, n.d.). Through this initiative, free in-school lessons with 'experienced educators' can be booked to teach disaster preparedness to students, including that concerning earthquakes. Other regional councils have developed initiatives such as film competitions, board games, evacuation exercises and online courses, while schools also utilize resources such as the internet, civil defence staff, trips to museums, and talks with earthquake survivors (Johnson, 2011).

A related resource, 'What's the Plan, Stan' (or WTPS), was introduced in 2006 to aid in the teaching and planning of disaster and emergency preparedness for primary and intermediate schools nationwide (Johnson, 2011; MCDEM, 2007). With Crown funding, the MCDEM developed the resource in response to a 2004 Civil Defence analysis of disaster and hazard education in New Zealand schools. The report identified a significant lack of cohesive teaching material and widespread inconsistencies in the information that schools were imparting their students with (Johnson, 2011). WTPS, which is updated approximately every four years, has been provided as a hard copy binder 'information pack' to all primary and intermediate schools nationwide. The pack includes an interactive CD-ROM (containing stories, games and research material), unit plans, fact sheets and activities that address a range of potential disasters, including earthquakes (Johnson, 2011). Also available is an interactive, child-friendly website. The subject of earthquakes is only one of many emergency and disaster preparedness topics covered in WTPS, along with floods, storms, tsunamis, volcanic eruptions and landslides (MCDEM, 2007).

Earthquake Safety Procedure: *Drop, Cover, Hold*

The MCDEM advocates a simple yet effective earthquake response procedure called *Drop, Cover, Hold* that has become very well-known in New Zealand. As the eminent entity for communicating and fostering earthquake safety in the public, the ministry developed the easy-to-remember and unanimously comprehensible technique to be easily executable by adults and children alike in virtually any environment, but particularly indoors where immediate hazards are often more numerous and relatively proximate. In the event of an earthquake, the procedure's three steps are: immediately drop to the ground; assume cover beneath an appropriate piece of nearby furniture (generally a table); hold onto said furniture (such as by a table's legs) (MCDEM, n.d.; Ministry of Education, 2012). This technique is to protect people from falling hazards such as collapsing walls and broken glass, as ground vibrations are not usually the direct cause of injuries or death (MCDEM, n.d.). It is heavily communicated by Civil Defence as the most appropriate emergency procedure for individuals to undertake during earthquakes, including the WTPS school resource. *Drop, Cover, Hold* is the procedure that is taught to children in New Zealand schools in earthquake education and in drills (Johnston et al., 2011) and it is the accepted national standard for earthquake safety in New Zealand. In the context of this research it is salient to point out the inherent connection between this procedure and the vital role of furniture (and tables in particular) in seismic events.

Shortcomings in Earthquake Education

While there are many organisations striving to address earthquake safety and preparedness in New Zealand schools, there is an apparent disparity between information provided by the different parties. While most contain more or less the same information, there is very little depth or breadth to it as it specifically relates to earthquakes. Teachers perceive a lack of congruency and conflicting messages across the range of available resources, particularly in those not advocated by government ministries that often get mistaken for reputable established procedures (MCDEM, n.d.). Johnson (2011) identifies the 'Triangle of Life' theory as one such procedure that has created much confusion and debate in the past. This controversial theory encourages sheltering beside building walls and large solid objects in earthquakes as opposed to beneath tables and other such solid objects as per the *Drop, Cover, Hold* procedure practiced in New Zealand. Widely-circulated in the format of an email by a self-professed expert from the United States, it has been thoroughly and widely discredited, including in New Zealand and in its country of origin. As it has been proven to be ineffective and potentially dangerous, Civil Defence and national schools have worked hard to dispel the misleading theory amongst students, parents and even teachers (MCDEM, n.d.). Many of the available resources to promote and facilitate earthquake education do not utilize a format that has immediacy or significant presence in the school environment. Rather, they are retrieved for use or reference, such as in the format of a booklet or a website. For example, teachers have said that the 'What's the Plan, Stan?' resource has often been kept in a schools' resource room. As schools were only given a single copy, teachers were not provided with personal copies for faster and easier reference in the classroom (Johnson, 2011). This requires a user, such as a teacher educating a class of students, to be aware of the resource and the proper ways to utilize it. This also makes for difficulty in comprehension or retention of information by children. As most available resources are not available in formats that promote earthquake safety ubiquitously within classroom environments, the vital information they provide can easily be forgotten if not regularly revisited and reiterated in emergency exercises.

National studies have revealed many teachers' sentiments and feelings towards emergency education in a study about the effectiveness of the WTPS resource (Johnson, 2011; Johnson et al., 2014). Complacency, apathy and low prioritisation are recurring themes in schools where it has not been systematically adopted. One teacher stated that disasters only become a relevant subject of learning when they are in the news because students "[do not want to] learn about the same thing, over and over again, every year" (Johnson, 2011, p. 19). Johnson also found that some teachers felt the resource, with its multiple subjects, had too much material and that it was difficult to sufficiently teach in its entirety without disrupting regular education, even when included as part of a school's curriculum. The aforementioned studies clearly recognise an apparent lack of interest in some schools to teach disaster preparedness, with it often becoming an ad hoc topic only once a disaster has occurred. For example, many admitted that their schools were spurred into action only after the 2010/2011 Canterbury earthquakes, and then only for a brief period. Also identified is a 'fatalistic' perspective amongst some teachers when they expressed opinions that Christchurch schools managed to get through the earthquakes adequately without intensive prior emergency response planning to same degree that WTPS encourages. One teacher even stated that she was in denial about the possibility of a disaster occurring at her school. What is apparent is a pressing need for new methods to rekindle awareness of the crucial importance of disaster education and to aid in its communication in primary schools. Unfortunately, such changes are often only triggered by catalytic events, particularly earthquakes, in New Zealand. Another overarching theme is the challenge of integrating disaster education into schools and their curriculums when it is wholly voluntary. It is only conducted at the discretion of teachers, principals or school boards of trustees. Even so, this education has often been found to be ineffective if not adopted as a school-wide subject or as a curriculum 'theme' (Johnson, 2011; Johnson et al., 2014).

In the case of the Canterbury earthquakes, the vital importance of developing such preparedness and imparting thorough knowledge of emergency procedures before an earthquake occurs is clearly evidenced. Local schools performed demonstrably well during the devastating February 2011 aftershock and when faced with the daunting challenges brought about in its wake. This can be attributed to the fact that, in response to the first September 2010 earthquake, they made significant efforts to be better prepared. Mutch (2015) affirms that "children were well drilled after the September earthquakes and they got under their desks" (p. 286). This can be attributed to the fact that, in response to the first September 2010 earthquake, they made significant efforts to be better prepared. The earthquake thoroughly tested the effectiveness of pre-established response procedures in a real scenario and served to highlight areas for improvement. Consequently, virtually all schools "updated their emergency response plans, communication strategies, child collection policies, first aid kits and disaster supplies" (Mutch, 2015, p. 287).

Primary School Furniture in Earthquakes

Most tables, desks and other similar pieces of furniture are able to be utilized as rudimentary shelter for people during severe earthquakes, but are unable to withstand heavy stresses, such as in building collapses. Qualities that facilitate 'earthquake-proofness' are not commonly incorporated into the design and construction of furniture intended for use in New Zealand schools. In earthquake scenarios, risk is an inherent and undeniable factor that must be understood and acknowledged. Physical threats in such events can never be predicted, nor fully mitigated. Crowley and Elliot (2015) warn against inadvertently fostering an incapacity in users to accept even small degrees of risk. Total dependence on extrinsic entities and influence from external loci, or a belief that absolute personal safety is constantly assured may result in a blasé or passive mentality in children that should not be encouraged. To categorically mitigate any threat of physical danger is an impractical objective that is virtually unachievable in a product such as a classroom table intended to provide shelter in an earthquake, especially when considered alongside other equally-important and potentially restrictive design factors such as usability, material suitability and manufacturing affordances. Rather, some level of 'acceptable risk' must be identified and addressed. Accordingly, the outcome of this research, a table designed to mitigate the physical threats and promote preparedness around earthquakes, is not intended to be 'earthquake-proof'. Nor should it be referred to as such, as this term is misleading and unrealistic. The term 'earthquake-resilient' is more apt, and will be used henceforth where appropriate. Beyond performance in actual seismic events, consideration must also be given towards the performance of the proposed table prototype in practice scenarios such as earthquake drills. Because classroom tables are frequently used by students in the capacity of a safety apparatus in accordance with established emergency practices, there is a need to incorporate a straight-forward and uncomplicated user experience in this interaction. Consistency of the user experience in practice is paramount to increasing the effectiveness of safety procedures in real emergencies. Johnston et al. (2011) analysed the behaviours of primary-level students during a school's earthquake drill and identified a tendency for them to role-play when adopting the Drop, Cover, Hold position beneath their desks. When holding onto the desk legs, some children were seen to enjoy shaking the desks to simulate an earthquake, while others encouraged their peers to huddle together to ensure their bodies were fully covered.

Another important objective should be to decrease children's vulnerability in earthquakes by enabling independent action when unsupervised (Finnis et al., 2004). Ubiquitous classroom furniture presents a suitable means of encouraging this, and the new table design proposed in this project can serve to empower students with a greater sense of confidence to react quickly and correctly. In a primary school environment, a major seismic event may render teaching staff unable to communicate with or aid their students instantaneously. Moreover, while they may be more adept than children at performing competently in seismic events, they are just a susceptible to psychological stress and sudden indecisiveness. "Teachers were shaky. They were quite nervous. There was a lot of pressure on them to keep students safe" stated a student interviewee in a study undertaken after the 2011 Christchurch earthquake (Mutch, 2015, p. 286). Individual human reactions in such upsetting scenarios are never predictable, nor consistent (Johnston et al., 2011). Teaching staff who have never experienced a large scale earthquake in a school environment cannot necessarily be expected to perform as required, and may well experience psychological trauma equal to, or greater than that of children in their care. This highlights the importance of enabling children to react in a composed and efficient manner without total dependency on an authoritative adult figure. Mutch's (2015) analysis of US psychology studies affirms that children "look to significant adults for guidance on how to respond to a crisis, during and after the event" (p. 284). Understanding the teacher-student relationship as a fundamental factor in the effectiveness of earthquake responsiveness in classrooms also makes clear the need to enable children to act independently. Communication of safety procedures in such a way that is universally comprehensible by children is thus a crucial objective in this project.

Everyday use of classroom furniture, such as movement around a room, stacking, or being sat on or leaned against, reiterates the necessity for fundamentally strong and sturdy construction techniques. Furthermore, it can be expected that, following a major earthquake, schools will be faced with a need to modify learning environments drastically. Furniture addressing earthquake safety must not only perform adequately during a real seismic event, but also pre- and post events as well as in the everyday context. A classroom table would provide a more useful solution in an unforeseen and changeable situation, such as that following a major earthquake, if it can be readily relocated or adapted for use in different areas where necessary.

Conclusion

In New Zealand, it is essential that preparedness for earthquakes is observed in all environments and is upheld as a fundamental priority in building and design practices. Furniture presents an ideal medium through which earthquake education can be better implemented in New Zealand primary schools. As proposed by this project, a classroom table inclusive of intuitive instructional features has great potential to act as a contemporaneous and pervasive medium to enable this learning of vital knowledge concurrently to in-school practice. By providing a more pertinent learning experience in parallel with the use of existing resources such as WTPS, such a table can encourage behaviours consistent with the procedures taught in mitigating the risk of seismic events. A dependable and constant means of readily providing improved safety for children in primary school environments, such as that presented by an earthquake-resilient classroom table, could not only mitigate physical hazards, but also serve to allay the negative psychological impacts that result from trauma and the everyday threat of disasters.

3 | Research Methodology

The research methodologies employed in this project have been selected to inform the design of a product in which the quality and ease of the user experience is a top priority. They are predominantly qualitative in nature. Kahn (2012) provides a concise explanation that underlines the rational for this project's use of qualitative inquiry as an overarching approach:

> "Compared to quantitative methods, qualitative research involves a deeper understanding of a phenomenon as well as smaller and more focussed groups of research subjects, and relies on the researchers to carefully observe and understand the phenomenon being studied" (p. 233).

It is necessary for the collected and extrapolated data to result in conclusions that address the function of school furniture not only in earthquake scenarios, but in day-to-day use as a fundamental part of a primary school classroom. Understanding the needs of the end user and the features of the intended environment is therefore of fundamental importance.

The research has been conducted in two phases:

Phase 1:

a) Classroom Observation
b) Focus Group
c) Teaching Staff Questionnaires
d) Interview with School Principal

Phase 2:

e) Design through Research
f) User Evaluation

Phase 1:

The objective in this phase was to gain a sound foundational knowledge of earthquake safety within the context of the primary school environment in order to inform and inspire the design component of the project. Through consultation with both school students and teaching staff, this empirical research has benefitted from a balanced cross-referencing of these two different perspectives. The research for Phase 1 was carried out with two participating parties:

- Te Aro School, Wellington
- Mr Charles Levings, principal of Avonhead School, Christchurch

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Student-centred Methods:

Contemporary studies concerning research with children have heralded a shift towards a reconceptualised view of children as valuable and valid research participants that can contribute directly to a research process (Fargas-Malet, McSherry, Larkin, & Robinson, 2010; Gibson, 2007; Greene & Hogan, 2005; Morgan, Gibbs, Maxwell, & Britten, 2002). Children's views surrounding earthquake safety at school are indicative of a simple yet rational understanding gained through experience, whereby the act of utilizing classroom furniture for safety in a seismic events has, for most participants, been fully realised through drills or during actual earthquakes. Acknowledging the validity of their views for this reason serves to constructively inform the design process. Their unaffected and uncomplicated responses are ultimately suggestive of some of the shortcomings in primary school earthquake safety that this project is seeking to address. Greene and Hogan (2005) stress the advantage gained through "granting children their rightful position as 'experts'", and how young research participants can thus feel a sense of empowerment (p. 16). As children are the ultimate end-user of this project's final product, their vital input has been sought through both indirectly in an ethnographic classroom observation session, and directly in a focus group.

a) Classroom Observation

To attain a sufficiently cognisant understanding of the physical and social dynamics within the typical classroom environment, especially as they relate to earthquake safety, an ethnographic approach was taken for the first session with Te Aro School. Ethnographic observation, wherein the researcher becomes immersed amongst the people that are the subjects of the research (Kahn, 2012), was selected as the preliminary research method to be employed. The researcher was attached to a class of 31 pupils in Years 5 and 6, with an age range of 9 to 11 years old, and was present as a non-participatory observer during two 45 minute lessons followed by an earthquake drill involving the whole school. Fieldnotes were taken throughout the session as relevant observations were made. As this research concerns children's understanding and behaviour, the researcher made an effort to dismiss preconceptions about the contemporary classroom environment and the experiences of the students within it. Indeed, Greene and Hogan (2005) affirm that "ethnographic approaches require us to suspend any ideas we may have as to our adult notions of childhood" (p. 15). They continue:

> "There is danger in taking an ethnographic approach whereby researchers make sense of children's behaviour through an adult lens. The filtering of information through our own experiences of childhood and its associated meanings can distort what children are telling us (p. 15)."

Accordingly, care was taken during note-taking to "record events experienced principally through watching and listening" (Schatzman & Strauss, 1973). Schatzman and Strauss recommend that field notes/observational notes "contain as little interpretation as possible and are as reliable as the observer can construct them" (p. 110). This tactic was also continued beyond the observation session and through into the focus group session when recording student responses to questions. A particular advantage of ethnography that was deemed to be beneficial to this research is the selfcorrective and flexible nature of the approach (Eder & Corsaro, 1999). As the researcher had no previous experience of working within a primary school environment in the capacity of academic investigation, the observation session, with its open scope, afforded a degree of freedom to adjust attention and emphasis for data collection as was deemed fit. Conducting this session first also served to inform the selection of the subsequent methods for data collection based on the researcher's analysis of the environment and the people within it. The overall intention in the use of this method was to gain an understanding of the students' physical relationship with their existing desks and tables in a typical classroom scenario. Particular attention was paid to their posture and positioning, movements, work habits, and interpersonal communication. The goal was the identification of recurring patterns or behaviours, both positive and negative, concerning the students' everyday use of the classroom furniture.

b) Focus Group

Two weeks after the observation session, a single focus group session was conducted with 6 students from the aforementioned class (4 males, 2 females). Thus the participating students had already learnt about the purpose and worth of the research, and were acquainted with the researcher. The 40 minute session was conducted in the school's library – a familiar and comfortable environment that the children were at-ease within. The resultant qualitative data was solicited through open-ended, unbiased questions intended to foster a topical discussion about earthquake safety in the classroom.

In focus groups the researcher is not in position of power or influence, but merely a moderator in more of a participatory role (Krueger & Casey, 2014). For this reason it was selected as an appropriate research method to use with children within the age range specified. This even balance of power creates an atmosphere in which spontaneous contribution is encouraged (Morgan et al., 2002). Krueger and Casey (2014) affirm that the social and non-threatening nature of a small group is conducive to the self-disclosure of children, wherein the presence of one's peers in an informal setting motivates the sharing of opinions with a lessened fear of being judged. Kitzinger (1995) states that focus groups "can be used to examine not only what people think but how they think and why they think that way" (p. 299). Correspondingly, the loose structure of a focus group allows the researcher to subtly probe for elaboration on interesting and relevant points brought up by participants, therefore addressing not just the 'what', but the 'how' and 'why' (Gibson, 2007). This is particularly beneficial, as the research data is needed to inform the design of a product that positively influences child comprehension of earthquake safety. Furthermore, the format of focus group will often "facilitate the expression of ideas and experiences that might be left underdeveloped", thus empowering participants by allowing individuals to be an "active part of the process of analysis" (Kitzinger, 1995, p. 300). The elucidation of unidentified themes of importance was hoped to be achieved through the use of this method. The researcher wanted the children to feel that their input was a useful and positive contribution to the research, thereby encouraging their engagement and attention.

The session was concluded with a ten-minute drawing exercise in which the students were provided with coloured pens and paper to draw their own ideas for a classroom table to keep them safe in an earthquake. These drawings were not intended for use as participatory design contributions towards the final product, but rather as a simple engagement tool. Fargas-Malet et al. (2010) assert that drawing is a particularly fun and engaging way for children to express their ideas and experiences, particularly if they are less inclined to contribute to a conversation. Morgan et al. (2002) have also found 'pen-and-paper' exercises are an effective way to reveal and expand upon ideas that are brought to light verbally by children, especially as drawing allows for personal reflection without the pressure of having 'an immediate question to answer' when conversing in the group (p. 12). While the drawing exercise was conducted at the end of the session, the students were told at the start that it was something they could look forward to at the end. Thus it served to retain interest, as students were encouraged to remember what they identified as inadequacies in their classroom tables and desks and to then draw their ideas for how they can be improved.

Staff-centred Methods:

While emphasis has been placed upon the experiential considerations of the primary school students themselves, a more mature and holistic view of the subject has been sought from the participation of adults. In New Zealand primary schools, teachers are assigned a class for the duration of the school year. A large majority of daily lessons are conducted in the same classroom by the same teacher. Thus a teacher will spend a substantial amount of time every week with the same group of children in an environment with great familiarity. Other school staff, such as principals and administrators, will often have a very prominent school-wide presence and will engage in many interactions with students. For this reason, teaching staff have been identified as a valuable source of data for this research.

c) Teaching Staff Questionnaires

A voluntary, anonymous paper questionnaire was provided for the teaching staff at Te Aro School. The brief questionnaires contained questions addressing students' use of the existing furniture in the classrooms and their knowledge and confidence in earthquake safety procedures. Questionnaires are inherently easy to quantify and extrapolate, and are a familiar means of data collection for virtually any participant (Walonick, 1993). Using a straightforward and time-effective method was particularly important with teachers as the participants, as they are often very busy and thus less inclined devote even a small amount of time to contributing towards external research. Paper questionnaires present a discreet, non-obligatory way for interested teachers to participate in a meaningful yet simple way in their own time and at their own discretion (Walonick). Focused, pre-set questions in a questionnaire usually take relatively little time to complete (Baracco, 2007), and this standardized, identical format makes for greater ease of extrapolation and analysis of individuals' varying views concerning common themes addressed in the questions themselves. The mixture of Likert-scale questions and written-answer questions results in and both quantifiable data and qualitative reflections for further analysis. The open-ended questions, in particular, such as those where a participant can write a bulleted list of short answers, are included with the goal of bringing to light issues that the researcher had not identified through prior other research methods. Conversely, design considerations hypothesized to be of a low priority for addressment could in fact be revealed as important aspects to focus on improving for the final product.

d) Interview with School Principal

The researcher travelled to Christchurch to conduct a one-on-one interview with the principal of Avonhead School, Mr Charles Levings. As the head of the school he experienced the 2010/2011 earthquakes first hand and was pivotal in the implementation of school-wide infrastructure and earthquake procedure updates in response to the disasters. This method was selected because a qualitative interview typically allows for the interviewees to feel and act as a 'meaning-makers' – positive influencers whose imparted information is of use to the research, rather than just "passive conduits for retrieving information from an existing vessel of answers" (Gubrium & Holstein, 2001, p. 83). Thus, in this context of a personal account of particular events, the participant is motivated to disclose their experiences as they are deemed to hold valuable and relevant information. The naturalistic process allows ample opportunity for the interviewee to freely express views, details and feelings (Baracco, 2007). In keeping with the empirical research approach applied, Gubrium & Holstein (2001) also affirm that "the purpose of most qualitative interviewing is to derive interpretations, not facts or laws, from respondent talk" (p. 83) As a large emphasis of this project's research addresses experiential considerations of a subjective and varying nature, this semi-structured interview allows for greater freedom for the researcher to shift the focus and scope of the topic of conversation when necessary in order to unearth new information or specific details. Moreover, in this particular interview the interviewee was told that their meaningful contributions will directly influence the creation of a product that can, hypothetically, positively augment the functionality of their working environment.

Phase 2:
This phase involved the construction of the fully resolved, full-scale working prototype, and its subsequent evaluation by primary school students. The User Evaluation for Phase 2 was carried out again with the help of Te Aro School.

e) Research through Design
Based on the research conducted in Phase 1, an iterative design process was undertaken utilizing 'Research through Design' as a method of inquiry. Gaver (2012) provides a succinct explanation of this method:

> "[Design practitioners'] work often takes the form of Research through Design, in which design practice is brought to bear on situations chosen for their topical and theoretical potential, the resulting designs are seen as embodying designers' judgments about valid ways to address the possibilities and problems implicit in such situations, and reflection on these results allow a range of topical, procedural, pragmatic and conceptual insights to be articulated" (p. 937).

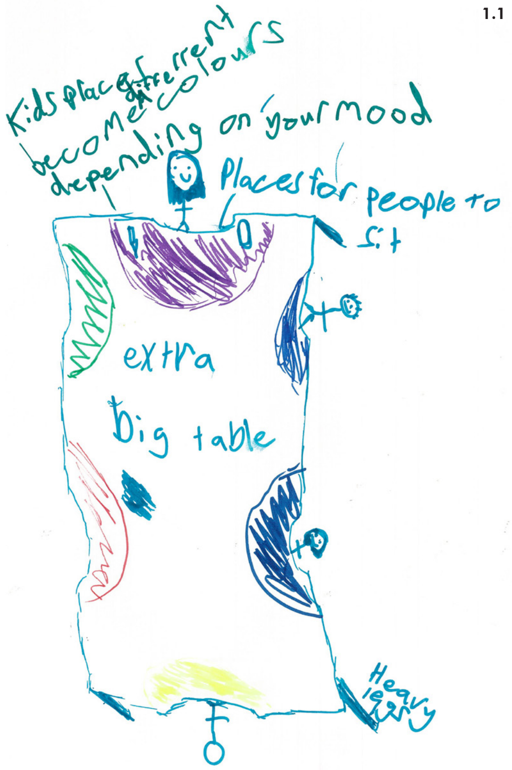
Durrant et al. (2015) identify the undertaking of Research through Design as a 'knowledge-generating activity', whereby a successful product can be generated through attaining a cognisant understanding of different perspectives and visions in a design process. The method is informed further by the 'borrowing' of conceptual and theoretical perspectives from other disciplines, such as Education, Child Psychology, Architecture and Structural Engineering. Translation and rearticulation of themes and ideas from a diverse selection of supplementary fields provides valuable touchstones to influence a design process and to maintain relevance (Durrant et al., 2015; Gaver, 2012; J. Zimmerman, Stolterman, & Forlizzi, 2010), as well as providing a designer with a bountiful source of inspiration. Zimmerman et al. (2010) recognise Research through Design as a suitably applicable means to inform a pragmatic design process when purely scientific and engineering modes of inquiry will not suffice. The researchers ascertain that such approaches can disregard subjectivity in pursuit of a single 'truth' rather than an optimal, universally-applicable solution based on any number of possible scenarios. In the context of this project, absolute protection from disaster-related events cannot, realistically, be fully implemented when the phenomenon and its environment is interminably variable. There cannot be one solution that can realistically afford unequivocal 'safety' for children. Rather, a project such as this should take into account the unpredictability of hypothetical factors to result in a product that addresses all to some extent and can conform to utilization in applicable circumstances and eventualities. In this regard, considerable attention has been given towards the table's materiality and overall construction for its intended use as both a functional day-to-day part of the classroom and as an earthquake safety apparatus.

Within the application of research to the development of a successful design outcome, an iterative design process was employed. Iterative design may be understood as a methodology based on a cyclic process of prototyping, testing, analyzing, and refining a work in progress (E. Zimmerman, 2003). In his essay, 'Play as Research', Zimmerman expands on this idea: "In iterative design, interaction with the designed system is used as a form of research for informing and evolving a project, as successive versions, or iterations of a design are implemented (p. 176)." This approach has been rigorously applied throughout the research process whereby the initial idea underwent intensive conceptualization by way of preliminary investigations into form and function through sketching and scale model-making. Once the design parameters were reasonably defined, the conceptual design was translated into a digital model for further modification and improvement. Physical prototyping was also employed, and this initially took the form of full-scale cardboard prototypes for the assessment of ergonomic characteristics and general user experience needs. Ultimately, a full-scale 'real-world' prototype was fabricated through which construction techniques and materials were evaluated and applied. In applying an iterative design process, the research is conducive to 'community discourse', in which peers and other external parties can aid in the identification of gaps in currently employed theories and the implementation of new ideas (J. Zimmerman et al., 2010). The Earthquake-Resilient Classroom Table project developed according to an ongoing dialogue between the designer, design, and target users and, accordingly, the observation, focus group session, questionnaires, and interviews were pivotal to the resolution of this design. The 'real world' prototype produced enabled the most valuable feedback for this research in the way of user evaluation.

f) User Evaluation

At the completion of the design process, the completed prototype was taken to Te Aro School for an on-site evaluation by the students who participated in the Focus Group for Phase 1. This method was not intended to inform the design process as such. Rather, the goals were to attain an unpretentious preliminary evaluation of the product's efficacy and to inform the creation of a list of improvements that could made should the product undergo further development beyond the completion of this thesis. The regimented scope, time constraints and material and funding limitations of the project have only allowed for limited product development; certainly insufficient for the resolution of a product that is truly manufacturable, marketable and implementable. Indeed, the product is conceptual and speculative in nature, but it is intended to act as a catalyst to foster further development of furniture design that addresses and facilitates earthquake safety in New Zealand schools. Conversely, the chance to allow the aforementioned participants to see the tangible result of their positive contributions was also a major motivation.

1.1



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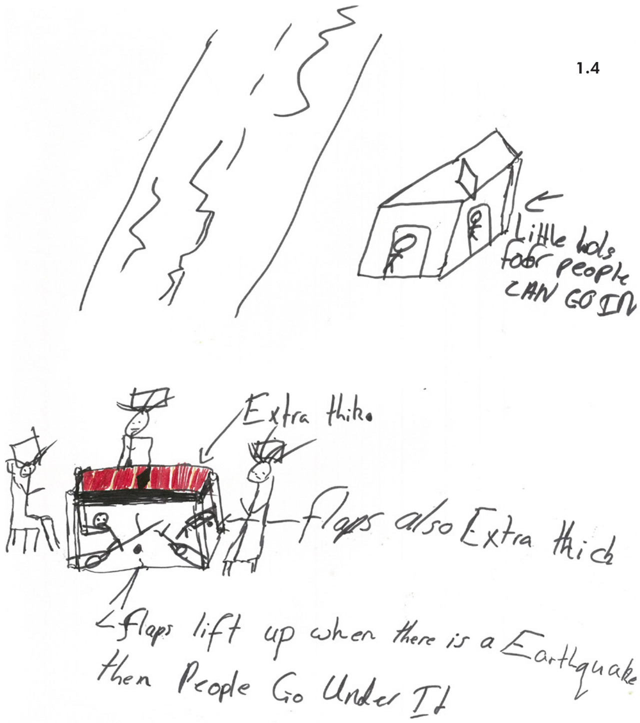

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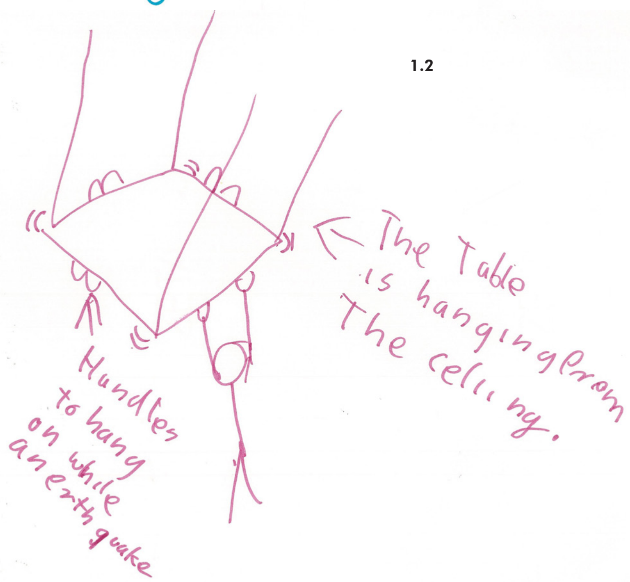

1.5

1.3

Assorted pictures of 'earthquake-proof' classroom tables drawn by the student participants of the Focus Group research session.

4 | Research Analysis

a) Classroom Observation

This session entailed two lessons (a math lesson followed by a creative writing lesson) during which the researcher occupied a single desk as a regular student would, but nearer to the rear of the classroom where they were in full view of the children but in an unobtrusive position. The lessons were not taken part in per se, but the researcher acted as a member of the class and conversed with the children at times about the work they were doing.

Classroom Furniture Layout

The room included an array of different types of tables and desks, including older, more traditional single desks; high tables that had an elevated work surface for standing rather than sitting at; larger group tables for multiple seated users, both rectangular-shaped and kidney-shaped; and even a low knee-high table surrounded by soft pillows for seating, specifically for students who wished to read. It should be noted that the tables in the classroom were scattered and were not all orientated to face one particular direction, as has been a more traditional layout in the past. While the room did have a dedicated 'front', it soon became clear that not all lessons were taught from this position, and that the 'front' in fact shifted from lesson to lesson, as there were multiple whiteboards on different walls. Due to the shape of most of the group tables causing the seated users around the outside to face inwards by default, they often turned in their chairs, sometimes away from their table entirely. At any one time, the majority of the seated students would in fact not be naturally facing the 'front', and would have to turn change their position to face the teacher. The arrangement of the furniture within this particular classroom resulted in an environment that was very dynamic rather than regimented and static. As the layouts of New Zealand primary school classrooms are undoubtedly very varied, certainly an important design consideration to address is not only the facilitation of less-structured furniture arrangements such as this one, but also that of classrooms that employ more structured, traditional layouts.

Children's Interactions with Furniture

The researcher noticed an array of different behaviours concerning the students' use of, and relationship with, their classroom tables and desks. Many children were seen to shift their orientation constantly. This was because they were keeping their attention on their teacher, who did not merely instruct from one end of the room, but also moved amongst the tables when not writing notes on a whiteboard. When the class was not being addressed as a whole, the students were allowed to work on the task at hand of their own accord while the teacher moved from student to student to provide assistance. When working, the children at the group tables also shifted and turned around frequently when conversing with their neighbouring peers or with those on nearby tables. It should come as no surprise that, in terms of posture and positioning, the students were never stationary. They would change their positions relative to the tables and desks almost constantly throughout their lessons. Very few students adopted proper posture for extended periods of time. Some students would slouch low in their chairs and stretch their legs far beneath the table, while others would lean out of their chairs and far across the top, raising their legs while the tabletops supported their weight. The obvious fact that children never remain in one position when seated a table needs to be factored into a new table design. As they are extremely restless and fidgety, general freedom of movement is an inherent necessity. Unimpeded and sufficient legroom was identified being particularly important during the observation due, as previously stipulated, to the students' tendencies to move about and turn around in their seats. Some students were seen to spread their books and stationery across a wide area on the table tops when working, taking up a large surface footprint that sometimes encroached on their adjacent peers. There is potential to provide a larger work area for individuals, and to more clearly demarcate and define their own 'space' at the table.

Earthquake Drill Behaviour

For the earthquake drill the school's bell was sounded near the end of the second lesson to signal the start of the imaginary shaking. The teacher immediately told the students to get under their tables and hold on until they were told they were allowed to get back up. The researcher continued to act as a member of the class and proceeded to use the *Drop, Cover, Hold* procedure under their own desk while observing the children's actions around them. All students immediately got down, and those that were seated at desks and tables went beneath and grabbed hold of the frames and legs. Approximately four students had not been seated at the time and were transiting between different points in the room. They too dropped to the ground exactly where they were at that moment, but only one student got under their nearest table. The others simply adopted protective *Drop, Cover, Hold* positions on the floor, leaving themselves exposed. This was even when it was noticed that, for at least one of these students that happened to be close to the researcher, there were tables in close proximity under which shelter could have been taken. None of them were seen to make any moves to change their location until the bell ceased ringing and the teacher announced that the drill was over. These actions were peculiar and the researcher made a note to raise them with the students in the focus group, however at the time it was deducted that students were trained to drop immediately in an earthquake and were discouraged from moving from their position unnecessarily. On the larger tables, it was noticed that, even though they could accommodate more seated students, the same number of users struggled to fit beneath the area defined by the table top. As a result, some students were left partially exposed, often with only their heads and upper bodies beneath the table despite their best efforts to huddle together as closely as possible. This observation, combined with the aforementioned realisation that students may not habitually seek shelter beneath a table, clearly emphasizes the need for tables that can shelter at least as many people as can be comfortably sat at them. Providing even more room than this would be advantageous, as people who are not in immediate proximity can thus still find space to hide in when rushing to a position of safety. One student who was seated at a single desk began to shake its legs vigorously when he got beneath it, making a disruptive noise. When the teacher told him to stop he replied "I'm pretending it's an earthquake though," before ceasing his shaking. The potential for children to role-play in disaster scenarios had been identified prior to the session in this thesis' literature review, and this particualr observation affirmed a requirement for a table that either cannot be shaken, or is sturdy enough to endure shaking by children when conducting drills. The class then filed outdoors as a group and followed their teacher to the basketball courts where the whole school assembled for a roll-call and a debrief from the principal. The students were notably orderly and were obviously well-trained in the procedure.

Key Findings:

Based on observations made during this research session, the following preliminary considerations were identified as requiring addressment in the design process for the new classroom table:

- Ability to easily conform to different classroom layouts and orientations.
- Allowing for as much freedom of movement as possible, particularly concerning leg movement and legroom.
- Incorporation of sufficiently sized and unobstructed work surfaces.
- Providing enough room beneath to shelter the usual number of seated users, and possibly even more.
- Sturdy construction that can tolerate vigorous movement from role-playing children during disaster drills.

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b) Focus Group

Table Typologies and Aesthetics

One student expressed their preference for sitting alone or in small groups where they can have their 'own little space'. This sentiment was echoed by two more of their peers. The remaining participants said that they prefer sitting with a larger number of their peers so that they could discuss the work at hand or simply be close to their friends. Dissatisfaction with the seating arrangements was also raised. The students confirmed what was suspected in the Classroom Observation session by saying that some of them are assigned particular seats to use for the majority of the lessons in the classroom by their teacher. Presumably this is to maintain a conducive learning environment by seating students with peers who are going to be a good influence rather than a distraction. One student said "I don't like it, but it helps with our learning," therein revealing a shared perception that it is enforced by the teacher for a good reason. In considering the dynamic nature of the classroom's seating arrangements, the importance of creating a design that is inherently flexible in this regard is clear. Where students all have varied seating preferences, or even set positions imposed by their teacher, a new table should allow for them to be able to sit with any number of their peers, or to even have an adequate degree of separation – their 'own little space' – should they wish. The possibility of enabling user customization in future design development could also address this need further. Aesthetically novel and radical furniture designs seem to intrigue students, and the participants expressed a penchant for tables that looked out-of-the-ordinary. The 'jelly-bean', or kidney-shaped, tables in their classroom were identified as a favourite for their 'cool' looks and also because their smoothly curved edges make for more comfortable workspaces. Colour was also identified as a dominant factor that influences user attraction. By logical digression, the superficial appearances and stylistic qualities of different materials, beyond just colour, can certainly be acknowledged as an important design consideration. To appeal to children's sense of novelty, there is potential for the new design to incorporate aesthetic qualities less typical of traditional tables and desks, particularly in its form, materiality and colour.

Table Construction

Surprisingly, the students appeared to be acutely aware and critical of the construction of their existing classroom tables; definitely more so than was first anticipated by the researcher. Due to their suddenly forthright and animated response to the question "what don't you like about the tables and desks in your classroom?" it can confidently be surmised that, prior to this research, the students had never been provided with a means to openly express their dissatisfaction with the quality of some of their tables. Most of the students complained about squeaky and wobbly tables, and one student even suggested that it is "because the bolts keep coming undone". Such parts that are not firmly secured are not only symptomatic and causal of weakened construction, but also present hazardous protrusions that could cause injury. Another student expressed a firm dislike of the outdated, single-person desks in the classroom. He explained that are usually assigned to students who do not wish to sit at group tables, or for misbehaving students that need to be temporarily separated from their peers in order to focus. Specifically, the hinged lids on the desks were said to not only be very squeaky, but also dangerous as they can easily slam on down onto fingers if care is not taken when opening and closing them. This report speculates that students do not often raise these issues with their teachers, be it because feel that their concerns are not important, they will not be resolved, or that they could simply fall upon deaf ears. Nevertheless, it is important that children feel confidence in the structural integrity of their tables at all times, especially when this trust is paramount to prompting appropriate action during actual earthquake scenarios in which they must carry out the *Drop, Cover, Hold* procedure.

Tables in Earthquake Scenarios

The students were asked to elaborate on their dissatisfaction with the construction of many of their existing tables and desks, but within the specific context of earthquake scenarios. The researcher was surprised to expose a unanimous opinion that they were wholly insufficient as earthquake safety apparatuses. Despite their deeply-engrained training in the *Drop, Cover, Hold* procedure, the students did not believe that the act of hiding beneath them would make a difference if a large earthquake struck and brought down heavy objects and debris on top of them. Again, they were fast to critique the structural shortcomings of their squeaky and wobbly tables, and felt that their flimsy frames would almost certainly collapse under the concentrated force of falling objects. This almost fatalistic view was particularly concerning. None of the students questioned the efficacy or relevancy of the *Drop, Cover, Hold* procedure, but nor did they express a lot of faith in it given their unfavourable perception of the structural integrity of their tables and desks. "If there's an earthquake and you're not holding on to them tight enough they [could] slip out of your hands and [move] across the room and maybe hit people," said one student, while another affirmed that they are 'really light' and would probably move around if they are not grabbed hold of quickly. Some students also raised the issue of the tables being too small at times to accommodate all of the students seated at them when conducting earthquake drills, as was noticed during the Classroom Observation session. When asked for clarification, they affirmed that they are trained to get beneath the table or desk closest to them in an earthquake, and to not move about if they find themselves partially exposed when hiding with others under an insufficiently sized table, even when there may be enough room for them elsewhere. The students were also very mindful of the various types of hazards that could befall them in an earthquake. While most of their responses revolved around a scenario in which structural components of a building, such as walls, roofs and masonry might collapse or fall on top of their tables, they were also aware of smaller, but no less dangerous and perhaps more likely, hazards in the classroom. Hanging lighting fixtures, computers and monitors, and broken glass from shattered windows were identified as potential falling threats from which tables can afford some degree of protection. Two of the male students expressed a somewhat indifferent view throughout the session in which they trivialized their past earthquake experiences and saw them as exhilarating experiences rather than something to be fearful of. One said that it was 'funny' when a sizeable earthquake struck during a school day earlier in the year, in which the students found themselves seated on the open floor of the school's assembly hall and had to *Drop, Cover, Hold* without the protection of tables. "A few people screamed. I was kind of freaked out but happy at the same time because earthquakes are fun," said the other student. However, one of their female peers rebutted quickly to say "it's not fun. It was really scary because there was nothing to hide under and we were in the middle of the room." It is logical to surmise that child perception of danger is defined by past experiences, or, perhaps in the case of these two particular children, lack thereof. They did not show any indication of having negative or upsetting memories pertaining to earthquakes. Their rather blasé attitude exhibited not necessarily a lack of vigilance, but rather a lack of regard for the magnitude of potential risk in a major earthquake scenario. Compared to similarly aged children from Christchurch, for example, where public awareness and preparedness for earthquakes is obviously extremely high, this outward sense of laxity revealed a decidedly less developed and attuned sense of awareness due to their comparatively inconsequential experiences of earthquakes in Wellington. This highlights the importance of pre-emptively developing an informed awareness of potential risk to personal safety in an earthquake scenario, and a constant readiness to react appropriately. As an aside, the students said that they often do arts and crafts at their tables, and thus they have to be cleaned when they get messy. Furthermore, they also said that they have seen the use of tables and desks similar to theirs for computers and monitors elsewhere in the school.

Key Findings:

Based on responses from the participating students in this research session, the following preliminary considerations were identified as requiring addressment in the design process for the new classroom table:

- Children are more partial to, and accepting of, tables designed to be novel and visually-intriguing
- There is a need to accommodate a varying number of students not only in a conventional capacity, but also when used as a safety apparatus in an earthquake scenario. Enough room needs to be provided for, at the very least, all users that would typically be seated at the table, and potentially even more.
- Susceptibility to malfunctioning of components must be minimised throughout and overall physical construction should be robust and hard-wearing. This is important not only for its utilitarian application as an everyday table, but also to dispel fears that it may not provide sufficient safety in an earthquake.
- The new table should be perceived to be well-made and designed pragmatically, whereby the semantic language of the design features imply strength and robustness rather than fragility and weakness.

- When sheltering underneath the table in a seismic event, children should able to easily and intuitively anchor it by grasping legs or a frame. Moreover, it should be designed to be less prone to movement in an earthquake even when not anchored by users.
- The tabletop needs to be durable and easy to clean in order to be suitable for arts and crafts.
- Use as a computer desk should be considered. The tabletop should have space for the placement of computers, monitors and other peripherals such as keyboards and mice.

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c) Teaching Staff Questionnaire

In total, 10 questionnaires were completed by teaching staff at Te Aro School. As was expected, the results provided were straightforward and generally very consistent. Rather than highlight previously unidentified issues for addressment, they instead served to reiterate the validity of considerations that had been conjectured prior to the undertaking of research, and thus worthy of addressment in the subsequent design process. While some responses yielded data that was of negligible importance or relevance, the results were generally very conclusive.

Note: Many of the following answers have been slightly reworded where appropriate. These revisions have been carefully made to express opinions and ideas to the effect of the original written answers. Many responses to the questions were virtually identical despite being provided by different respondents. Therefore, for the sake of simplicity, discretion has been used to combine some responses together, or to omit some in favour of similar ones that are more suitable. The answers included below are thus not indicative of the actual number of responses to the questions.

Question 1: If you have noticed any, please list some particular habits that the students have developed while sitting/working at the existing tables and/or desks (This could be in terms of posture, fidgeting, movement, etc.):

- Swinging/leaning on chairs and balancing them on their rear legs
- Slouching in chairs
- Not tucking chairs back beneath tables when vacating them
- Lying across tables
- Preference for variety in table shape/form (ie: standing tables or low tables around which users sit on the ground)
- Standing tables suit children who fidget a lot

These responses reiterate the generally restless nature of children aged between 5 and 12 in classroom situations, and therein the importance of incorporating furniture that is not ergonomically restrictive. In a contemporary New Zealand classroom environments, where less-regimented layouts appear to have become the norm, it would seem that such regular movement of furniture could encourage increased body movement too. Regardless, the simple fact that children cannot be expected to continually use furniture in a 'correct' way necessitates designs that allow for children to reposition themselves and change their posture safely and with ease.

Question 2: For what reasons might you rearrange the furniture in the classroom? How frequently?

For the first part of this question it is immediately apparent from the responses that the furniture layout within a contemporary classroom is, at least in the case of this particualr school, very fluid. Variety in activities and variable student numbers clearly necessitates fairly regular change in day-to-day use of the spaces:

- Different groupings of tables and desks for different activities, ie: large group activities need more table space to work at
- To use the space for different purposes
- When accompanying another class in the same room
- To accommodate the learning needs of all children
- To make more floor space for activities, ie: aerobics
- As new children join the class
- As the learning programme changes

The dynamic nature of furniture arrangements in most classrooms is evidenced further when 9 out of 10 respondents provided similar answers to the second part of this question. Answers generally ranging from 'daily' to 'weekly', affirming that their classroom layouts are changed with a relatively regular frequency. Only 1 respondent said that their classroom layout "stays the same for the term".

Question 3: Please list some qualities or features that you believe would be appropriate to be included in a new design for a classroom table/desk (This could be in terms of shape, function, aesthetics, size, materials, extra features, etc.):

- Ability to be pushed/connected together to form clusters to accommodate larger groups
- Stackable
- Storage shelves underneath
- Shapes that allow children to be close for quiet talking, but with enough space for work materials
- Durable, strong and of good quality
- Easily cleanable
- Range of sizes and heights
- Adjustable height
- Variety of different shapes
- Easy to move
- Bright colours
- Legs that can easily be held onto in an earthquake
- Room for five to six 5 year old children to hide beneath
- Doesn't have set areas for chairs to occupy. Prefer more regular and open shapes that can squeeze in extra chairs

- Some single desks for children who work better alone

Adaptability is the main theme that is apparent here. As the previous question ascertained that classrooms are ever-changing environments, these answers affirm that this necessitates classroom tables and desks that can readily conform to different uses and layouts. While it is not realistically possible to address all of these requirements in a single product, all are totally valid and are worthwhile considerations to inform the definition of design criteria and subsequent design process.

Question 4: What would you be most worried about in the event of an earthquake while at working school?

- Items falling off of shelves onto students
- Broken/flying glass from windows
- Children being injured
- Falling shelves/furniture tipping over
- Children not being able to leave school to go home

The respondents identified fairly typical concerns about physical safety to themselves and their students. These concerns are more consistent with risks posed by light to medium-scale earthquakes, the likes of which are more probable than a catastrophic, large-scale earthquake that could severely damage or destroy infrastructure. Nevertheless, the *Drop, Cover, Hold* procedure primarily serves to mitigate more likely risks such as these when executed in a seismic event. Suitably, a protective table that can adequately endure these forces would further enhance the consistency and relevancy of established practice, unlike many existing desks in tables in classrooms nationwide.

Question 5: How confident are you in your personal knowledge of the school's earthquake procedures and your ability to carry them out in a seismic event?

Eight out of ten respondents rated their personal confidence at 8 or higher, while the remaining two rated themselves 5 and 6 respectively. This affirms the notion that there is potential for the design proposed by this project to further supplement the influence of teachers in earthquake scenarios. While they can give directions to their students, another pervasive means of positively augmenting this vital communication can further facilitate correct action.

Question 6: How confident are you in your students' knowledge of the school's earthquake procedures and their ability to carry them out in a seismic event?

Overall the respondents had more confidence in their students than was hypothesized, however their answers still indicate that there is room for improvement. Half rated their confidence in their students as 5 or 6, and the other half as 8 or 9. Interestingly, the two teachers that rated their personal confidence lower in Question 5 rated their own students' confidence exactly the same as they had themselves. Again, the capacity for another effective means of alerting and assisting students in seismic events is evident in these responses.

Question 7: What sorts of tools or resources do you utilize to educate your students about earthquake preparedness and safety procedures?

- Civil Defence Resources
- Online sources
- Youtube, internet videos
- Worksheets for students
- Songs, poems, stories
- Discussions, conversations
- Books
- Regular drills, both with just the class and with the entire school
- Posters
- Specific class lessons

One respondent made an extra note saying that awareness of earthquakes needs to be heightened without scaring them.

It appears that teachers have some discretion as to how disaster preparedness and resilience is taught to their students. One important consideration is the varying levels of comprehension across children aged between 5 and 12. A new table that facilitates the learning of earthquake education must incorporate educational elements that are easily comprehensible by any child, such as through clear and recognisable imagery. Moreover, efforts need to be made to ensure that this educational design component is as universally compatible with other teaching resources as possible. Those stated here are indicative of the wide range of resources across the classes in only one school. As for schools nationwide, it can be assumed that this range can be lot more varied. Regardless of this variance, consistency with 'correct' practice – in this case the *Drop, Cover, Hold* procedure – is of utmost importance in the design process.

Question 8: Please list some of the behaviours you would expect your students to display during a seismic event:

- Panic
- Anxiety
- Fear
- Excitement followed by worry
- Calm
- Immediate Drop, Cover, Hold
- Waiting for instructions
- Quiet/silence
- Following practiced routines
- Crying
- 'Turtle' (*Drop, Cover, Hold* in open spaces without the cover of tables or desks)
- Staying still
- Facing away from windows/glass
- Unpredictable behaviour

Question 9: Please list some of the behaviours *you would expect your students to display immediately after a seismic event:*

- Anxiety
- Panic
- Fear
- Worry
- Concern for families
- Resilience
- Following of established procedures/ processes
- Waiting for further instructions
- Crying
- Obeying adults, following instructions
- Quiet
- Excited energy
- Wanting to move outdoors
- Unpredictable behaviour

This wide range of behaviours identified across both of these questions reiterates the importance of facilitating correct earthquake response practices so that children can follow them confidently regardless of their emotional state. As was also identified in the Classroom Observation session, some children may be prone to indecisiveness and erratic behaviour, even in practice scenarios. Moreover, despite regular reiteration of knowledge through lessons and drills, some respondents still expected behaviour that could deviate from, or hinder, the execution of these practices. A contemporary classroom table designed to mitigate these issues, therefore, would ideally integrate a persistent, perceptible, and unanimously comprehensible means of prompting proper action during an earthquake.

d) Interview with School Principal

The earthquake that occurred on 4 September 2010, the first major quake to strike the Canterbury region in recent memory, occurred at night and therefore, despite widespread damage to infrastructure, it did not physically affect children while they were at school. Nevertheless, according to the interviewee a heightened level of awareness was sparked at his own school. "The September earthquake, to some extent, was a bit of a God-given indication that there was something else on the way," he said. "We had a lot of aftershocks so we started treating [earthquake safety] very seriously and we rehearsed [drills] quite often." This precautionary reaction was a direct result of this event and its constant aftershocks. "We had aftershocks and we were kind of getting used to them until the 22nd of February when the large earthquake struck at 12:51," he continued. He expressed a great deal of confidence in his school's earthquake preparedness prior to this event. "[Response procedures were] something that we had practiced and rehearsed since the September earthquake, so the kids knew [how to act] and I was delighted [that the] kids knew exactly what to do", he explained. This second, more destructive quake struck at the start of the lunch break. It is understood that most of the students were eating their food beneath the outdoor awnings of the buildings due to light rain, while a few others were still in their classrooms or scattered across the outdoor areas. These circumstances presented a challenging scenario, as earthquake drills had previously only been rehearsed inside the students' own familiar classrooms where they were always in close proximity to desks and tables. Although many children were in areas within which they had not practiced safety procedures at the time of the quake, the interviewee praised his students and affirmed that, to his best knowledge, they "still did exactly what they were expected to do regardless of where they were." When asked if he knew if his students would have correctly performed the *Drop, Cover, Hold* procedure, he replied "the kids had been through that process and they knew what to do. It's very likely that kids who would have been in the classrooms would have done exactly what we had trained them to do. "If there are desks or tables nearby they go for those, and if they are in the open they curl up like a 'turtle'. Most, if not all kids did that for the quake, I believe. *Drop, Cover, Hold* is what the kids know and we still teach them that."

The interviewee went on to explain that immediately following the quake there was a prevalent "sense of bewilderment" amongst the children, and that the "main focus [of the staff] was to keep the kids together and reassured", as the extent of the devastation and the loss of life in the city had still not been fully realized due to the lack of power and overloaded communications networks. Despite the constant aftershocks, the interviewee made a preliminary effort to assess damage to the schools infrastructure before allowing the staff and students to return indoors. "A free-standing bookshelf had fallen over [in one classroom] and it probably would have caused some damage and some injury to a child had they been in the classroom," he said. "Shelves had collapsed in the library and chairs were toppled, as well as some desks." Approximately an hour after the quake, the students were still assembled outdoors as the interviewee and his staff were unconfident that the structural integrity of the buildings had not been compromised, and aftershocks were still occurring regularly. When it began to rain again the call was made to move the children into the school's hall so they would not get wet and cold. The hall building, which had only been opened seven months prior, had been built to rigorous earthquake safety standards. The open floor space of the hall could accommodate all students and staff, but it did not contain any furniture to act as means of providing safety from falling objects and structures. Once they were indoors a large aftershock, thought by the interviewee to be a second earthquake, occurred. Because of the lack of safety apparatuses in the hall, such as tables, and the hazards posed by hanging light fixtures and large glass windows, the decision to move the children indoors was quickly rescinded, despite the overall structural strength of the building. "[The aftershock] was quite a big one as well", explained the interviewee, "so we had to quickly evacuate the hall because you had to prioritize: wet and cold, or dead underneath a building. So we actually opted to be outside."

Throughout the session the interviewee made frequent mention of what he called 'collaborative/flexible learning environments', explaining that these contemporary classroom layouts leant themselves to the use of larger tables rather than individual desks. As previous efforts to update and renovate the school in the years following the earthquakes had seen a shift towards the implementation of these new furniture arrangements, he was faced with apprehension and resistance from some parents. These concerned parties, he explained, worried that the removal of the original desks no longer guaranteed a means of protection for all students in a classroom. Where each individual desk was perceived to provide an adequate means of safety for one student, these new tables, despite their larger overall size, were doubted for their capacity to shelter all students in a classroom. "You have a range of parents' opinions, but some of the more anxious ones were really keen that we had enough solid furniture for the kids to get under. So now we've got a lot of tables that children can get under because they have more room underneath to accommodate them", he affirmed.

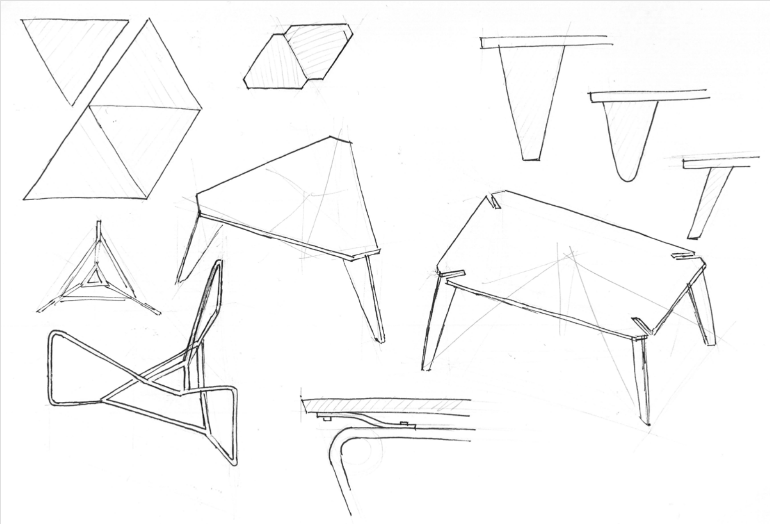
Key Findings:

The responses provided in this interview serve to reiterate the importance of creating a classroom table that, in an earthquake scenario, is inherently dependable as a means of providing safety for schoolchildren. While Avonhead School was spared any injuries to its students and any major damage to infrastructure and property during the earthquakes of September 2010 and February 2011, these events greatly heightened awareness of the role that classroom furniture can play in mitigating physical harm. The interviewee's recount of parents' insistence that renovated classrooms be fitted out with sufficiently strong and numerous tables and desks is one such example of this intensified level of concern that resulted from this series of devastating seismic events. It can be surmised that concerned parties, such as students, staff and parents alike, all have some level of cognizance related to the perceived effectiveness, or lack thereof, afforded by classroom furniture as the primary means of providing safety in an earthquake. Clearly, there needs to be minimization of the apparent disparity between the *Drop, Cover, Hold* procedure that is taught and actual capacity of a table or desk to meet a realistic standard of structural integrity that this procedure implies can be afforded by such an object. Not only this, but the importance of assertively implementing and maintaining a school-wide knowledge of the *Drop, Cover, Hold* procedure is made particularly evident. Following the 2010 earthquake, Avonhead School made concentrated efforts to update their earthquake responsiveness procedures to maximise efficiency and build confidence in students and staff to perform appropriately in such an event. While this increased resilience was tested and proven in a real situation 4 months later, the fact that these actions were only triggered by a catalytic event suggests that schools nationwide may neglect the importance of being fully prepared even before a seismic event strikes. It is essential that, amongst other procedures that are generally specific to individual schools, the *Drop, Cover, Hold* procedure in particular is fully understood and experienced by all members of a primary school.

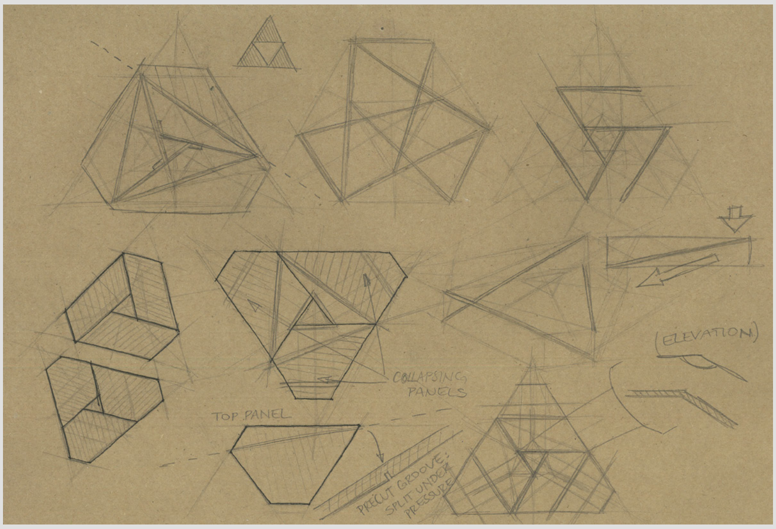
Design Criteria:

According to the research conducted, a set of design criteria applicable to the research question has been defined. Reflecting on many of the key considerations identified over the course of the research and in the review of literature, the criteria outlined below has been instrumental in directing the development of the design solution and, ultimately, the evaluation of the resolved design. Some specific considerations identified in the research are not explicitly outlined in the criteria below, but are nevertheless applicable within these four categories and subject to addressment in the design process.

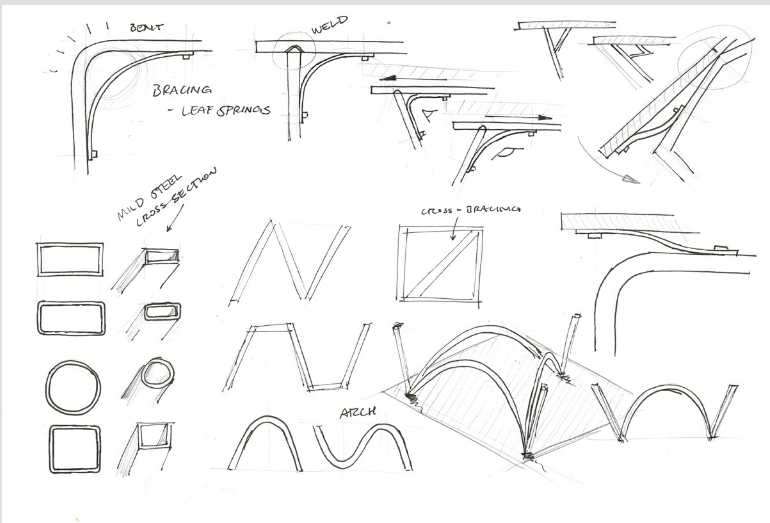
1. *Suitability for Primary School Classrooms*
   The design will be adaptable to changeable classroom layouts and different activities specific to this context. In this capacity, it will also be suitably durable and aesthetically appropriate for the environment and its users.
2. *Structural Integrity in Seismic Events*
   The earthquake-resistant design will effectively mitigate the physical threats posed by seismic events and be intuitively functional as a safety apparatus for children in this scenario. Furthermore, it will be able to withstand everyday rigours typical of a primary school classroom.
3. *Integration of an Earthquake Alert System*
   Correct user action consistent with established practice will be prompted via an alert system that is triggered in an earthquake.
4. *Facilitation of Earthquake Education*
   Reinforcement of established earthquake safety practice, specifically *Drop, Cover, Hold,* will be facilitated in the design's integration of features that educate users through ubiquitous graphic elements in day-to-day use.



2.1 Concept sketch #1: Form exploration



2.2 Concept sketch #2: Shape exploration

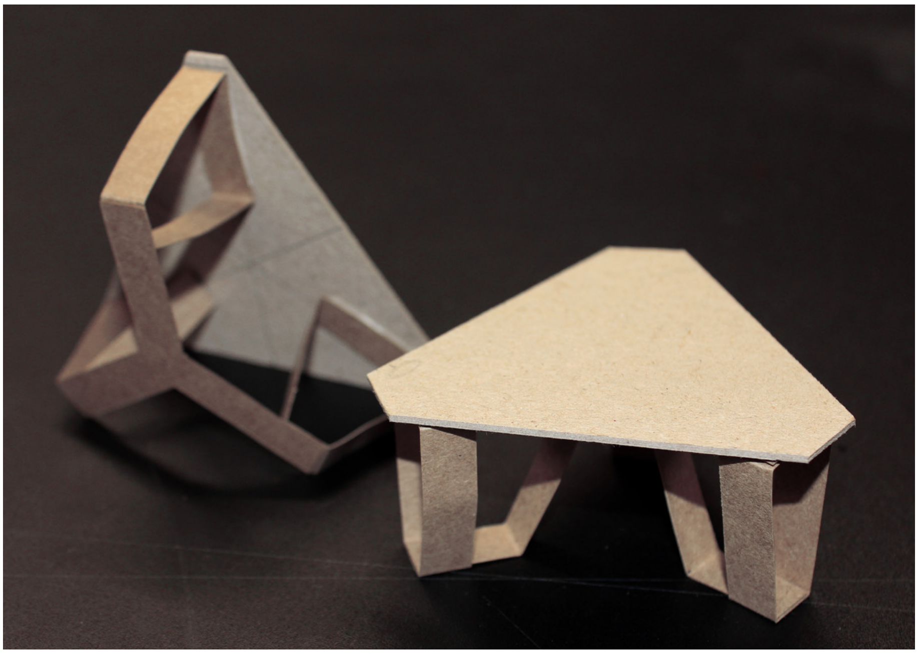


2.3 Concept sketch #3: Frame composition

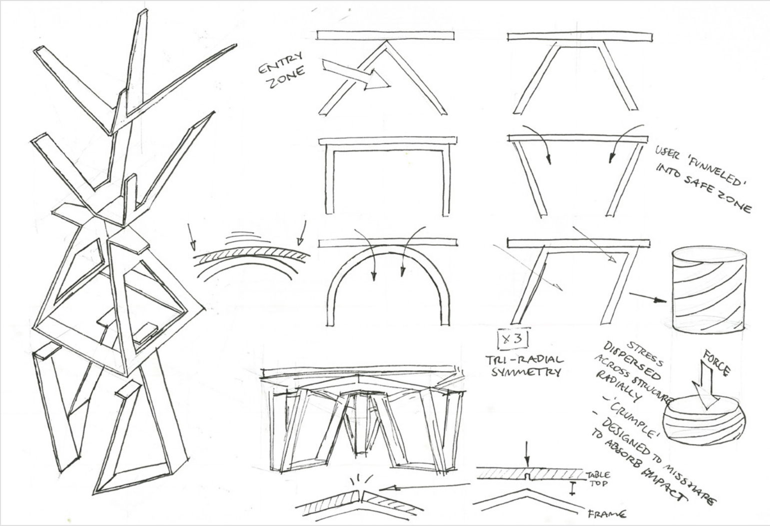
5 | Design Development

Form and Size

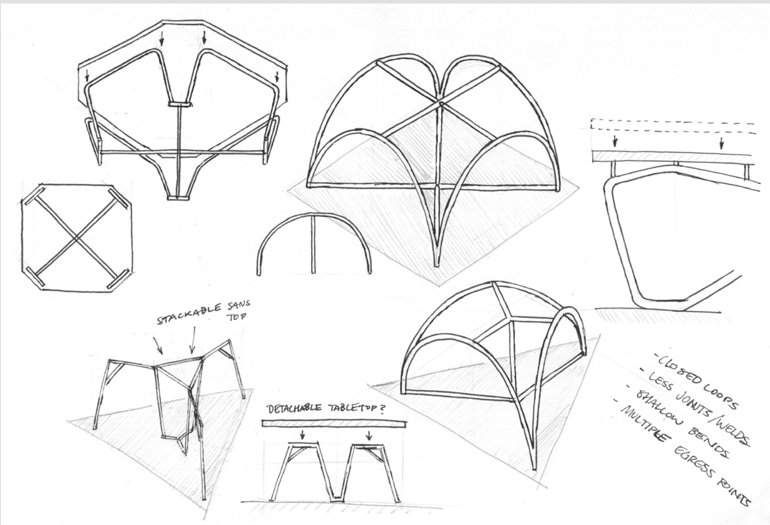
As research revealed an inclination towards dynamic and readily changeable furniture layouts in contemporary classrooms, the table's overall shape was identified as an element that was essential to its usability in this capacity. Addressment and resolution of this fundamental characteristic was decided upon as the first step for the process of conceptualization and idea generation. The design had to be one that lent itself to frequent movement around a room and constantly shifting user orientations. A table that dictated a single user orientation, whereby seated students have to face one particular direction, is no longer suitable nor convenient for primary school classrooms in New Zealand. The researcher's observations and the recommendations from teaching staff also established a tendency for tables and desks to be shifted together to make larger work areas or to accommodate larger groups of students. While conceptualization of the basic form explored many shapes, a triangular profile showed promise early in the process for its inherent capability to meet these requirements. Moreover, children's penchant for aesthetically radical and novel designs of classroom furniture further substantiated the validity of the form. Only limited examples of triangular classroom tables had been encountered throughout the research, and the shape was selected as much for its visual appeal as it was for its utilitarian benefits. Variances in size were contemplated alongside the investigations into shape. It was concluded from the research that children liked to sit in groups more often than not, be it due to the requirements of the task at hand or for the simple reason that most would seize on the opportunity to sit with friends during lessons. Room for six seated students was thus decided upon as sufficiently addressing the needs of the the typical primary school classroom.



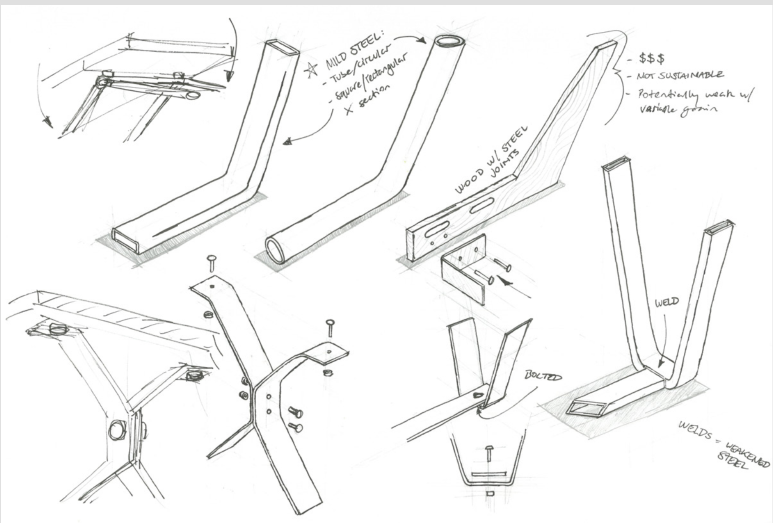
2.4
Small-scale cardboard concept models



3.1 Concept sketch #4: Frame composition



3.2 Concept sketch #5: Frame composition

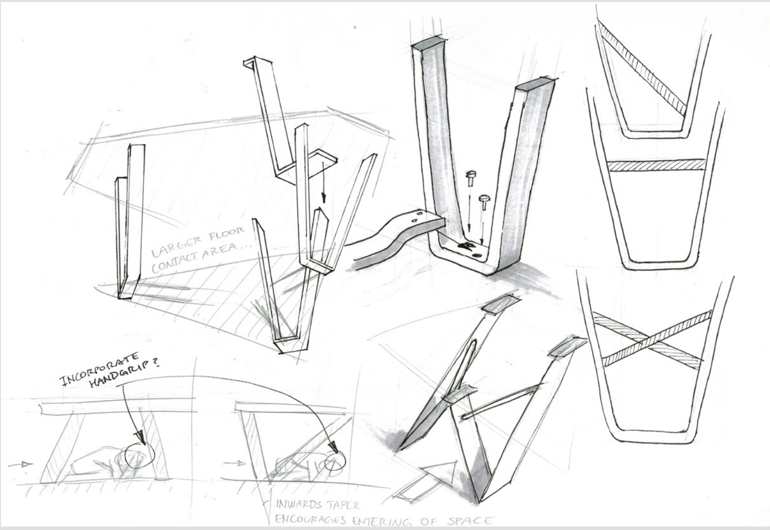


3.3 Concept sketch #6: Frame construction

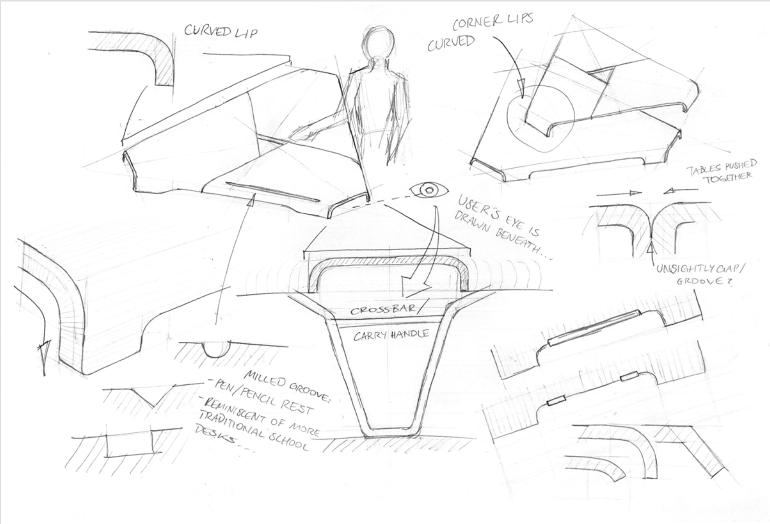
Ergonomics and General Usability

With children as the ultimate end user for the product, particular attention to the ergonomic requirements of children aged from 5 to 12 has been at the fore for every stage of the design process. The height of the tabletop from the ground has been set to be suitable for seated children. As such, the proportions of the table are too small for most adults, but perfect for children within the age range stipulated. There is, however, potential for the design to be scaled to be suitable for different users, such as teenagers at high schools, or even adults in workplace environments. Consistent review of allowances for active interaction between the students and the table resulted in innumerable adjustments and iterations of the table base in particular. The base was designed according to the facilitation of various functions, including allowing for adequate space for chairs and the legs of seated users. This was a crucial prerequisite not only in the capacity of day-to-day use, but also to ensure that, when utilized as a safety apparatus in an earthquake scenario, children are able to take shelter without anything impeding this action. Throughout the process, modifications to specific features of the base necessitated constant reiteration and compromise. For example, changes to the form of the table base or alterations to the shape of the tabletop often created new obstructions with positive or negative implications on to the user experience. Accordingly, one of the challenges faced in the design process was striking a balance between the needs identified for everyday use, and the specific needs identified for the mitigation of earthquake-related impacts.

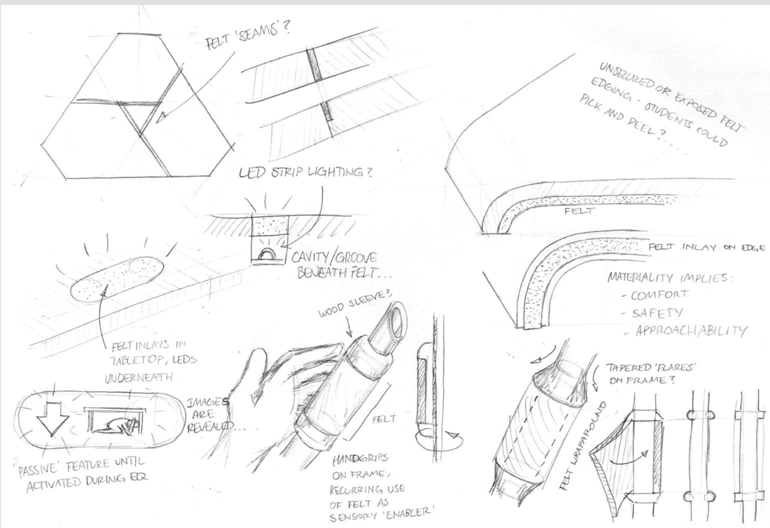
3.4
1:1 scale cardboard mock-up demonstrating basic size and shape



4.1 Concept sketch #7: Frame construction



4.2 Concept sketch #8: Tabletop detailing

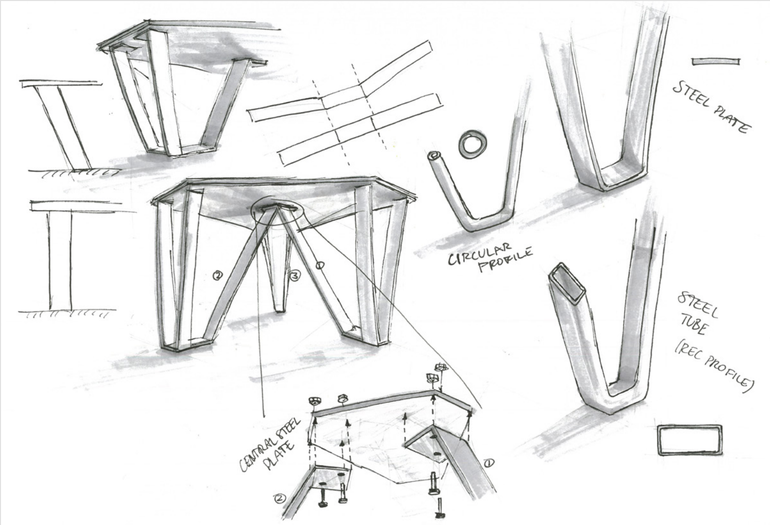


4.3 Concept sketch #9: Tactility exploration

Functionality and Aesthetics

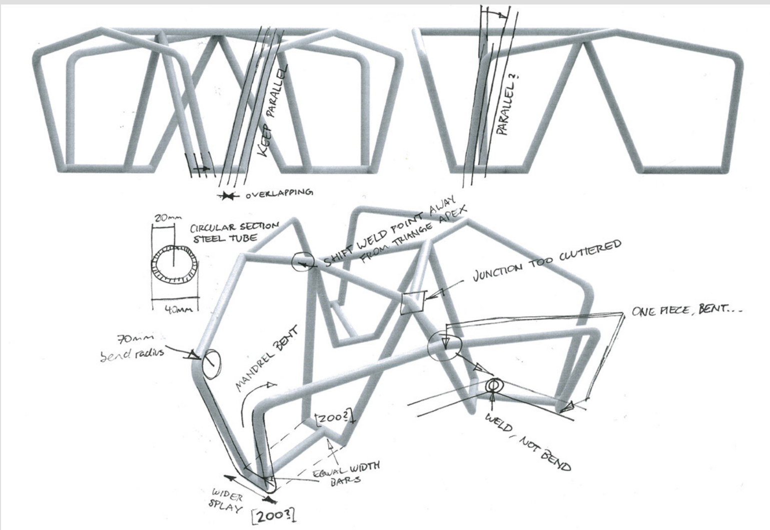
By reflecting on what was learned throughout the research process, simplicity was frequently recognized as the best approach to apply in addressing the concerns raised by participant feedback. Although the design of the table was ultimately comprised of a separate tabletop and base, the design processes applied to each of these two components were pursued in parallel to ensure visual and structural cohesion in the final product. The benefit of enabling a separate tabletop and base was that it could be taken apart for storage, movement and relocation, maintenance, or even replacement of individual components as necessary. Aesthetically, a dynamic yet balanced contrast of materials, form, and colour has been been pursued. The relationship of angular geometries counterbalanced with the soft rounding of corners was a consistent design strategy applied to the refinement of the overall aesthetic. The juxtaposition of the straight line and the curve was pursued from an early stage of the design process for its refined and appropriate insinuation of strength and steadfastness, as well as approachability and playfulness. In order to create a product wholly appropriate for its intended environment and its young users, constant consideration was given towards the semantic interpretation and emotional response embodied in visual language of the design features.

4.4
An early rendering showing the initial overall form prior to further refinement



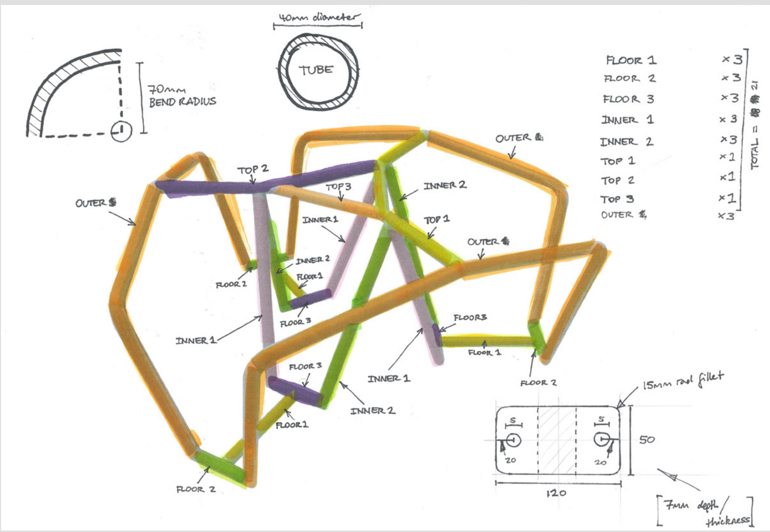
5.1

Concept sketch #10:
Frame construction



5.2

Concept sketch #11:
Frame composition

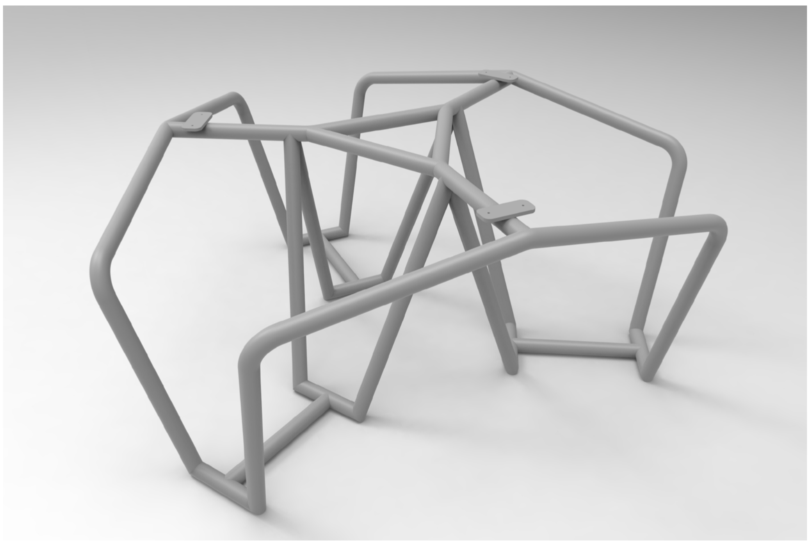


5.3

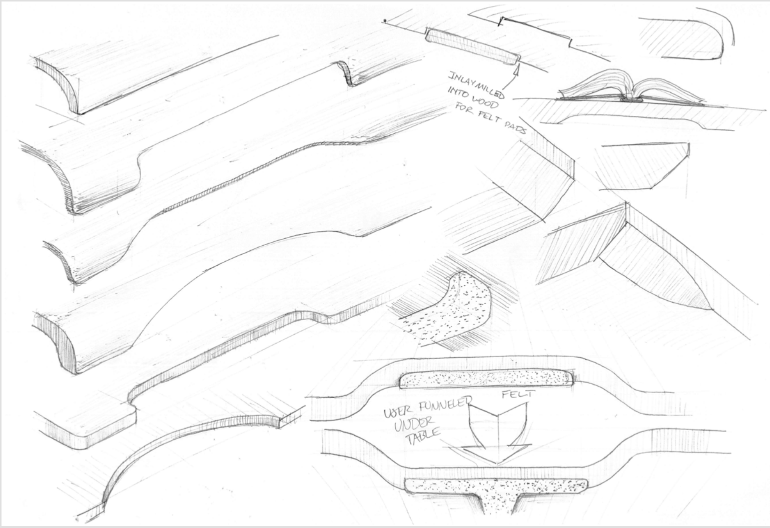
Concept sketch #12:
Frame composition

Table Base Design

The utilitarian function of the user experience was the most important factor throughout the development of the table base, necessitating constant review and alteration to ergonomic tolerances, weight, scale and methods of assembly. As the table had not one but two primary uses – as a regular classroom table and as a safety apparatus – particular attention was simultaneously paid to the requirements necessitated by the conditions of both scenarios. Characteristics such as materiality, form and construction had to be suitable for both sets of circumstances. In advance of committing to the steel tubular framework that was ultimately used in the final prototype, many concepts were developed incorporating the use of wood and aluminium, both separately and in combinations. Once the basic frame structure was established, further investigation into steel as an ideal material lead to iterations around the type of structure and methods most suitable to the design: the researcher contemplated the use of square and round tube and bar, laser-cut and waterjet-cut plating, welding, bolting and riveting. As the graspability of the bars was essential, the diameter, shape and placement of the bars was scrutinized and the tubular steel frame was determined to be best suited in meeting the design's intentions. All available possibilities, however, underwent consideration not only for their strength and aesthetic suitability, but also for cost-effectiveness and ease of manufacturing and assembly. Stackability of the table was also raised as potentially advantageous attribute by teachers in the research, and was considered throughout the design process. In order to facilitate efficient storage of the frames (when stacked without their tabletops), the layout of the framework underwent many revisions in effort to allow for this capability. In terms of the stability of the table base, multiple points of floor contact were deemed to be necessary in order to disperse any irregular impacts to the tabletop or to the base itself. By providing a larger footprint, the base is able to more evenly absorb and transfer the forces it may be subjected to from falling debris, as well as active children.

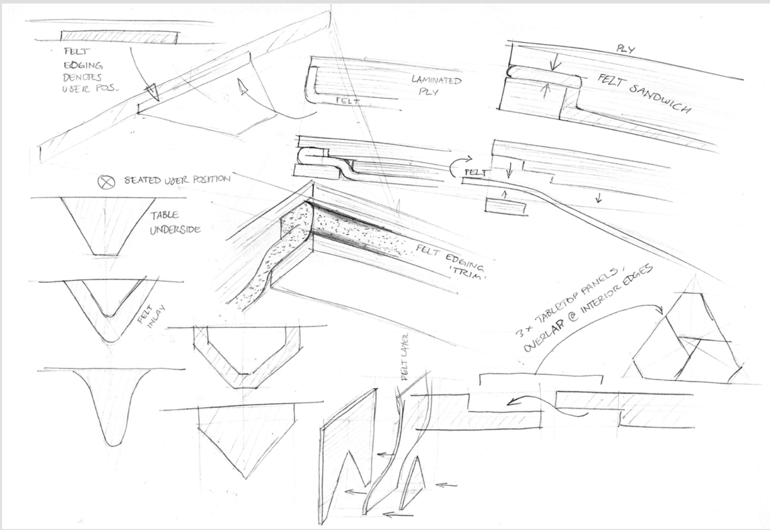


5.4
Render of finalized steel frame



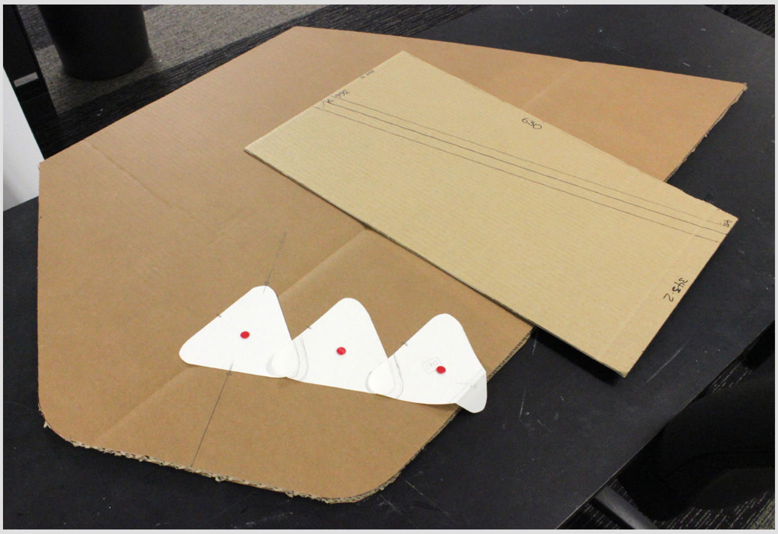
6.1

Concept sketch #13: Tabletop detailing and tactility exploration



6.2

Concept sketch #14: Tabletop construction and tactility exploration

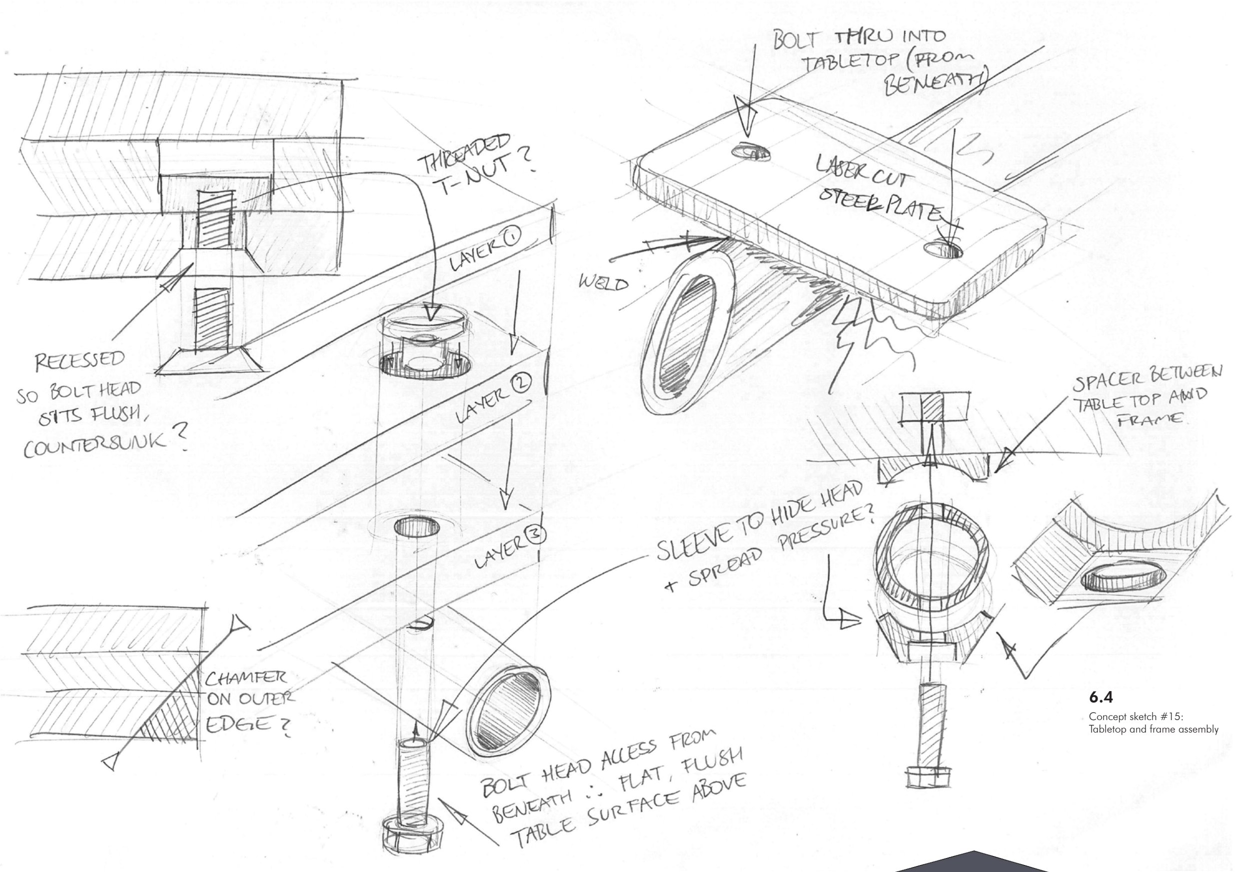


6.3

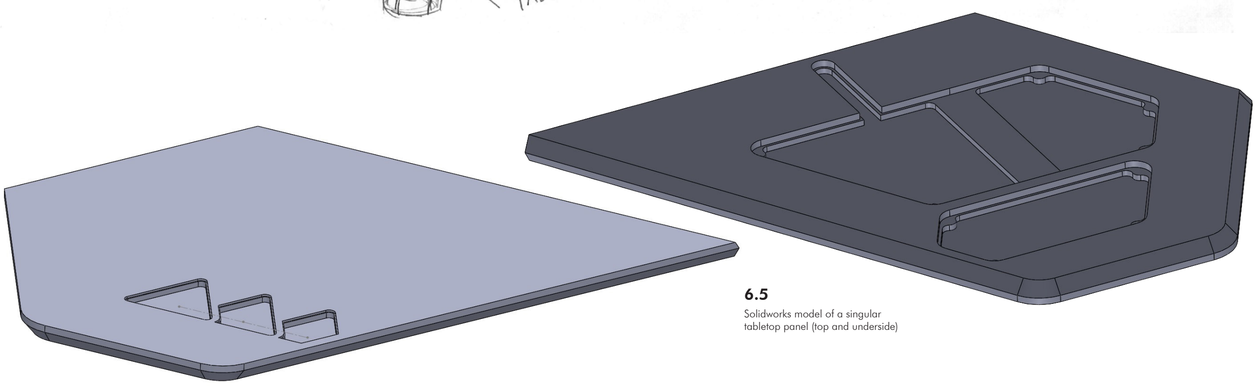
1:1 scale cardboard mock-up of singular tabletop panel with graphic 'triangles'

Tabletop Design

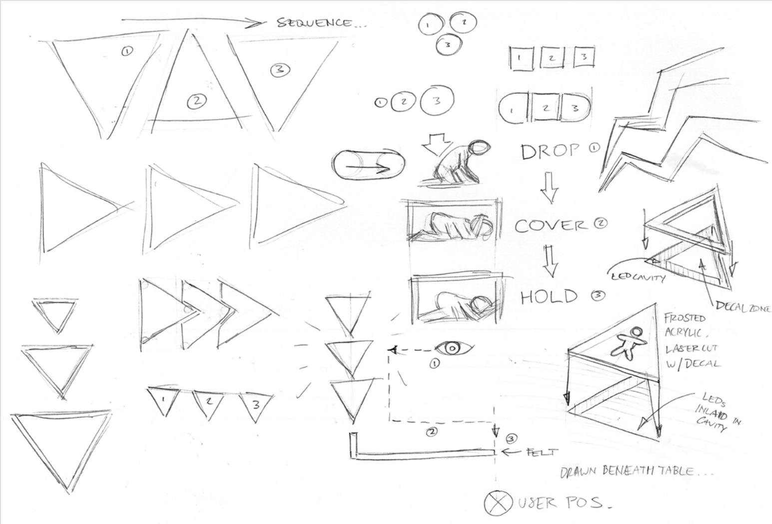
As the foremost feature to be seen and utilized by the user, the tabletop had to exemplify approachability and aptness for purpose. While many materials were considered, wood was selected early in the process for its inherent warmth and natural charm, as well as for its appropriate contextuality in New Zealand. A smooth and unbroken work surface was as much a requisite feature for efficient general usability as it also was for ease of cleaning and comfort. Again, the triangular shape of the tabletop lent itself well to this requirement, as the radial symmetry allows for an equally sized area for all six intended users. An expansive work area for the students was identified as a key consideration, as students were found to utilize table surfaces for a variety of activities, including writing, computer use, drawing and art-making, and reading.



6.4
Concept sketch #15:
Tabletop and frame assembly

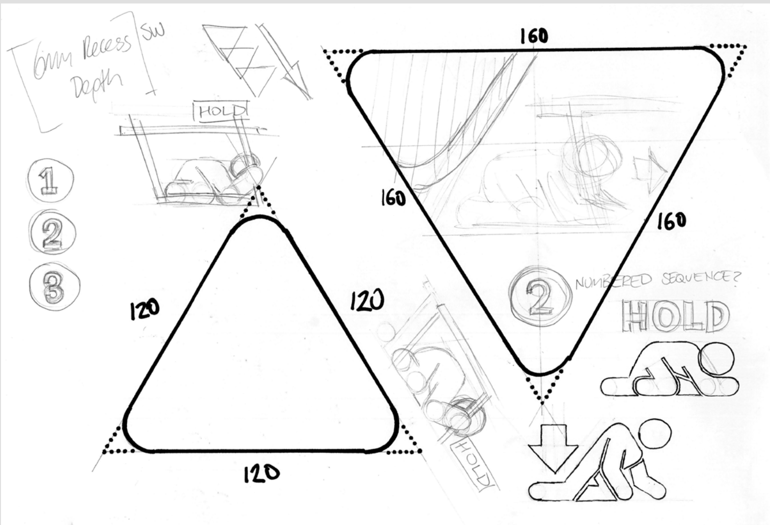


6.5
Solidworks model of a singular
tabletop panel (top and underside)



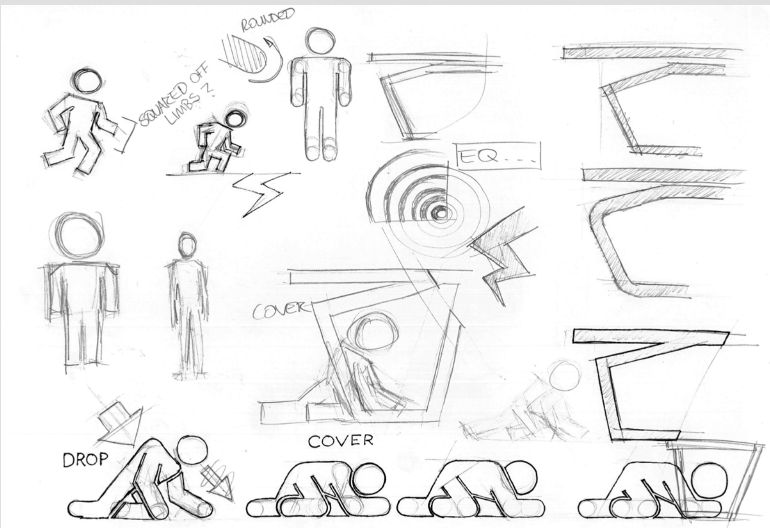
7.1

Concept sketch #16:
Alert system exploration



7.2

Concept sketch #17:
Graphic imagery exploration

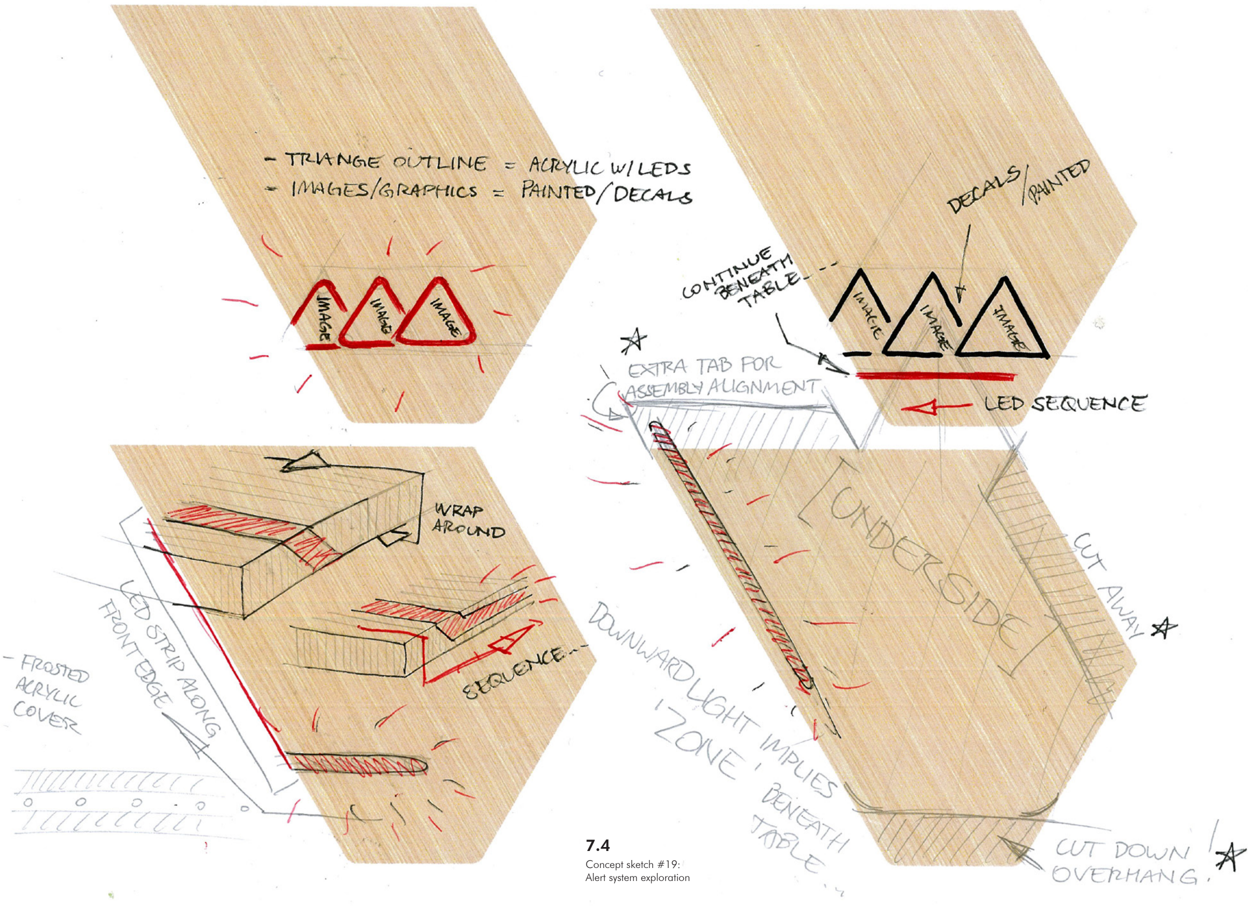


7.3

Concept sketch #19:
Graphic imagery exploration

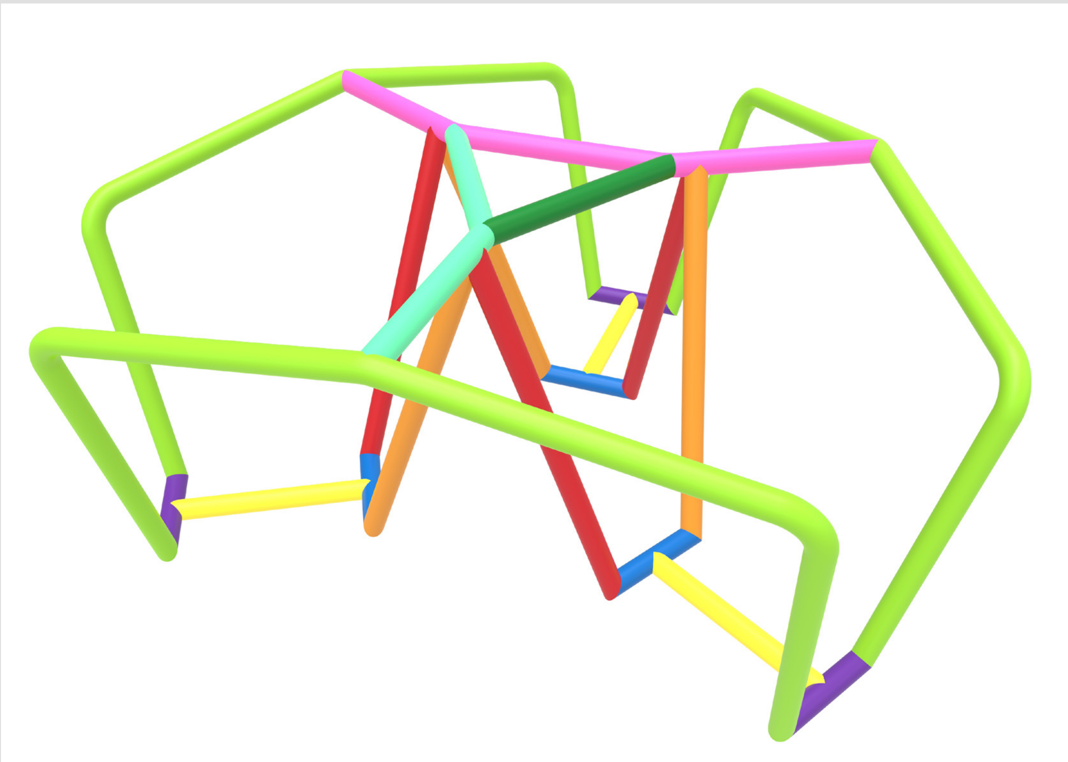
Educational Component and Alert System

Mitigation of the effects of seismic events was addressed via the two-pronged approach established in the design criteria: the facilitation of earthquake safety education, and the provision of a means of increased safety in actual earthquakes consistent with the procedures that are taught. The integration of technology was identified not only for its potential as a conspicuous and easily perceptible enabler for immediate action in a seismic event, but also as a point of difference as an innovative contemporary design solution. The use of LEDs was inspired by emergency lighting in passenger aircraft cabins, the likes of which line the aisles to define exit paths to be followed in emergencies. Hypothetically, the lights built into the tabletop will illuminate in a seismic event, alerting users of the threat and encouraging immediate action. The intention of this design element was not for the system to provide step-by-step instructions, but rather to supplement children's pre-established knowledge of *Drop, Cover, Hold*. The legibility and decipherability of graphic elements and imagery had to be suitable for the target audience, particularly as emergency scenarios necessitate absolute clarity in the impartment of instructions and in interpersonal communication. Equally valuable, however, is the instilling of resilience and empowerment that is enabled through student's everyday interactions with the table and the visual and structural security that it provides.



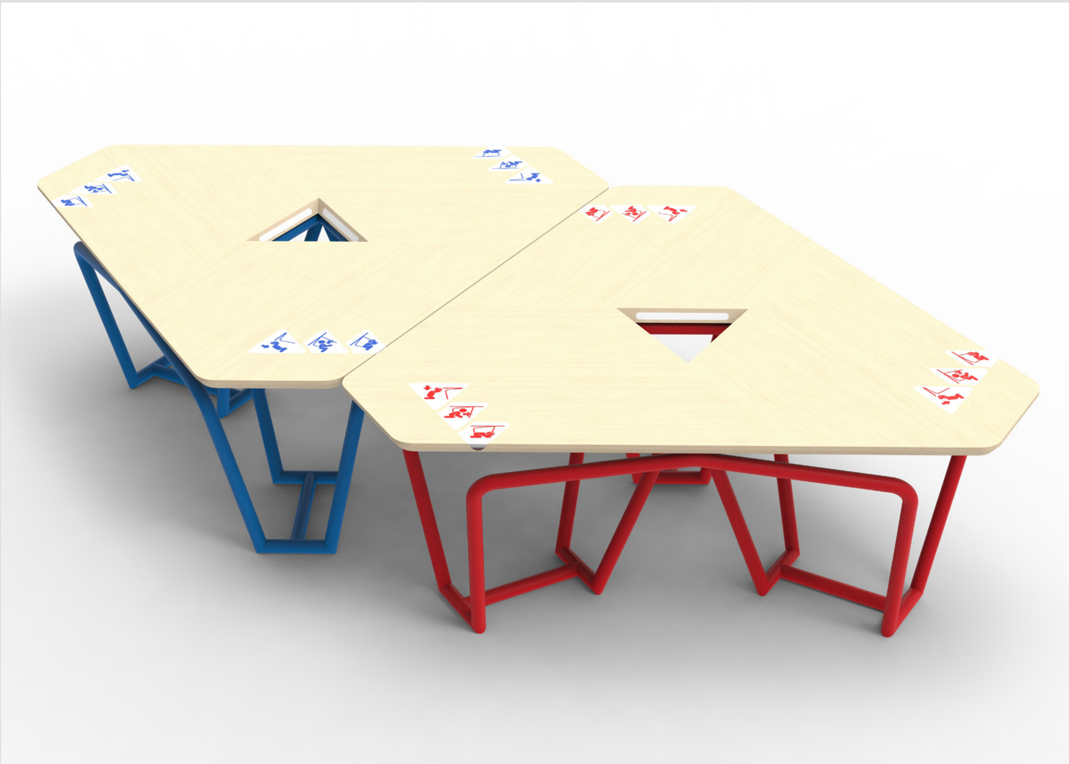
7.4
Concept sketch #19:
Alert system exploration

8.1
A basic preliminary render of the finalized design

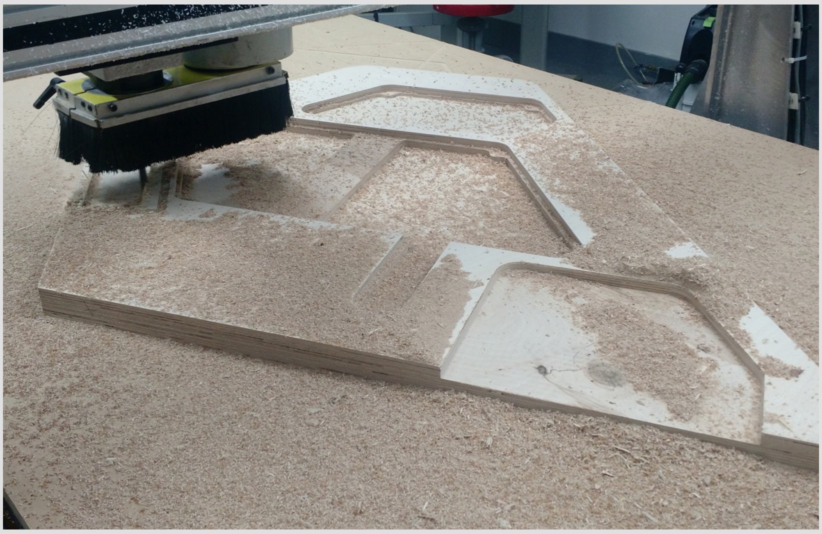


8.2
Render showing the frame's composition of seperate steel tube parts

8.3
Alternative blue colour scheme



8.4
Render showing two examples of the final design arranged to accomodate more users



9.1

CNC milling a tabletop panel from birch ply

9.2

The three tabletop panels arranged for assembly

9.3

Close-up of an outer cavity for the installation of LED lighting

6 | Final Prototype

Designed to successfully meet the criteria established after analysis of the research, the 'Earthquake-Resilient Classroom Table' represents a culmination of the extensive inquiry, conceptualization, and product development explored in the course of this project.

1. Suitability for Primary School Classrooms

The design will be adaptable to changeable classroom layouts and different activities specific to this context. In this capacity, it will also be suitably durable and aesthetically appropriate for the environment and its users:

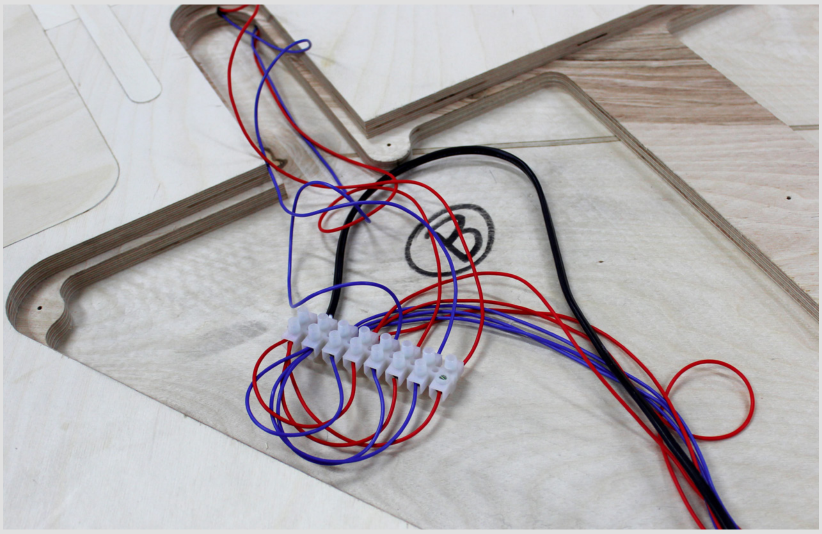
- The triangular shape of the table enables multiple configurations within the classroom, affording greater flexibility of furniture to suit various learning needs.
- The application of a clear varnish to the wood surface is ensures ease of cleaning and protection from wear and tear.
- In terms of aesthetics, the distinctive tabletop, with its three adjoining panels in a radial formation, was inspired by the earth's tectonic plates. In New Zealand schools, students are commonly taught about the science behind earthquakes to augment their learning of safety procedures and to promote the development of resilience. Likewise, the edges where the tabletop panels meet are bevelled at the join. This subtle visual feature has been included to represent seismic forces, and specifically 'convergent boundaries'.
- The table is well-crafted with a high attention to detail employed in the building process. This is important to the design as it reflects the structural integrity of the table, as well as providing an inviting and aesthetically pleasing object.
- The colour of the base, red, is suitably playful while also bearing an association to the visual language of emergency-related alerts.
- The central triangular hole in the tabletop has been included as means of keeping electrical cables safely out of the way when the table is used for computers and other electronic devices.

2. Structural Integrity in Seismic Events

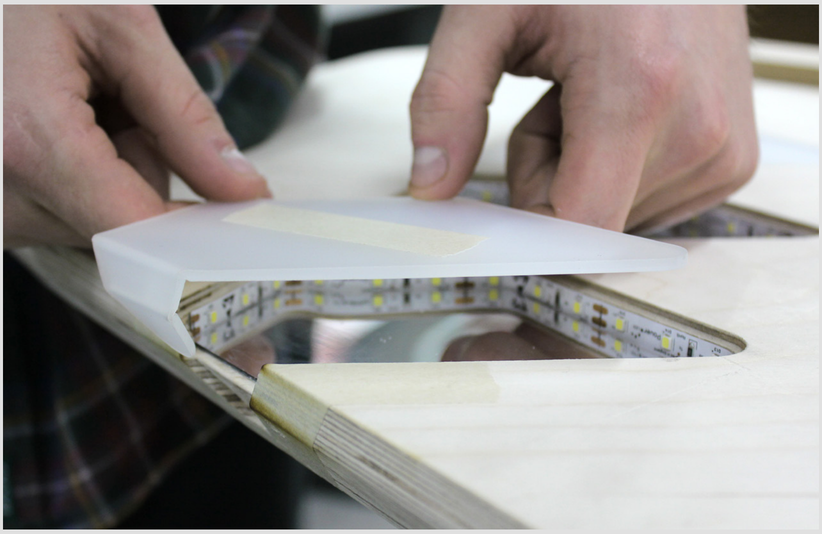
The earthquake-resistant design will effectively mitigate the physical threats posed by seismic events and be intuitively functional as a safety apparatus for children in this scenario. Furthermore, it will be able to withstand everyday rigours typical of a primary school classroom:

- The highly-resolved configuration of the frame is designed not only for robustness in everyday usage, but also for its ability to withstand impacts during major seismic events.
- The 35mm birch plywood used for the tabletop has been internally reinforced with rebar, carbon fibre cloth and epoxy to ensure flexibility and strength.
- When subjected to significant downwards impact, the cantilevered outer corners of the triangular tabletop have been designed to 'break' downwards onto the sturdy steel frame structure beneath. While they are suitably robust and can withstand the unsupported weight

10.1 Manually routing cavities for LED lights



10.2 Wiring for LED lighting



10.3 Testing the acrylic inserts for the lighting cavities of an adult, this 'crumple' function, inspired by modern motor vehicles, is intended to absorb and dissipate the forces of falling debris whilst ensuring the continued protection of users sheltering below.

3. Integration of an Earthquake Alert System

Correct user action consistent with established practice will be prompted via an alert system that is triggered in an earthquake.

- The pattern of small triangles on the outer corners of the tabletop and lights in the central hole comprise a visual alert system that is automatically triggered in a seismic event. Although the full-scale prototype does not entail the integration of sensor-based technology as speculated, the design is intended to be activated by either direct sensors or via a link to live data (such as with GeoNet).
- Likewise, in future iterations, the intention is to sequence the lights of the small triangles rhythmically to indicate directionality as a means to urge children beneath the table.
- The graphics on the pattern of small triangles clearly expresses the *Drop, Cover, Hold* procedure, which may function as a reminder during seismic events.

4. Facilitation of Earthquake Education

Reinforcement of established earthquake safety practice, specifically Drop, Cover, Hold, will be facilitated in the design's integration of features that educate users through ubiquitous graphic elements in day-to-day use:

- Perceived as a component that supports the daily education of students about earthquake safety procedures, the graphic triangular inserts on the tabletop function as subtle, non-obtrusive reminders of the importance of earthquake safety preparedness. The images integrated within the light-up triangles have been created to as synonamous as possible with existing material that communicates *Drop, Cover, Hold*. Designed to be simplistic and unanimously comprehensible, the images show a childlike figure carrying out the three stages of the procedure sequentially with a stylized representation of the Earthquake-Resilient Classroom Table. Easily visible on the top of the table, the imagery is intended to be a pervasive presence that students are constantly aware of. Consequently, the illumination of these images in an earthquake will immediately elicit full attention of the users, and by preconceived association of the images with action, the children can react rapidly.
- Together with the aforementioned alert system, this feature comprises what has been dubbed 'EASE' or the 'Earthquake Alert and Safety Education' component: a unique and innovative facilitator for fostering resilience and improving safety in seismic events.

11.1
Testing the assembly of the frame and tabletop

11.2
The powder-coated steel frame

11.3
Installing the acrylic graphic inserts

11.4
Molding acrylic inserts to fit their cavities

12.1
The completed prototype

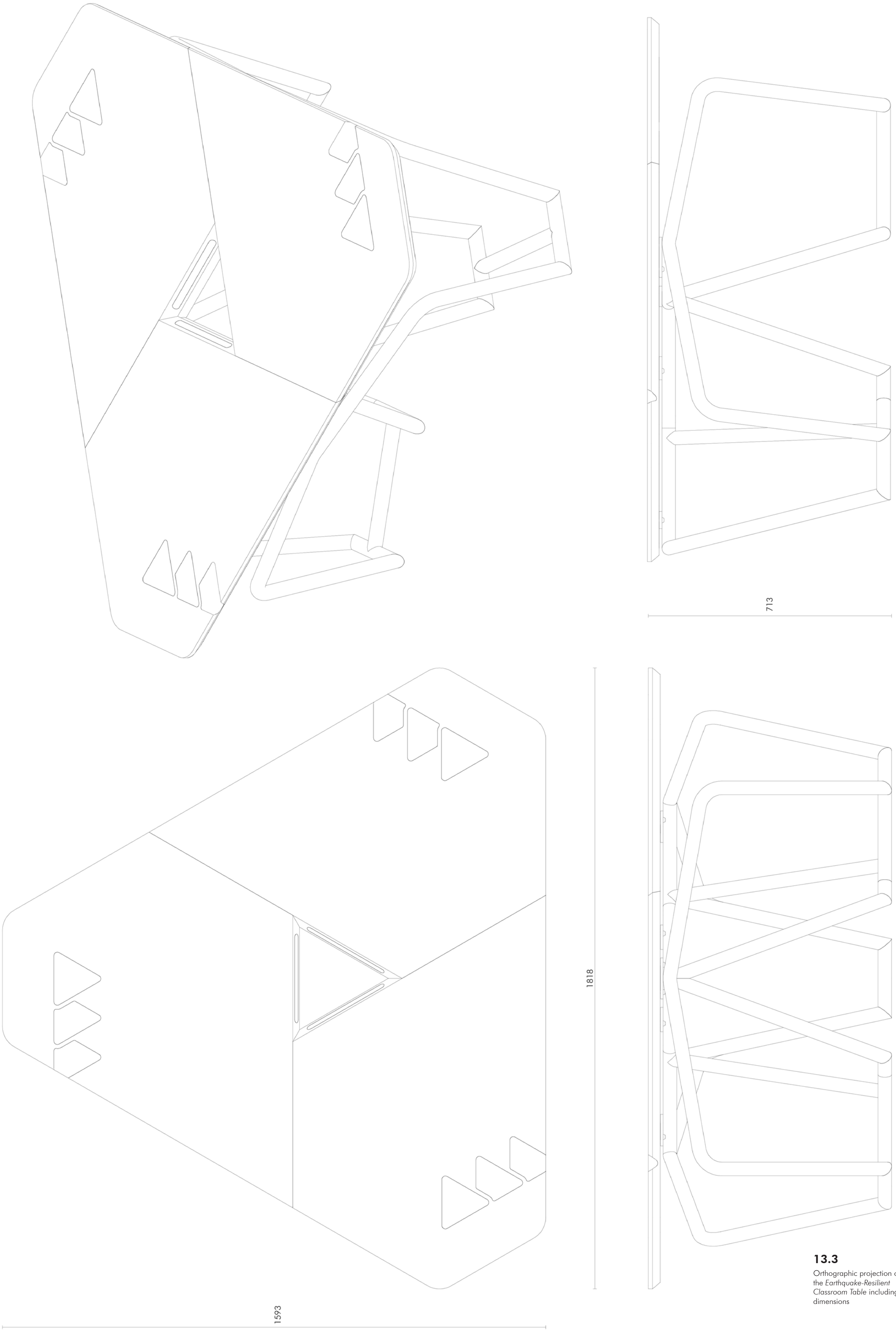
12.2
Illumination of the LED lighting

12.3
Close-up of the tabletop's central triangular hole

12.4
Detailing on the outer edges of the tabletop

13.1
The graphic inserts showing *Drop, Cover, Hold*

13.2
Close-up of the illuminated graphic inserts



13.3
Orthographic projection of the *Earthquake-Resilient Classroom Table* including dimensions

7 | User Evaluation

The full-scale prototype of the Earthquake-Resilient Classroom Table underwent essential user evaluation in a session at Te Aro School in Wellington. Based on the structure of the focus group session 8 months prior, it was again conducted in the school's library under the supervision of the researcher, and was audio recorded. The participants were five students (3 boys and 2 girls) from the original six that took part in the focus group, aged from 9 to 10 years old. Although the prototype had not yet been wired with lights and did not have the intended surface finishes, the students were able to provide useful feedback on the design.

To begin the session, the researcher asked the students to take a seat at the table and gave a brief explanation of the design process that had ensued in the eight months since initial focus group session. The table's features were explained one by one, and the students were provided with pictures of renders showing what the Earthquake-Resilient Classroom Table would look like when fully completed. They were then allowed five minutes to look around, sit at, and hide beneath the table in their own time, and were encouraged to ask any further questions they had regarding the design. Once their questions were satisfied and it was ascertained that they had a sufficient understanding of the prototype's features, they were again seated and asked three questions about their initial impressions of the design. As in the focus group session, the questions asked were deliberately simple and open-ended to allow for a natural progression of dialogue and the inclusion of new questions where appropriate. The discussion was constructive throughout and all questions were answered satisfactorily in the 30 minutes allotted for the session. The questions were (in order):

1. What are some things that you like about this table?
2. What are some things that you think could be improved on this table?
3. If you can imagine hiding underneath this table in an earthquake, what are your thoughts on the design? Are there parts of it that you think work well, or are there others that you think could be improved?

The feedback offered by the participating students regarding the table design was generally favourable. In particular, the students praised the shape and materiality applied to the design, as well as the integration of the EASE component. Even simple responses such as "I like it", "it's really cool" and "can we have some in our classroom?" served to validate their encouraging first impressions of the prototype.

As had been previously surmised in responses from the preliminary Focus Group session, the students did indeed respond favourably overall to a more radical table shape and frame design that was unlike anything seen in the existing tables in the school. Interestingly, this response was as much for the perceived utilitarian benefits as it was for the visual novelty. The triangular shape was identified immediately as an interesting and functional aspect that all students approved of. "It's a big triangle and I like triangles; it's a bit different", said one, while another affirmed the convenience of the shape for its ability to be moved together with multiple tables to accommodate larger groups of students. Relatedly, they were asked if they felt the 6-person table was a satisfactory size overall, and whether they would suggest making it larger or smaller. All students said that they liked the current size, however one said that the size could be even larger to allow more seated students. When the researcher reiterated that the tables could be arranged together for larger groups, he then recognised the possibility for the individual tables to be smaller and asked if it could indeed be downsized, mainly for ease of movement. This valid suggestion is a worthwhile consideration for future development of the design.

The students were quick to comment on the large work area provided to each student on the tabletop. One student even asked to borrow the researcher's paperwork to spread out to see how much usable space they had before them. Although it was explained at the start of the session to the students at the start of the session that the table was designed comfortably accommodate six working students, most agreed that up to nine could be seated around the outside if need be, and at least seven could hide underneath in an emergency. The "very clever" triangular hole in the table's centre was commended, especially for its capacity to keep computer cables out of the way and for the placement of the LED lights in its interior edges where they could be easily seen from around the outside. Also praised was the birch ply tabletop. As opposed to the melamine tabletops on the most of existing school tables, the students liked the look of the prototype's natural wood grain and the 'nice feeling' of the smooth surface. When asked about their thoughts on the table's steel framework, one student remarked that he believed it was "built very well' and that "the bars are all thick and strong". There was a unanimous perception amongst the students that the whole table was robust and able to withstand the rigours of everyday use in the classroom.

The EASE component elicited a lot of intrigue and a great number of questions. The students explained to the researcher that they had never seen or heard of anything like it before, and that it was a 'cool' feature. The also believed that it could be effective not only as a warning system in an actual earthquake scenario, but for practice drills too. The initial assumption of the students was that the lighting system would be triggered by any shaking movement to the table, but two students questioned the effectiveness of such a system. They explained that many of their peers are restless and would often move or shake tables in everyday use, and they were concerned that the alert might be inadvertently triggered. The researcher discussed this concern with the students and explained that, in the future realisation of the design, the sensors would ultimately be electronically connected to a shared network that could correctly differentiate various types of movements. One student remarked that he liked the inclusion of this lighting system because "[it] can tell us [if] there's an actual earthquake or if it's just the kids shaking the table." While the affirmative assessment of these students regarding the EASE component is very encouraging, it should be mentioned that this is not necessarily indicative of its actual efficacy. Positive preliminary feedback aside, this feature cannot be properly evaluated within the scope of this research and would require further development and testing to assure its efficacy.

When asked to identify aspects of the prototype that could be improved in future, the students had comparatively less to say. Nevertheless, vandalism of the tables was raised as a potential issue when one student asked "what if kids play with it?" Her peer affirmed that some children have tendencies to scratch table surfaces or to pick at loose coverings and protrusions. Another then told the researcher to "make sure the lights (when installed) are covered really well and [that] they're not sticking up so they can't be pulled off." The same student also identified the wooden tabletop as being more susceptible to vandalism and damage, stating that "wood is easy to scratch so maybe kids will put lots of marks and scratches on it." Although the prototype experienced by the students did not include the anticipated surface finishes, the researcher offered that the plywood surface is envisioned to be protected with a durable clear coating that would inhibit damage to the wood surface. The five student participants were asked to attempt to lift and move the table a few metres as they might when rearranging the furniture in a classroom. Although they had no trouble lifting it in place, they remarked that its weight made it hard to move around the room easily. Moreover, they said that younger children would have even greater difficulty doing so. Conversely, they did say that they felt the weight of the table would help to keep it firmly in-place in an earthquake, and that they felt reassurance in this characteristic of the prototype. As they had previously expressed concern that the light and flimsy tables in their classroom could move across the floor in an earthquake. Accordingly, the awkwardness of moving the prototype was mutually decided upon as a tolerable compromise when considering the design benefits. Without making drastic concessions to the perceived steadiness of the table, there is room here for the materiality of the design to be revised to make for a lighter object.

The possibility for the table to be downscaled, as raised by a student earlier in the session, has merit in this regard too.

Another noteworthy observation was the lack of safety afforded by the hole in the centre of the tabletop. Even before the students were given the opportunity to try hiding beneath the table, one identified and questioned this potential problem. “What if somebody is hiding underneath in the middle and something falls in the hole?” he asked, adding “maybe you could put something over it.” When the students were told to take cover underneath as they would in an earthquake, he climbed through the frame into the centre section as if to prove his point. This section of the frame was not intended to be hidden within, and thus it was not assumed that children would immediately think to climb into it. When the other students were asked if it had occurred to them to do so, they said that they would if they wanted to make more room on the outer edges for others trying to shelter beneath the table. In determining the overall worth of the inclusion of the central hole in the design, its functionality must be contemplated against this unforeseen and possibly dangerous design flaw. There is room for this element of the table too to be redesigned in order to mitigate or even eliminate the potential risk of debris falling through the central hole. In regards to the table base, one student said that there could be slightly more room between the frame’s outermost and innermost vertical bars to allow for more room to crawl from section to section if need be. Again, further reiteration to the base’s design could easily resolve this.

The student who had remarked that the base was ‘built very well’ was asked if he believed it would be stronger than a normal table’s legs and/or frame in an earthquake. “Definitely. It’s not going to break and it doesn’t wobble,” he replied whilst trying to shake the frame vigorously. Two other students then joined in and they proceeded to shake the frame together. Similar behaviour had been noticed by the researcher in the project’s earlier research, where students were frequently seen to physically shake their tables in an attempt to simulate earthquakes in practice scenarios, or to demonstrate their perception of weak construction. Despite the combined efforts of the three students, their shaking of the prototype did not result in a lot of movement. Their point proven, all students expressed substantiated confidence in the frame’s sturdiness. The base of the table prototype was complemented further by the students when they were asked to perform the Drop, Cover, Hold procedure in a test earthquake drill. “[This table] is good because on a normal table there are only four legs to hold but here there are like 10 parts to hold, or even way more,” said one, while the others all affirmed that there was no shortage of bars to hold and that their diameter was comfortable for gripping. One student, however, complained that she sometimes hit her head on the steel bars around the edge of the tabletop when sitting almost upright, but decided that the problem was redundant when adopting the proper Drop, Cover, Hold position. When asked if she felt that these outer bars could possibly be a hindrance to getting beneath the table in an emergency she determined that they would not cause any issue. Of the design flaws identified by the participants, one student raised concern about the outer corners of the triangular tabletop where the material is designed to break downwards when subjected to heavy impact. Despite the fact that he was sitting upright and not in a protective body position when he raised his concern, he asked "what if somebody if something lands on [the corner] and it bends down? What would happen if your head was up here and not down low?" The researcher explained that, in an actual earthquake, children's heads should be kept low if they correctly adhere to *Drop, Cover, Hold* procedure, but the student was quick to say that some might not do that. He also then realised that if students hold onto the upper outermost bars, their hands could potentially be crushed when the corner of the table gives way and comes to rest on them. As there is no discernible means of discouraging students from holding on to this particular section of the frame, this flaw, which had not previously been given much attention in the design process, is unquestionably in need of addressment in potential future development of the design.

8 | Conclusion

As one of the most seismically active regions in the world, the need to protect, educate, and inspire resilience in New Zealanders of all ages is essential. In a geographic location where the very real threat of earthquakes is confronted daily with potentially catastrophic effect, the importance of fostering resilience in our everyday lives, pre-, during and post-disaster, is particularly relevant in securing the well-being of our nation's children. The research outlined in this thesis challenges the ability of design to meet these extraordinary needs, the result of which is a highly valuable and innovative prototype in the form of the Earthquake-Resilient Classroom Table. The central research question - *How might furniture effectively mitigate the physical threat of earthquakes and aid in the education of schoolchildren about earthquake preparedness within primary schools in New Zealand?* - has required the interrogation of existing furniture typologies in primary school settings as well as the procedures taught to children in this context. Although the research has identified many strengths in the current system, a great number of potentials have also been revealed. As furniture takes on the inherent role of 'shelter' during seismic events, the ability of furniture to be designed to better meet this demand deserves further consideration and development.

The investigation into an extensive range of ideas and concepts has resulted in a product that integrates child psychology, primary school education, structural engineering, and various pre-established and contemporary, technology-centred design practices. This research has hinged upon a Research through Design methodological approach that synthesises multiple disciplines and methods, and that prioritises the design process as a tool for expanding, creating, and communicating knowledge. Within this process of research, a set of criteria has been identified to guide and evaluate the design of tables that aim to mitigate the physical threat of earthquakes and aid in the education of schoolchildren about earthquake preparedness within primary schools:

1. Suitability for primary school classrooms, whereby the table is adaptable and appropriate for this context in terms of form, aesthetics, construction and usability.
2. Structural Integrity in seismic events to provide schoolchildren with increased physical safety when they carry out the Drop, Cover, Hold procedure beneath the table.
3. Integration of an earthquake alert system that is automatically triggered in an earthquake to prompt correct user action consistent with established practice.
4. Facilitation of earthquake education through the integration of features that educate users in established emergency procedure through ubiquitous graphic elements in day-to-day use.

In looking beyond the scope of this thesis and its design output, the hope is that this criteria and supporting research will function to inspire future developments in the design and construction of classroom furniture, especially as they relate to the facilitation of earthquake-related safety in New Zealand. Future development will ideally improve upon the conceptual protoype and address the shortcomings identified in the user evaluation. Possible areas of future development include enhancements to the manufacturability and assembly sequence applied to the table to ensure that it is affordable, ecologically sound, and efficiently produced. Ideally this design will undergo the development necessary to make it viable for mass production and distribution throughout New Zealand schools, thereby enabling the development of earthquake resilience and the provision of enhanced protection for schoolchildren. Moreover, some of the design's more complex features, particularly the EASE component, would benefit from the development of more streamlined systems of assembly, the integration of an efficient power source, and the application of advanced seismic sensors and data connectivity. Beyond the specific context applied to this project, the ideas presented in this research have universal applicability and may be adapted to suit the needs of children and adults globally. Accordingly, the goal is that this research is disseminated to support this expansion of these ideas in the disciplines of design and disaster management.

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