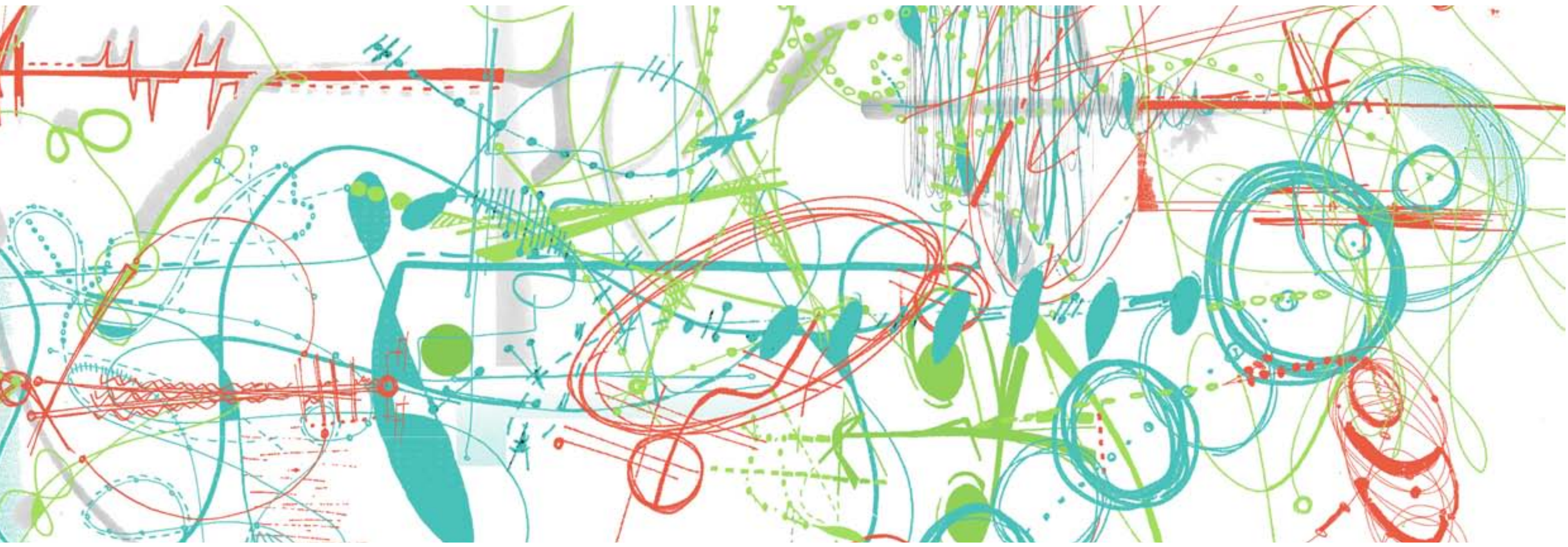
FLEXI-ED

BY

Megan Keats



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ABSTRACT >

As cities evolve, change and grow, the need and desire for adaptable architecture becomes evident across the nation. Architecture needs to undertake techniques that are flexible in order to adapt and align with the development of future generations in New Zealand.

The Education industry is a primary example of a sector which requires flexibility within both classroom architectural form and interior configuration. This is a resultant of the recently updated Ministry of Education requirements; which state that every new classroom built or renovated nationwide, must implement the MoE classroom design standards for Innovative Learning Environments.

ILE teaching spaces are configured as an open plan interior, supporting flexibility in classroom arrangement and teaching techniques. ILE classrooms are capable of evolving and adapting as educational practices evolve and change, allowing schools to remain modern and future focused.

As part of this movement to ILE, the Ministry of Education has also recently made an attempt to improve the quality of temporary classrooms. This has been done by looking into the initiation of a programme that utilizes relocatable classroom buildings. Relocatable classrooms have been selected for multiple reasons, primarily flexibility. Flexibility is key for a school environment as it allows the school to actively respond to fluctuating school rolls. It is anticipated that the programme will provide a faster delivery process with a standardised design that allows the classrooms to be relocated from one school to another with relative ease.

Following the devastating February 2011 earthquake the Greater Christchurch Region, the Education sector is in the midst of the Canterbury Schools Rebuild Programme. As a repercussion of this natural disaster, the majority of Christchurch schools have redevelopment or rebuild projects in progress, with preliminary design phases already in action for a small group of select schools regarded as high priority.

The primary funding for these projects are sourced from insurance money, implementing tight budget restrictions, affecting the architectural design, quality and speed of the construction and repair works. The available funding limits the affordable classroom options to basic teaching spaces that have been stripped back to simple architectural forms, dictating not only the re-design, but also how our future generations will learn. Thus causing the development of the new student-led learning ILE concept to become controlled by existing construction techniques and the Rebuild Programmes budget restrictions.

This thesis focuses on the future proofing of New Zealand schools by providing an affordable and time efficient alternative option to the current static, traditional construction, an option that has the ability to cater to the unpredictable fluctuating school rolls across the nation.

This has been done by developing a prefabricated system for standalone classroom blocks. These blocks have the ability to be relocated between different school sites, dynamically catering to the unpredictable school roll numbers experienced across New Zealand. This site flexibility is reflected with the interior flexibility in the classrooms, enhancing the internal teaching space composition and challenges the existing design standards set by the Ministry of Education for Innovative Learning Environments. This system is called “Flexi-Ed”.

Flexibility has been a key driver for this thesis, as the prefabricated structure is have to be flexible in three ways; first in the sense of being easy to assemble and disassemble. Second by offering flexible interior learning environments and thirdly the joints of the structure are designed with the ability to be flexible in order to cope with seismic activity. These three principles will provide schools with long term flexibility, minimal on-site interruption and heighten the standard of ILE across the nation

I strive to provide schools with long term flexibility and minimal site interruption, whilst heightening the standard of Innovative Learning Environments across New Zealand.

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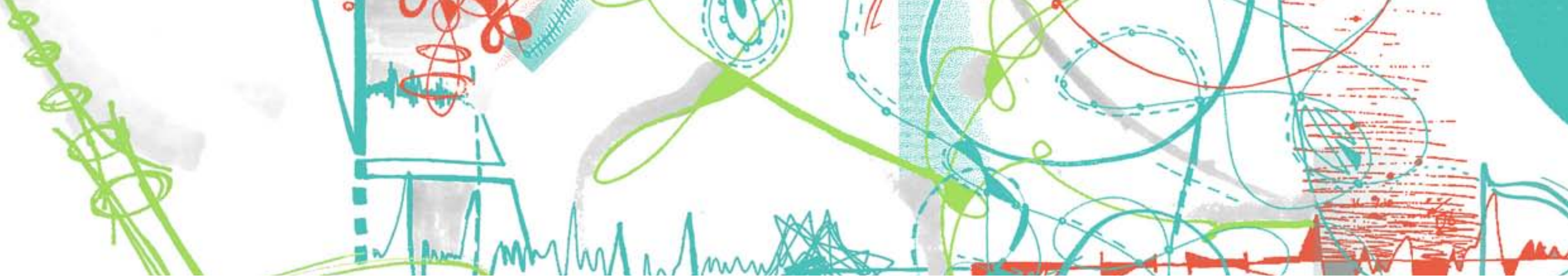

7.0 Future Developments >

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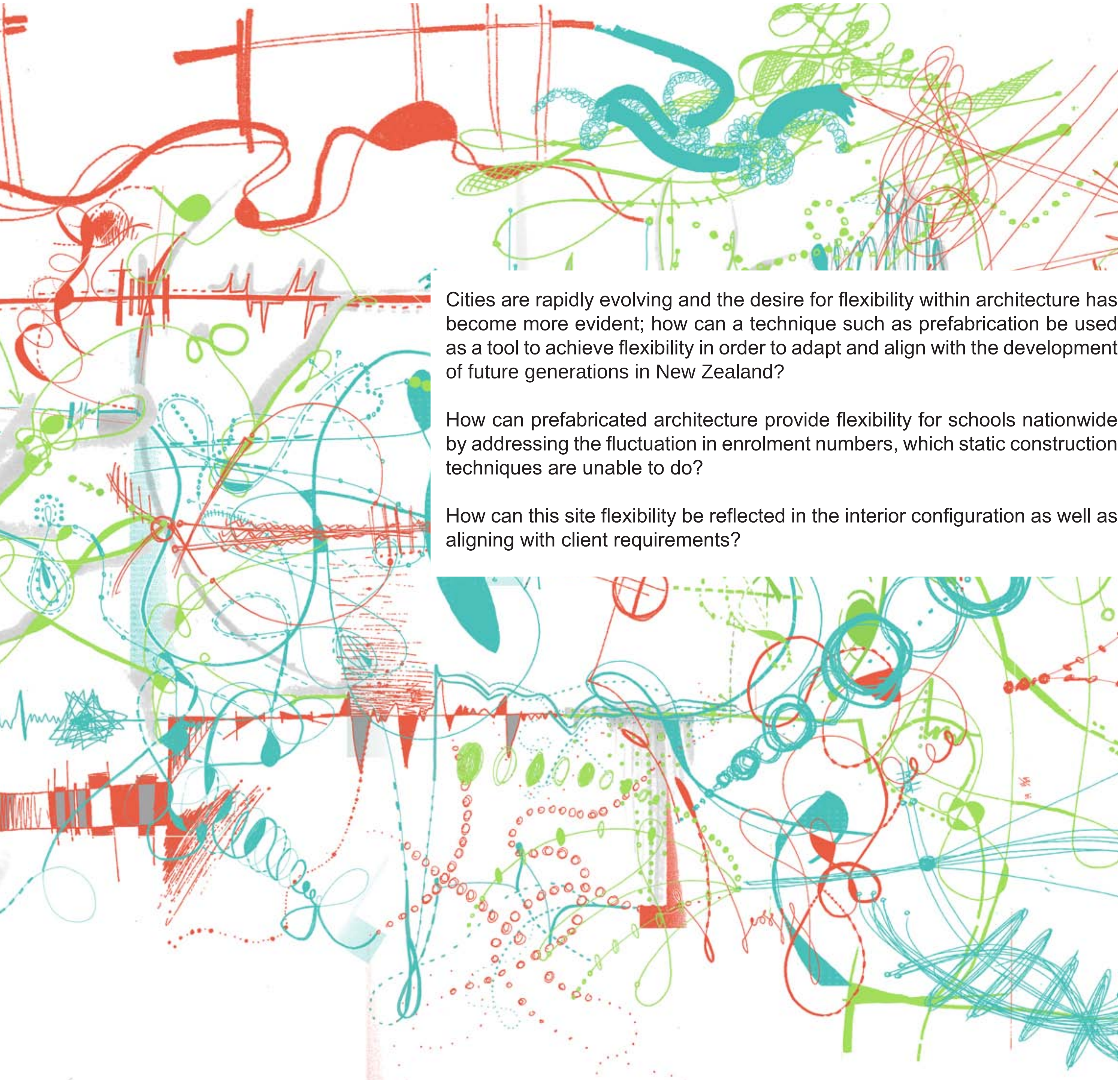
"Education is the most powerful weapon
you can use to change the World."
- Nelson Mandela

1.0 INTRODUCTION >

1.1 THESIS QUESTION >



Cities are rapidly evolving and the desire for flexibility within architecture has become more evident; how can a technique such as prefabrication be used as a tool to achieve flexibility in order to adapt and align with the development of future generations in New Zealand?

How can prefabricated architecture provide flexibility for schools nationwide by addressing the fluctuation in enrolment numbers, which static construction techniques are unable to do?

How can this site flexibility be reflected in the interior configuration as well as aligning with client requirements?

Fig 1.1. Thesis Mind Map

1.2 THESIS APPROACH >

1.2.1 Thesis Argument

Flexi-Ed will utilize prefabrication as a tool to demonstrate that innovative learning environments, fluctuating school rolls and unpredictable seismic activity can be catered to by one system.

Prefabrication can be the answer to the dynamic geographic and demographic context due to the construction nature having the ability to be implemented on to a school site, occupied, and relocated with relative ease. The ever changing school roll is reflected in the flexible construction of prefabrication and provides the opportunity to address a school site as the enrolment numbers differ throughout the schools' life time in New Zealand.

Due to the majority of prefabrication construction works being undertaken off-site, the time period spent on-site will be minimised when erecting additional standalone classrooms for schools. By using a construction technique that contains a predictable time frame, on-site disruption to daily school routine will be minimised as well as limiting hazards to the students and staff on campus.

As well as minimised construction time, on-site and rapid erection for increased roll numbers, prefabrication has the ability to work just as efficiently in the opposing situation when additional standalone classrooms are no longer required. When student numbers decrease, specifically designed prefab structures allow for on-site removal and relocation to occur, just as effectively and efficiently as on-site erection; thus encouraging the recycling of parts for school sites in need of additional teaching spaces.

Current products on the market that attempt to cater to fluctuations in school numbers are designed as temporary structures, using low budget finishes and materials to reduce costs for potential clients. However these 'temporary' structures often become permanent features within a school site, resulting in numerous teaching spaces across the country that are inadequately equipped for long term teaching purposes. Flexi-Ed will demonstrate a design that has the benefits of a relocatable classroom, whilst still providing a standard of design and construction that can withstand the life time of a school if required.

Fig 1.2. West side of Manchester Street, Christchurch from Lichfield Street Intersection

1.2.2 Thesis Project

In order to produce a potential alternative product for schools nationwide, Flexi-Ed will test the opportunities of prefabrication in relation to the provision of standalone relocatable classrooms within the framework of the Ministry of Education's Innovative Learning Environment design guidelines.

The Canterbury Schools Rebuild Programme will be utilized as an assessment tool to assess the site, interior and seismic flexibility.

1.2.3 Project Scope

Flexi-Ed will focus on the design and development of single storey, relocatable standalone classroom blocks for New Zealand schools, using the Canterbury Schools Rebuild Programme as a case study to test the design.

The key areas of focus will be the prefabricated construction system and the interior learning environment which this system will collectively cater for.

1.2.4 Thesis Structure

This thesis will be structured in two sections. The first will analyse existing precedents and products on the market. This was done via site observations, user surveys and product research, to provide an understanding and insight into the existing opportunities and constraints available across New Zealand.

The second section will explore the possibilities that prefabrication can provide whilst taking into consideration the knowledge gained during section one. This was done through physical, digital and analogue exploration, supported with constant analysis and reflection to challenge the design parameters. This structure allows for continual critical reflection in order to produce a successful alternative transportable product for the education industry.

"The whole purpose of education is to turn mirrors into windows."
- Sydney J.Harris

2.0 BACKGROUND >

2.1 MINISTRY OF EDUCATION >

2.1.1 Background

Demographic projections in the 'NZ School Property Strategy Guide' indicate that student numbers in both primary and secondary schools nationwide are expected to rise to 50,000 by 2020, estimating that an additional 2,500 teaching spaces will be needed in New Zealand within five years.[1]

Currently the Ministry of Education (MoE) proposes to address the estimated enrolment growth by encouraging nearby schools to merge together or retire old buildings on-site in exchange for modern facilities. In contrast the MoE roll decrease plan proposes that schools will be instructed to remove buildings that are no longer economical to maintain or the possibility of merging schools are likely options.[2] The process outlined above demonstrates that although MoE have predicted overall growth, some schools will see a decrease, particularly in areas severely affected by the earthquakes, proving that there is a need for flexibility in schools across the country.

2.1.2 Canterbury Schools Rebuild

Canterbury is currently undergoing a post-earthquake rebuild phase where the region is experiencing large fluctuations in population numbers. Prior to the February 2011 earthquake, Christchurch City had an urban population of approximately 400,000. However as the aftershocks have continued, a substantial number of residents moved away to regain the reassurance of safety and comfort (see pre and post-earthquake residential addresses in the Canterbury Region, figures 2.1 - 2.2).[3]

GNS Science, New Zealand's leading provider of Earth, geoscientific and isotope research, undertook studies as a part of their 'GNS Science Miscellaneous Series 44' to indicate the fluctuation in population that Canterbury experienced post-earthquake. The data collated revealed that school enrolment had a net drop of around 3,500 students in the greater Christchurch region during 2010 - 2011.[4] Although these statistics show that the number of enrolled school students across Christchurch has decreased post-earthquake, the Ministry of Education have predicted that these numbers will again begin to grow by 2021. Thus causing the capacity of proposed new schools for the Canterbury region to increase their roll by almost 30%.[5]

Canterbury School Roll Fluctuations 2010 - 2015			
	2010	2012	2015
# Students enrolled	91,560	87,339	90,872
Difference in roll		-4,291	+3,533
School Roll Response 2015			
# Schools with Increased Roll	159 Schools (incl. New schools)		
# Schools with Decreased Roll	141 Schools (incl. Closed schools)		

[1] Ministry of Education. "The New Zealand School Property Strategy 2011-2021." *New Zealand Government*, (2011): 16.
[2] Ibid
[3] Newell, J. Johnston, D.M. Beaven,S. "Population Movements Following the 2010-2011 Canterbury Earthquakes: Summary of Research Workshops November 2011 and Current Evidence." *Institute of Geological and Nuclear Sciences Limited*, no. 44 (2012): 4.
[4] Ibid
[5] O'Callaghan, Jody. "Size of Christchurch's New Schools to Be Boosted." *Stuff.co.nz*. http://www.stuff.co.nz/national/education/64886308/size-of-christchurchs-new-schools-to-be-boosted, accessed 5th March 2016.
[6] Ministry of Education. "Greater Christchurch Education Renewal Property Programme." *Christchurch Renewal Factsheet*, 2012: 1.
[7] Brownlee, Gerry. "More Than 80 Per Cent of Classrooms in Greater Christchurch Will Be Modernised by 2022." *Beehive*. https://www.beehive.govt.nz/release/more-80-cent-classrooms-greater-christchurch-will-be-modernised-2022, accessed 3rd March 2016.

The ‘Greater Christchurch Education Renewal property programme’ was initiated by the Ministry of Education to address the schools in the Canterbury region which sustained the most severe damage. Over the 10 year programme the Ministry proposes to construct 13 schools on new sites, rebuild 10 schools on existing sites, fully redevelop 34 schools and moderately develop 58.[6] This means that there will be approximately 1,200 new classrooms constructed as well as repair work on more than 1,200.[7] All of these classrooms must conform to the MoE’s Innovative Learning Environment design guidelines.

Greater Christchurch Property Programme	
# Schools affected	115
# New schools on new sites	13 (incl. Merged schools)
# Rebuilt schools on existing sites	10
# Redeveloped schools	52
# Major redeveloped schools	32

“(Canterbury Schools Rebuild Programme)(is)...great news for Canterbury’s new education network as it continues to rise from the rubble...”
- Hekia Parata,
Education Minister, 2016.

“We can see significant growth in parts of Canterbury and these new classrooms will complement the Christchurch schools rebuild programme”
- Nikki Kaye,
Assoc. Education Minister, 2016.

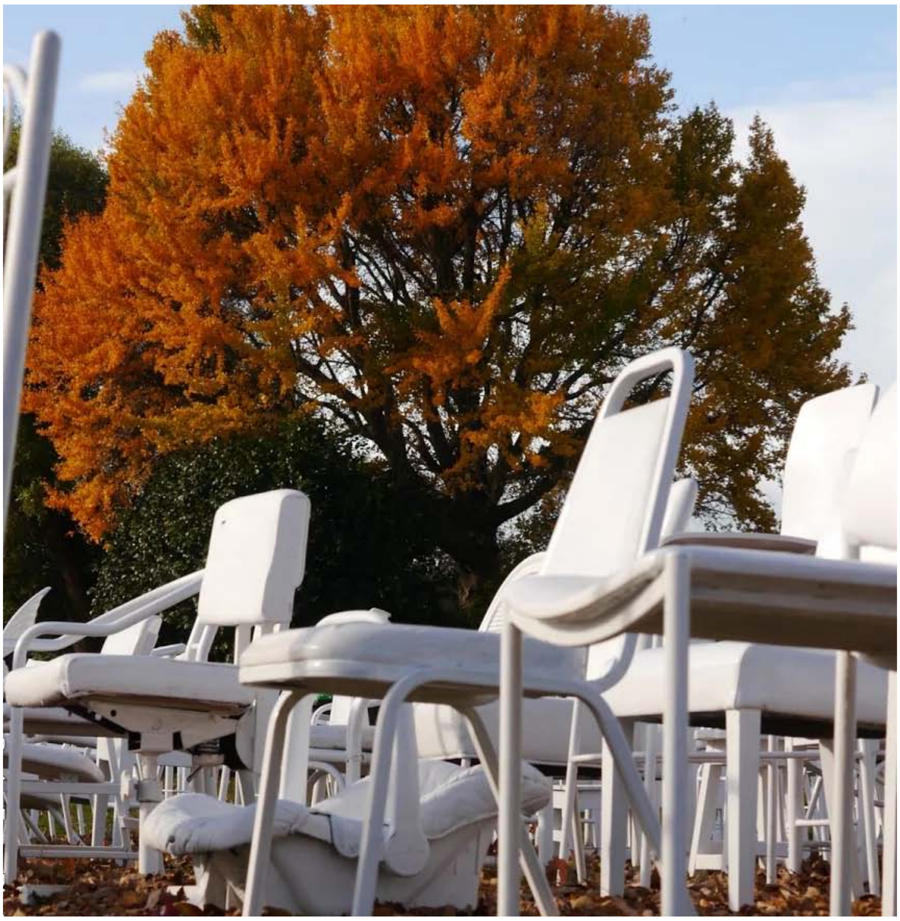


Fig 2.1. 185 Chairs - art installation by artist Peter Majendie; a memorial to those who died as a result of the February 2011 earthquake.

Residential Population Density:

Low

High

These diagrams show the dynamic movement of residential addresses in the Canterbury region as a repercussion of the Canterbury earthquakes. The shift in residential addresses can be seen as the residents move from the central region to the periphery.

Fig 2.2. Pre-Earthquake Residential Addresses in the Canterbury Region

Fig 2.3. Post-Earthquake Residential Addresses in the Canterbury Region

2.2 INNOVATIVE LEARNING ENVIRONMENTS >

2.2.1 The Education Movement

The Education Industry is in the midst of a transition from traditional teaching to modern learning. The pedagogy of schools in the 21st century is becoming focused on student-led learning in contrast to the traditional teacher-led learning (See teaching transition examples, figures 2.4 - 2.5).

Teacher led learning (see Traditional classroom, figure 2.4) centres around the teacher as the key point of reference for students. The classroom contains a ‘front of the class’ which students are often orientated towards in seating arrangements and/or fixed furniture. The focus becomes directive learning based upon tasks outlined by the teacher. Frequently these tasks are completed as individual work or with the person next to you.

Student-led learning (see Pegasus Primary School, Modern Learning environment, figure 2.5) encourages students to use the physical classroom space in a variety of ways, venturing into the realm of technology. The key focus for this education movement relies on the interaction between students, whether it be in small or large groups. By creating a collaborative environment where students begin to learn and thrive off of each they no longer become solely reliant on their teacher.

This pedagogical transition has resulted in the re-design of the classroom, and is reflected in the concept of Innovative Learning Environments, also known as ILE.

Fig 2.4. Hagley Community College, Traditional Classroom (top)
Fig 2.5. Pegasus Primary School, Modern Learning Environment (bottom)

[8] Ministry of Education. “Teaching and Learning Environments: Impact on Student Engagement and Achievement.” *Factsheet*.
[9] Ibid

2.2.2 Definition

ILE teaching spaces are configured as an open plan interior with multiple breakout spaces, encouraging students to engage in large or small group study (see Killester College Modern Learning Environments, figures 2.5 - 2.6).

The open plan nature supports flexibility in classroom arrangement and teaching techniques. This flexibility is often supported with moveable furniture to initiate different learning styles (see Killester College Modern Learning Environments, figures 2.6 - 2.7). ILE classrooms are capable of adapting as educational practices evolve and change, allowing schools to remain modern and future focused, eliminating the possibility of becoming outdated.[8]

Innovative Learning Environments have been chosen as the solution for the interior layout of all new build and renovated classrooms as a requirement by the Ministry of Education. This thesis will challenge the current standards set by the Ministry for Innovative learning environments. This will be done by redeveloping the existing design guidelines to become more effective and efficient for both students and teachers utilizing the tool of prefabrication, making not only the internal space changeable and adaptable, but also its exterior form.

To encourage future success for the students of New Zealand we must recognise that each individual learns in a variety of different ways, and teaching spaces need to be flexible to support the individual as well as providing a platform for quality teaching and learning. The opportunity for active flexibility relates directly to the key driver for this thesis, resulting in ILE as the most appropriate application for the teaching spaces.[9]

Fig 2.6. Killester College Modern Learning environment; Library (left)
Fig 2.7. Killester college Modern Learning Environment; Classroom (right)

2.2.3 Current Design Standards

The Ministry of Education have a Design Guidance Document which outlines the current design Standards for schools in New Zealand. They suggest that this document is viewed by both the Project Manager and Design team when a school is planning to upgrade an existing, or build a new learning space.[10]

The current design standards outline the spaces which a renovated or new build classroom must include. These spaces are as follows:

Large breakout spaces:
Large breakout spaces are open congregation spaces, with their primary use focusing on group interaction and activities.

Large breakout spaces must be:
> Connected to surrounding learning spaces.
> Occupants should be able to see from one learning space to the other
> Teachers should be able to supervise the large breakout area from adjacent learning spaces.
> You should not shut off a large breakout space and use it as additional learning space.

Breakout spaces:
Breakout spaces are smaller spaces placed between learning spaces. These areas encourage independent learning and small group work.

These breakout spaces must be:
> Separated from the main learning space with a transparent partition so that the teacher in the main learning space can supervise the space.
> Attached to a learning area.
> No larger than 40m2 if accessed from only one teaching space.

Outdoor learning areas:
Outdoor learning areas act the same as interior breakout spaces.

Outdoor learning environments must be:
> Directly accessible from an internal learning area.
> Easy for a teacher in the internal learning area to supervise.

Teacher work spaces:
Teacher work rooms are where planning, meetings and storage of personal items can occur.

These staff work areas should:
> Be no more than 2m2 per teacher.
> Spread through the school rather than all in one area.

[10] Ministry of Education. "Flexible Learning Spaces in Schools." *New Zealand Government*. http://www.education.govt.nz/school/property/state-schools/design-standards/flexible-learning-spaces/, accessed 10th April 2016.
[11] Ministry of Education. "Designing Quality Learning Spaces in Schools." *New Zealand Government*. http://www.education.govt.nz/school/property/state-schools/design-standards/flexible-learning-spaces/designing-quality-learning-spaces/, accessed 10th April 2016.
[12] Ministry of Education. "Space Entitlement." *New Zealand Government*. http://www.education.govt.nz/school/property/state-schools/property-planning/space-entitlement/, accessed 14th April 2016.

In addition to the Design Guidance Document for ILE classrooms, the Ministry of Education utilize a Space Entitlement Calculator which indicates the area of one teaching space which a school is entitled to. These space entitlements are critical in classroom spatial design as they outline the parameters for funding that the Ministry of Education will supply.[11]

These are as follows:
Sourced from the Ministry of Education Space Entitlement Calculator.[12]

Classroom Areas Entitlement	
Max students/Class	25 Students/Teaching Space
Primary	$87m^2$ = 1 Teaching Space
Secondary	$66m^2$ = 1 Teaching Space

2.2.4 Design standards Review

The existing Design Guidance Document has been strictly implemented on all new builds and redeveloped schools nationwide, without any prior evidence or prototyping in New Zealand.

These standards address the area restrictions of a classroom space, however they do not address interior spatial qualities such as acoustics, lighting and overall classroom flexibility.

Flexi-Ed challenges the existing standards by reviewing existing models that have aligned with the Design Guidance Document and surveying current users to gain feedback on the spatial success of the current Innovative Learning Environment. The feedback received from both the user surveys and personal site assessments was analysed to produce a set of design standards deemed more suitable for ILE and the users whom will occupy Flexi-Ed.

"Giving the power of learning to the students with a space flexible to doing so"
- Teacher Survey, Pegasus Primary School, April 2016

"It's a fun learning environment and I think others would like it and prefer it more because you get to work with lots of people"
- Student, Rangiora High School, June 2016

"I wouldn't promote it because it is harder to keep all the children on task..."
- Student, Pegasus Primary School, April 2016.

2.2.5 ILE User Survey

A combination of precedent studies and observations within existing Innovative Learning Environments led to the formation of two separate surveys, one teacher and another student focussed (see Survey Forms, Appendix 10.2.4). These surveys were designed to analyse the user feedback of occupants who inhabit an ILE that aligns with the current Ministry design standards; assessing the opportunities and constraints present within these requirements. The surveys were completed by approximately six teachers and nine students from three different schools in Canterbury, all of whom are daily users of ILE, classrooms during the months of April to July 2016.

The surveys produced results which indicated the most successful aspects of ILE and the changes which these existing occupants deem necessary in order to improve the efficiency and success of ILE.

Interestingly the survey responses contradict one another; this can be seen upon review of the results that outline what the survey participants deem 'the most successful aspects' and 'the changes to be made' (see ILE User Survey Results Collation, figure 2.8). The areas of conflict can be seen where the participants highlight the open plan classroom and flexible furniture as the most successful aspects; this is then contradicted by the results which consider the acoustics caused by the open plan teaching space the area of most concern. These results prove that the concept of Innovative Learning Environments is being embraced by existing users, however improvement needs to be made to these areas in order to produce a more effective prototype classroom.

After reviewing the existing Design Guidance Document produced by the Ministry of Education and the feedback from the surveys conducted, it has become evident that the acoustic treatment, breakout and teacher work spaces are the areas which require most attention.

"Flexible and more natural way of learning, ILE allows for a range of activities and setting"
- Teacher Survey, Rangiora High School, June 2016

"I like working in this learning environment because you can work where you want with your friends."
- Student, Pegasus Primary School, April 2016.

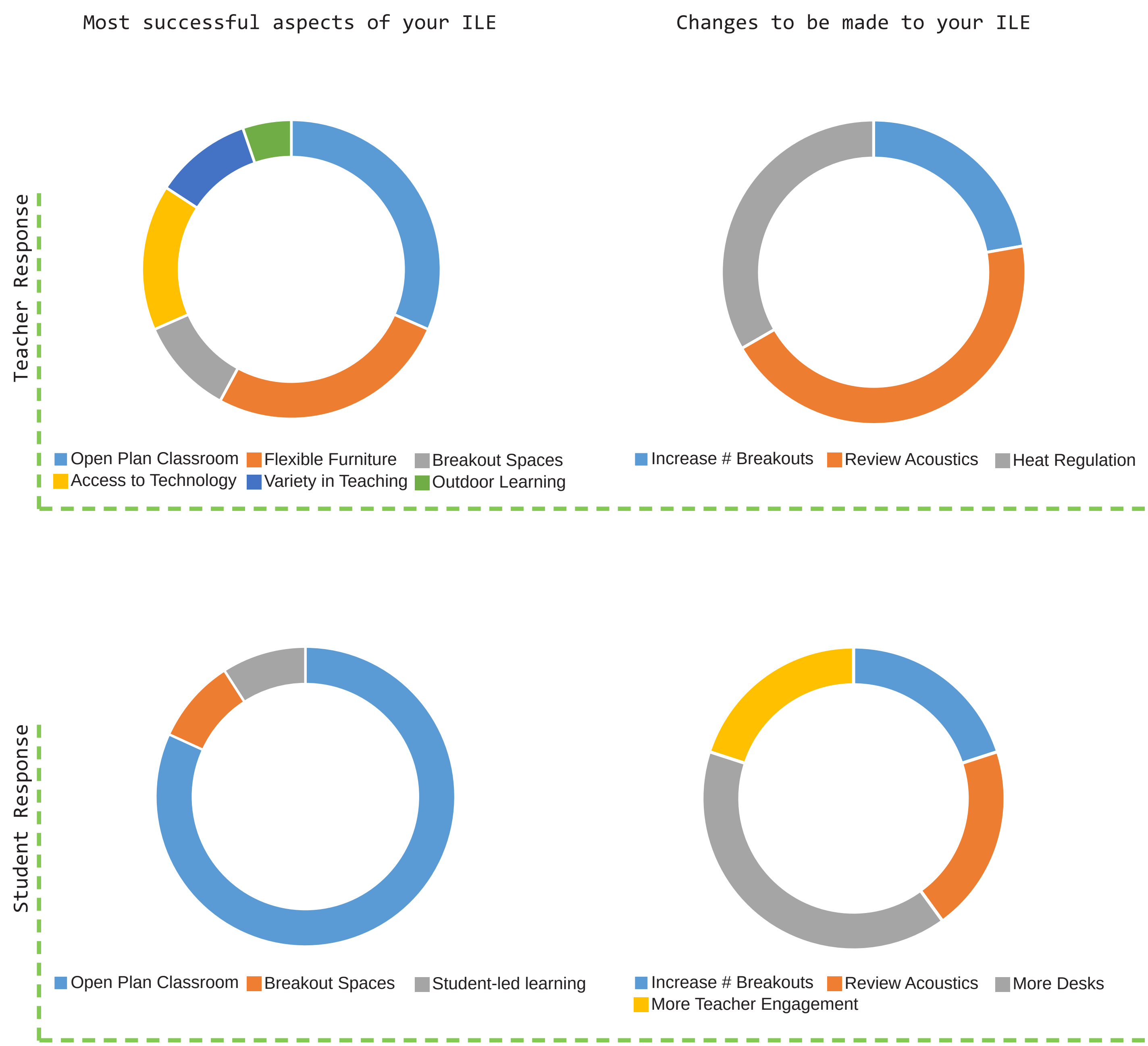
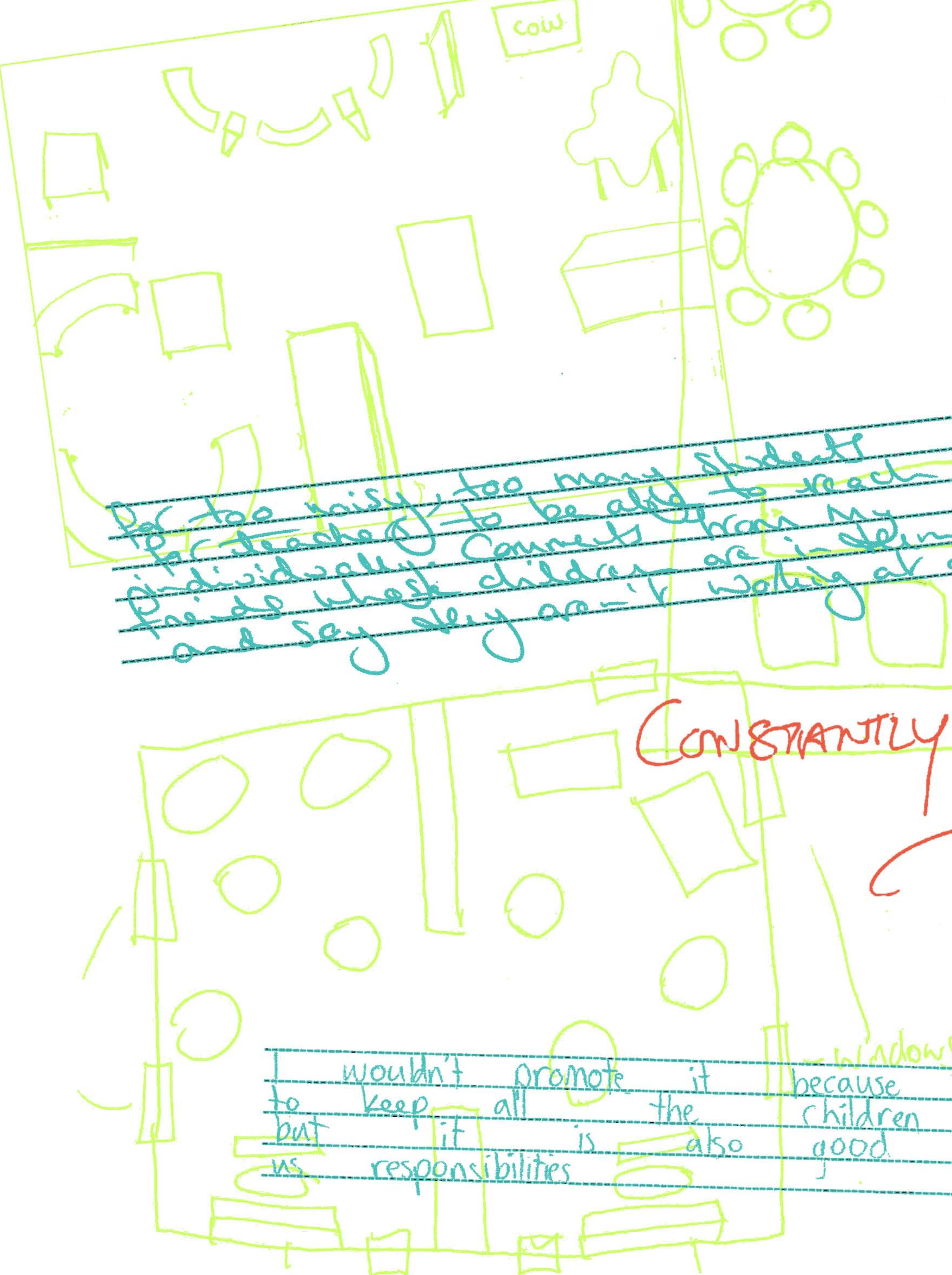
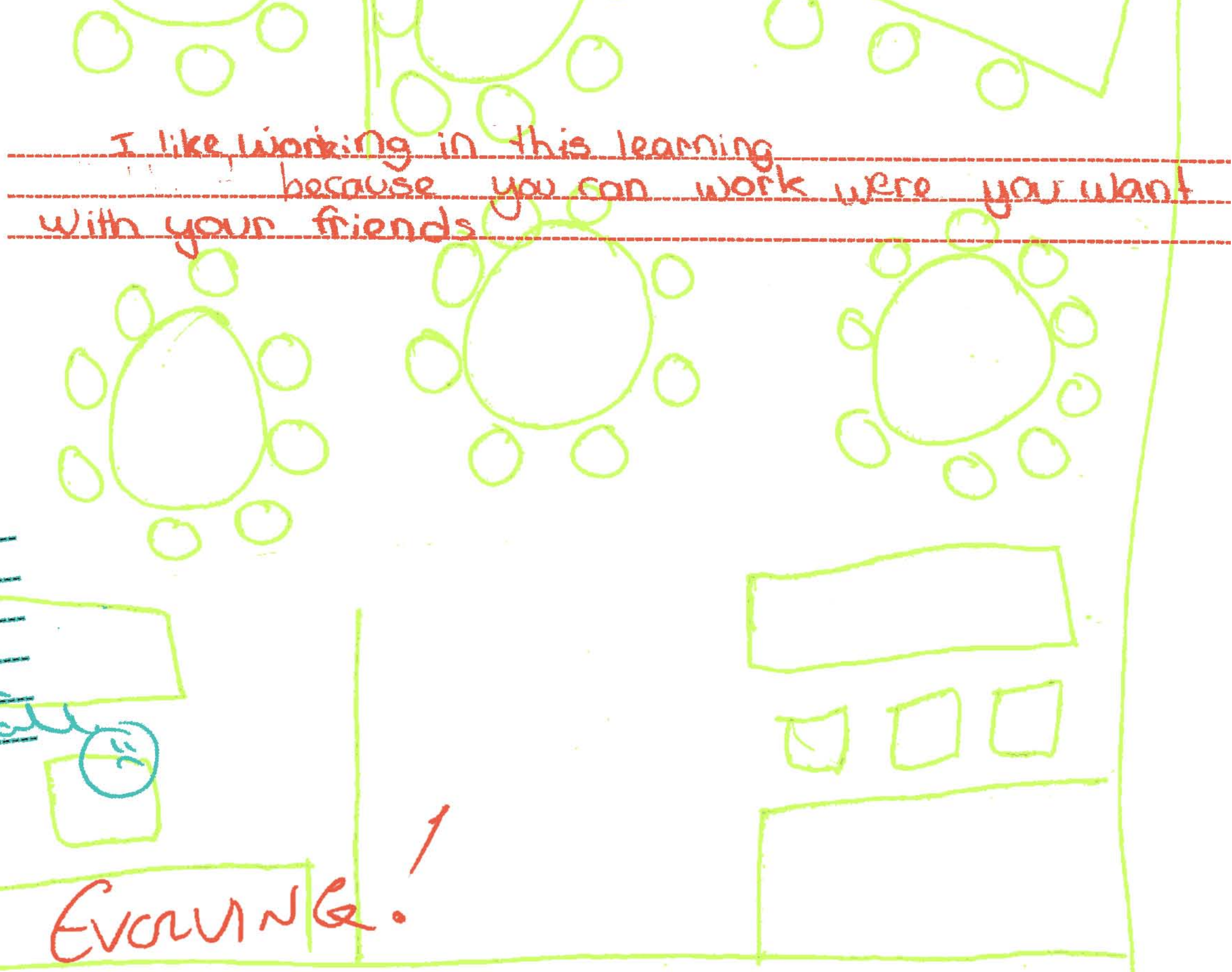


Fig 2.8. ILE User Survey Results Collation
Fig 2.9. Collation of Survey sketches done by students and teachers (Over page)


cow
Far too noisy, too many students
for teacher to be able to reach
individually. Comments from my
friends whose children are in
and say they aren't working at
CONSTANTLY
windows
I wouldn't promote it because
to keep all the children
but it is also good
us responsibilities

I like working in this learning because you can work were you want with your friends



it is harder
on task,
to teach

2.3 PREFABRICATION >

Prefabrication has been selected as the tool to demonstrate that one system can in fact cater to the flexibility that is required for existing and future New Zealand schools. Prefabrication has the capacity to deliver Innovative Learning Environments, and cope with fluctuating school rolls and unpredictable seismic activity due to the nature of the construction process and flexibility in design.

2.3.1 Definition

Prefabrication is a term that refers to the assembly of a structure off-site, in a factory or other manufacturing site. Whilst being constructed off-site, the prefabricated elements can be configured as panels, modules or complete builds, giving the client the opportunity to decide how they would like their project to be delivered on-site.

2.3.2 Prefabricating Flexi-Ed

Prefabricated construction is manufactured off-site, transported to site, occupied and then removed as the roll fluctuates throughout the lifetime of a school. By having the option to relocate the Flexi-Ed buildings it not only encourages recycling of built forms, but also caters to the unpredictable school rolls New Zealand wide.

When comparing conventional construction with prefabrication there are areas of significance where off-site construction can be more appealing to not just the construction industry but also the market. These areas include time frame; in most cases of prefabricated design many trades can work simultaneously, improving efficiency of a project by up to 60%.[13]

As the construction phase is primarily done off-site in factories, a controlled environment is maintained, removing external delays. Weather currently cause more than 13% delay in construction timelines, so by constructing in a controlled environment it allows the building process to become more predictable.[14]

Prefabrication also promotes a much safer working environment for the workers to occupy. Currently there are at least 60,000 fatal accidents on construction sites across the globe annually, equating to one incident every 10 minutes. By moving to prefabrication, workers can experience a much safer working environment by a factor of 2, due to the ability to work in factory environment that is safe, sheltered and allows labourers to construct components on a horizontal plane, eliminating the need for ladders and scaffolding.[15]

Another key influence to use prefabricated construction is the high standard of quality control. Factory sites use tools which are of a high quality, far superior to those used in traditional construction. These high quality factory tools provide smaller tolerances and improved finishes. The enhanced tolerances allow for a more energy efficient design by eliminating gaps between elements during on-site assembly.[16]

[13] Smith, Ryan E. *Prefab Architecture : A Guide to Modular Design and Construction*. (Hoboken, N.J: John Wiley & Sons, 2010), 84.
[14] Ibid.
[15] Smith, Ryan E. *Prefab Architecture : A Guide to Modular Design and Construction*. (Hoboken, N.J: John Wiley & Sons, 2010), 86.
[16] PrefabNZ Incorporated. “Value Case for Prefab.” *PrefabNZ* (2014): 2
[17] Smith, Ryan E. *Prefab Architecture : A Guide to Modular Design and Construction*. (Hoboken, N.J: John Wiley & Sons, 2010), 84.

In terms of cost, prefabrication may save considerably in regards to delivery and staging of materials; however factory produced components may initially be more expensive. Factory set up requires huge capital costs which does not make small projects a feasible option, Along with project set up, transportation costs can also significantly increase project costs as the elements are required to transition from the factory site to the construction site. In order to ensure a feasible thesis the quality of the project must warrant the investment in the infrastructure.[17]

Predictable Time frame:
Controlled factory environment = Predictable completion dates
> Eliminates prolonged waiting time for schools.

Safer working environment:
Factory work Station on horizontal plane = Elimination of Ladders etc.
> As the system is aimed at the uneducated individual, prefab promotes itself as the safest option.

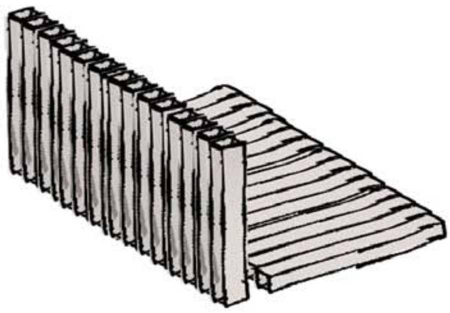
Quality control:
Factory production = Smaller tolerances and improved finishes
> More energy efficient design by eliminating gaps between elements.

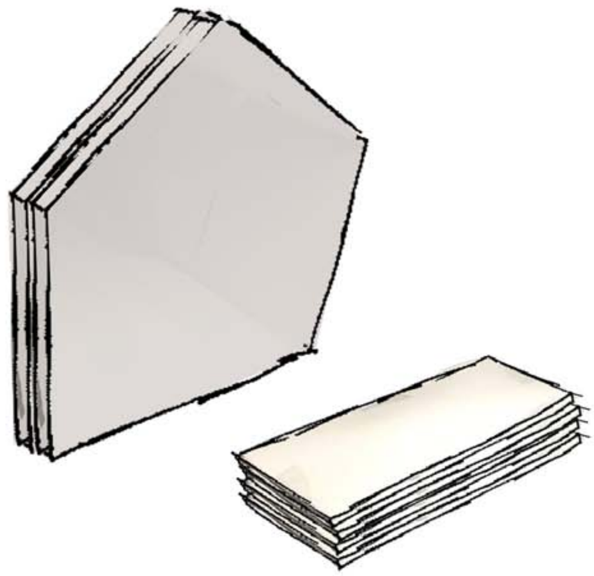
Reduced Cost:
High capital costs + Repetition of product = Reduced Costs
> Large range of valid transportation options due to the flat pack nature of the system.

"Off-site fabrication is about reinventing the way we build, carefully considering how we assemble and ultimately disassemble our buildings."
- James Timberlake, 2011

2.3.3 Prefabrication Typologies

Fig 2.10. Prefabrication Typology sketches





Components

Stick components are elements that have been precut, pre-sized or shaped prior to being delivered to site for assembly.

Opportunities

> Precision of elements
> Quality control and consistency of all elements
> Easily transportable to site

Constraints

> Requirement for primary construction to be done on-site

Panel

Panelised prefabrication consists of panels that can be transported to site as flat pack elements ready for on-site assembly.

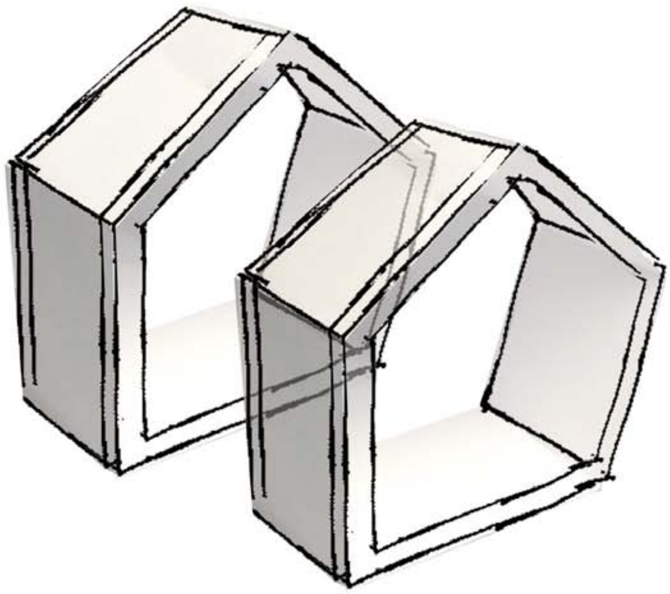
Opportunities

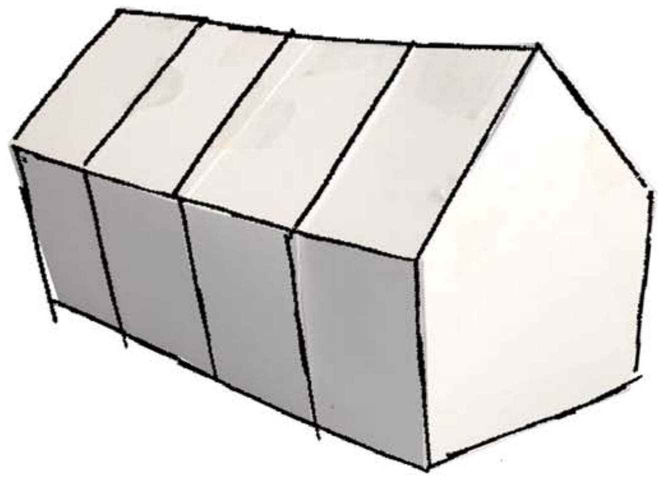
> Easily transported to site
> Opportunity to pre-install services prior to site delivery
> Reduction of on-site construction period
> Easily stored flat pack
> Ability to be delivered to site with interior and exterior linings applied

Constraints

> Panel sizes restricted due to transportation requirements
> Minimal tolerance allowed when elements come together on-site

[18] PrefabNZ Incorporated. “Value Case for Prefab.” *PrefabNZ* (2014): 2
[19] PrefabNZ Incorporated. “Value Case for Prefab.” *PrefabNZ* (2014): 10
[20] PrefabNZ Incorporated. “Kiwi Prefab Summary.” *PrefabNZ* (2009): 1





Module

Modular or volumetric prefabrication refers to three-dimensional structural elements which are joint together on-site with other units or systems.

Opportunities

> Opportunity to pre-install services prior to site delivery
> Minimum time required on-site
> Modules can cater for highly serviced areas such as kitchens and bathrooms
> Ability to be delivered to site with interior and exterior linings applied

Constraints

> Module dimensions restricted due to transportation requirements

Complete Build

Complete Buildings are often known as portable, relocatable or transportable buildings. This system is fully constructed in a factory or yard and then moved to site where they are overlaid onto the specified foundations.

Opportunities

> Minimal time spent on-site
> Most reliable projected time frame due to factory controlled conditions
> Reassurance of high quality due to controlled factory environment

Constraints

> Reduction in transportation options to site
> Site storage
> Site must be accessible by large transportation for delivery

"Relocatables (temporary prefabs)... at their best they can be described as cheap and cheerful – but they aren't always cheap and often aren't too cheerful. It's time to get some proper design thought applied to the problem..."
- Professor Alistair Gibb, Loughborough University, 2010

3.0 CASE STUDIES >

3.1 Portabuild >

Nationwide, New Zealand.

Currently the common option for schools requiring new classrooms is the 'Portacom', a prefabricated structure that has been designed as a temporary and relocatable module. Each module contains an open plan internal environment that comfortably suits the widest range of needs; giving the opportunity to tailor to a variety of situations. This flexible nature has resulted in the well known Portacom system to become the default solution for portable classrooms nationwide (see Exterior Portabuild classroom view, figure 3.3).[21]

These units are prefabricated as modules off-site, then delivered to as a volumetric element and installed within days. The Portacom time frame includes both the construction, delivery, permits and service connections, which can often delay other prefabricated constructions.[22]

The company, Portabuild, is one of few companies who manufacture these portable modules which are both for sale and hire. The classrooms in their hire fleet are 12 x 5.8m (approx. 72m^2). The available areas are dictated primarily by transportation and the dimension limitations for a flatbed truck.[23]

The base build and additional construction features of the Portabuild modules are primarily chosen based on budget, counteracting the transport expenses and reduce the capital costs for clients. This results in the choice of basic, mid-low range elements that are low budget.

The Portabuild company produce modules that are made up from the following structural materials:[24]

> Timber piles required as foundations subject to engineers and geotech reports
> Galvanised steel base
> Under floor insulation (60mm poly)
> A thermal moisture protection blanket
> 75mm insulated EPS panel for the walls and ceiling
> Double glazed joinery

Due to the low budget fixings, materials and construction techniques it allows Portabuild to provide customers with lower hire and sale costs. The approximate cost to purchase a 12.0m x 5.8m unit is approx. $61,935.67 + GST and with the approximate hire cost per week equating to an average $5/m2 per week GST exclusive.[25]

Portabuild have produced a usable module that is to be temporary and transportable. Due to the makeshift nature, Portabuild structures have lower quality finishes in specific areas to save costs for potential clients. However often the Portabuild system becomes a permanent feature on a school site due to the additional costs for module and foundation removal.

In some cases the interior finishes are left as exposed steel, implicating acoustic and thermal qualities as well as increasing overall life cycle costs of the module system. Due to the interior surface treatment and the inefficiency to control acoustics within the Portabuild modules, the system provides an incompetent product for innovative learning environments (see Portabuild interior view; Christ College example, figure 3.1).

[21] Portabuild. "Our Portable Buildings." *Portabuild*. http://www.portabuild.co.nz/our-portable-buildings, accessed 11th April 2016.
[22] Portacom. "Home." *Portacom*. http://www.portacom.co.nz/, accessed 11th April 2016.
[23] Lundberg, Jessica, Interview by Author. *Portabuild*. May 2016.
[24] Ibid
[25] Ibid
[26] Hagley Community College Teachers, Interview by Author. *Portacom Classroom User Feedback*. April 2016.

User Response

Two teachers who are frequent users of a Portabuild structure were surveyed to gain feedback from industry professionals.

The key issues which arose from the surveyed teachers highlighted multiple areas where Portacoms need improvement, this includes noise levels caused by high levels of reverberation, lack of temperature control throughout the year and the lack of respect students have for the 'temporary aesthetics' of a portacom.[26]

All of these issues are results of low budget material and finish selection which is intended for a temporary structure.

Summary

As the product is not designed for permanent use, New Zealand is becoming inundated with education campuses that are inadequately equipped for their students and the future generations of New Zealand. The low budget finishes and structural materials are designed to cater for temporary structures, resulting in modules that are not capable of efficiently heating, cooling and maintaining a comfortable working environment year round. Classes that are designed to be temporary are becoming permanent, providing our students of New Zealand with hot, stuffy and acoustically unreliable classrooms.

Fig 3.1. Portabuild Interior View; Christ College example (left)
Fig 3.2. Portabuild Pitched roof Duplex Building (right)
Fig 3.3. Exterior Portabuild classroom view (Over Page)


Portabuild
0800 668 322
Portabuild
0800 668 322

3.2 Concision >

Mike Greer and Versatile Homes Canterbury, New Zealand.

Concision is a Canterbury based business that produces prefabricated panels for two primary clients, Mike Greer Homes and Versatile Homes.

Concision was selected as a case study in order to analyse the construction process of the panelised prefabricated system, and provide some guidance for the selection upon which prefabricated typology would best suit the flexibility aims and requirements for Flexi-Ed.

The company, Concision, was set up in 2015 in a factory located in Rolleston, Canterbury. Due to the lack of awareness in the mass population about prefabrication, the business was slow starting. However as trust was earned and occupants begun to reap the benefits, the production volume increased rapidly, and in June 2016 Concision were producing over one hundred houses annually, averaging at one per day. The company seeks future growth in the hope to run even more efficiently to produce 10 houses per week by the end of 2016.[27]

Concision works in a factory environment that has been strategically laid out in a sequential format to allow for a linear assembly line. The process consists of approximately six phases, starting with the precision cutting of each individual stick component, by a 5 axis machine and finishing with the doors and windows being pre-installed before the site delivery process commences.

The beginning phases for the wall framing are done on a horizontal plane and are completed using a mixture of automated machinery and manual labour (see wall framing machinery, figure 3.4). Some of the larger machinery can produce walls up to 12m long every 20 minutes, with a maximum tolerance of 0.5mm.[28]

The wall framing includes no dwangs in the structural system as the studs along with the manually applied bracing provide sufficient structural support (see Wall insulation station, figure 3.5).

After the interior GIB is applied the framing is automatically tilted to become vertical, this allows the external strand board to be applied (see wall plane transition, figure 3.6). The window, door and socket openings are then machine cut, before the building paper is automatically applied to the strand board external face.

Following the window and door slot cutting, the panels are chronologically slotted into a 'wine rack' styled storage system, where smart fit glazing is installed prior to on-site delivery (see window installation example, figure 3.7).

Once the prefabricated panels have arrived on-site, they are chronologically unloaded, and erected with a turnaround time of approximately six hours.[29] This on-site efficiency is reliant upon prelaid foundations that have timber

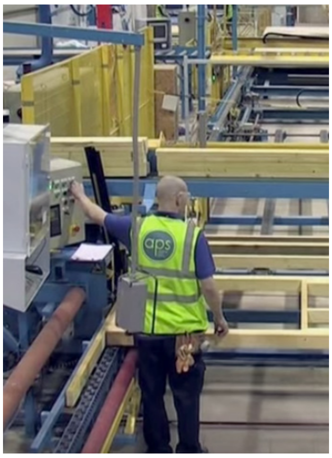
[27] Gerald, Donaldson, Interview by Author. *Concision*. April 2016.
[28] Ibid
[29] Ibid

slots and vertical pivots which help guide the panels into the correct placement (see typical site installation, figure 3.8).

The panels as individual components are restricted in terms of design, consisting of basic forms cut to different lengths. However the system as a whole highlights the flexibility prefabricated panels can provide by catering to an array of floor plans in the residential industry.

Summary

Flexi-Ed requires flexibility within the floor plan to cater for the current Innovative Learning Environment movement, therefore a panel system appears as the most applicable approach. In order to contribute an efficient product for New Zealand. Flexi-Ed will assess the option of designing in a panel form to encourage unique design schemes for each client, along with a modular delivery to reduce time on-site.



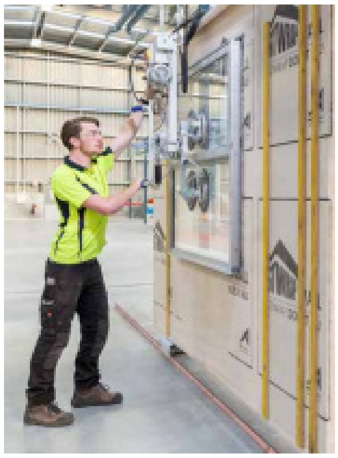


Fig 3.4. Wall Framing Machine (top far left)
Fig 3.5. Wall Insulation Station (top left)
Fig 3.6. Wall Plane Transition (top right)
Fig 3.7. Window Installation (top far right)
Fig 3.8. Typical Site Installation (bottom)

3.3 National Transportables Programme >

Ministry of Education
Nationwide, New Zealand.

In order to improve the quality of temporary classrooms, the Ministry of Education has initiated the National Transportables Programme (NTP) for schools nationwide, providing temporary teaching spaces for the provision of roll growth or replacement of existing teaching spaces.[30] The Programme has the potential to deliver over $100 million worth of transportable school classrooms over the next 10 years, resulting in approximately 50 classrooms per year.[31]

The Transportables Programme has been selected as a case study to analyse as it is the most relevant existing product on the market in comparison to Flexi-Ed, this is due to the system attempting to solve many of the same issues that this thesis has set out to achieve.

Fig 3.9. Two Learning Studio Axonometric

[30] Ministry of Education. "Modular Buildings for New Spaces at Schools." *New Zealand Government*. http://www.education.govt.nz/school/property/state-schools/school-facilities/modular-buildings/, accessed 4th April 2016.
[31] Ministry of Education. "Making Teaching and Learning Easier." *New Zealand Government*. http://www.education.govt.nz/news/making-teaching-and-learning-easier, accessed 6th April.
[32] Ministry of Education. "Modular Buildings for New Spaces at Schools." *New Zealand Government*. http://www.education.govt.nz/school/property/state-schools/school-facilities/modular-buildings/, accessed 4th April 2016.
[33] Ibid
[34] Ibid

The Ministry of Education has selected relocatable buildings for multiple reasons, one of the main being flexibility. Flexibility is key for a school environment as it allows the school to actively respond to fluctuating enrolment numbers which often differ significantly in the lifetime of a school.[32] It is anticipated that the programme will provide a faster delivery process with a standardised design that allows the classrooms to be relocated from one site to another with relative ease.

The Ministry are providing schools with three different floor plans to select from; these consist of single, double and triple learning studios. A single learning studio is approximately 10855mm x 10900mm (see floor plan examples, figures 3.10 - 3.12) with the option to apply exterior modular decking. One single learning studio is a collective of three modules that span 3600mm x 7700mm.[33] When these modules are delivered to site they simply line up side by side and slot together (see two learning studio example, figure 3.9).

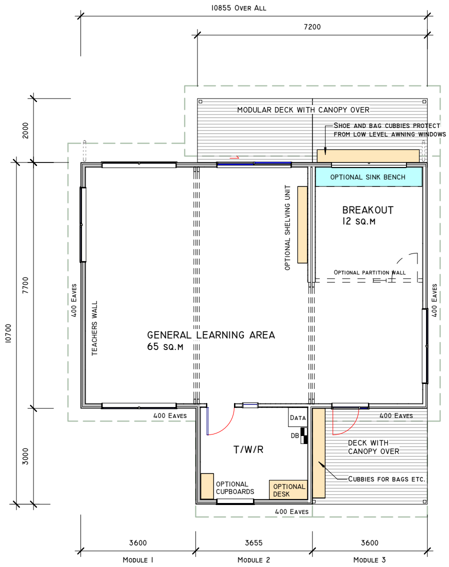
As well as giving the option of different classroom sizes, the programme allows the schools to input into the look and feel of each space, this includes colour choice from a fixed colour palette and also influence in placement of fixed furniture and equipment.

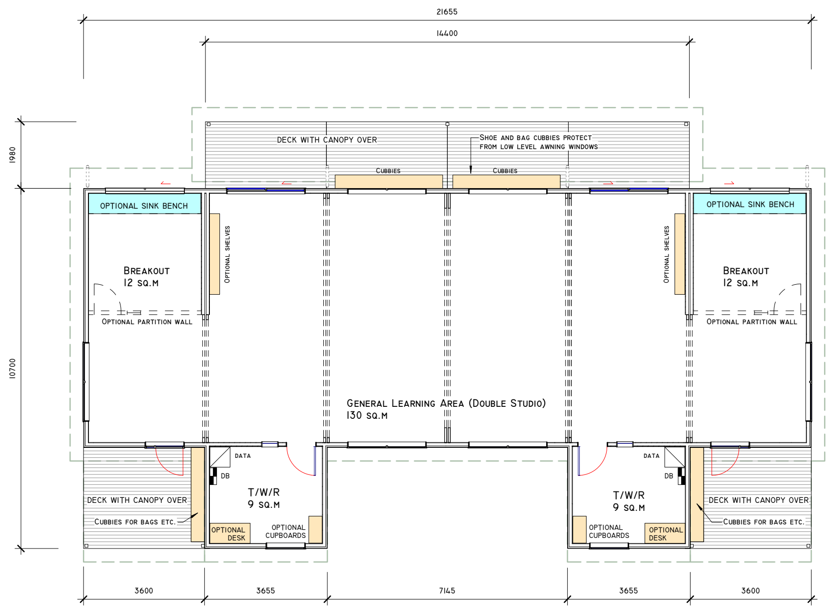
To boost the marketability the Ministry has recently set guidelines for future master planning of schools, making it a requirement to include 20% or above of the total school teaching space as modular transportable buildings that will help manage roll fluctuations.[34]

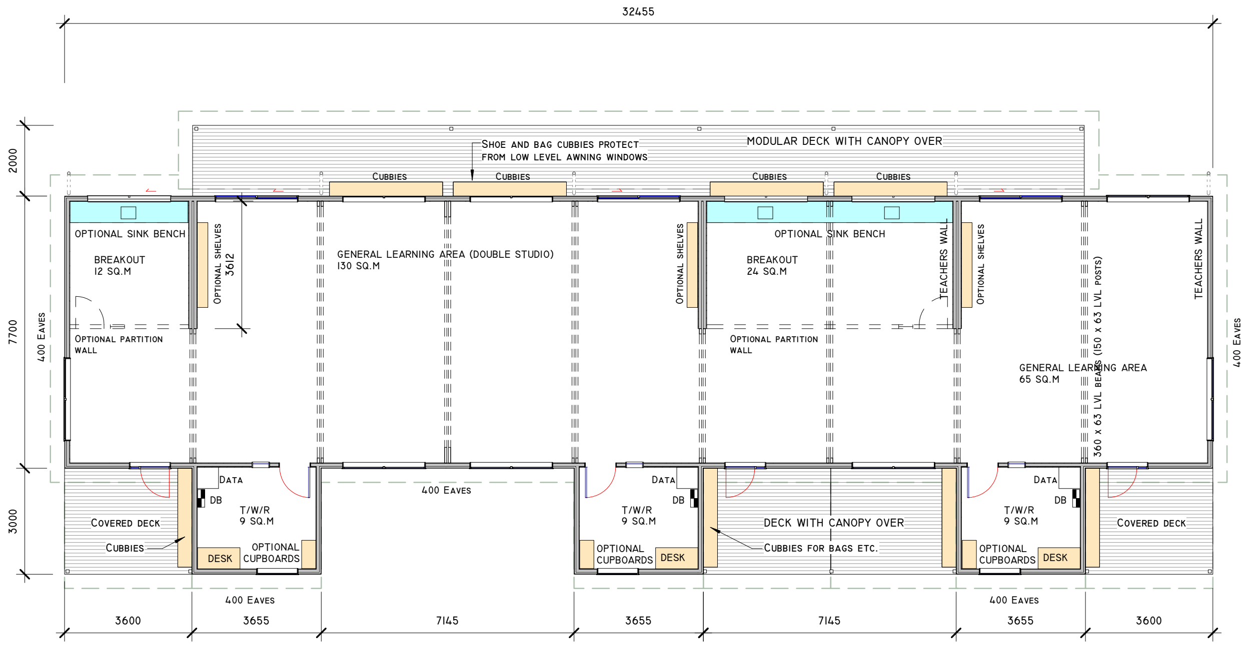
Summary

The programme has the ability to conform to ILE, unlike existing prefabricated solutions. However there are a few constraints which could hinder the marketability of this NTP system. The system is limited to providing only single story, standalone classrooms which produces a temporary and relocatable aesthetic similar to that of a Portabuild module. The Ministry also states that the modules are a standardised design which eliminates the opportunity for schools to customise classroom designs and cater to the individual learners whom are occupying the space on a daily bases.

Another area which needs to be refined is the classroom areas specified for the National Transportables Programme. The areas for the different number of learning studios does not directly correspond with the MoE dictated space entitlement for teaching spaces. The specified areas need to be altered in order to address the current entitlement standards in New Zealand to maximise the funding and support for schools intending to implement these modules within their campus.


10855 Over All
7200
Modular deck with canopy over
Shoe and bag cubbies protect from low level awning windows
Optional sink bench
Breakout 12 sq.m
Optional partition wall
Optional shelving unit
General learning area 65 sq.m
Teachers wall
400 Eaves
T/W/R
Data
DB
Optional cupboards
Optional desk
Deck with canopy over
Cubbies for bags etc.
2000
7700
10700
3000
3600
3655
3600
Module 1
Module 2
Module 3


21655
14400
Deck with canopy over
Shoe and bag cubbies protect from low level awning windows
Cubbies
Optional sink bench
Breakout 12 sq.m
Optional partition wall
Optional shelves
General Learning Area (Double Studio) 130 sq.m
T/W/R 9 sq.m
Data
DB
Optional desk
Optional cupboards
Deck with canopy over
Cubbies for bags etc.
1980
10700
3600
3655
7145
3655
3600


32455
Shoe and bag cubbies protect from low level awning windows
Modular deck with canopy over
Cubbies
Optional sink bench
Breakout 12 sq.m
Breakout 24 sq.m
Optional partition wall
Optional shelves
3612
General learning area (Double Studio) 130 sq.m
Teachers wall
General learning area 65 sq.m
360 x 63 LVL beams (150 x 63 LVL posts)
400 Eaves
T/W/R 9 sq.m
Data
DB
Desk
Optional cupboards
Covered deck
Cubbies
Deck with canopy over
Cubbies for bags etc.
2000
7700
3000
3600
3655
7145
3655
7145
3655
3600

One Learning Studio
Teaching Area: 77m2
Construction: 3 Prefab Modules + 2 Prefab decks
 # Students: Primary: 22 Secondary: 29

Two Learning Studios
Teaching Area: 154m2
Construction: 6 Prefab Modules + 4 Prefab decks
 # Students: Primary: 44 Secondary: 58

Three Learning Studios
Teaching Area: $231m^2$
Construction: 9 Prefab Modules + 5 Prefab decks
 # Students: Primary: 66 Secondary: 87

Fig 3.10. Floor Plan; One Learning Studio (top)
Fig 3.11. Floor Plan; Two Learning Studios (middle)
Fig 3.12. Floor Plan; Three Learning Studios (bottom)

Jasmax
Canterbury, New Zealand.

Pegasus Primary School was completed in April 2014 as the first Primary School in Canterbury to embrace the concept of ILE. Although not built using prefabricated construction, Pegasus was selected as a case study for Flexi-Ed in order to analyse an existing Innovative Learning Environment, assessing the opportunities and constraints that current users experience during daily occupation.

The architects, Jasmax, based the design of the school around the concept of 'learning communities'.[35] There are five Learning Communities at Pegasus: Te Kohaka: year 0-1, Rakahuri: year 1-2, Waikuku: year 3, Nga Tai o Mahaanui: year 4-5 and Maungatere: year 6, 7, 8. The five communities are set up in pairs with shared resources and specialised break out spaces between the open plan learning spaces.[36]

A single wing provides for three classes of approximately 25 students per class (75 students in total), and are furnished using flexible furniture that can adapt the open plan interior (see Pegasus Primary School typical learning area, figure 3.14). For students whom are assigned tasks that require uninterrupted focus and concentration, small breakout spaces have been situated near the main classroom space to encourage individual and small group work away from the hustle and bustle of the main classroom wing.[37]

The school design is based on a 'U' shape which wraps around a sheltered courtyard space, providing all classrooms with ease of access to the exterior environment for teaching and playing purposes (see Pegasus Primary School site plan, figure 3.13).

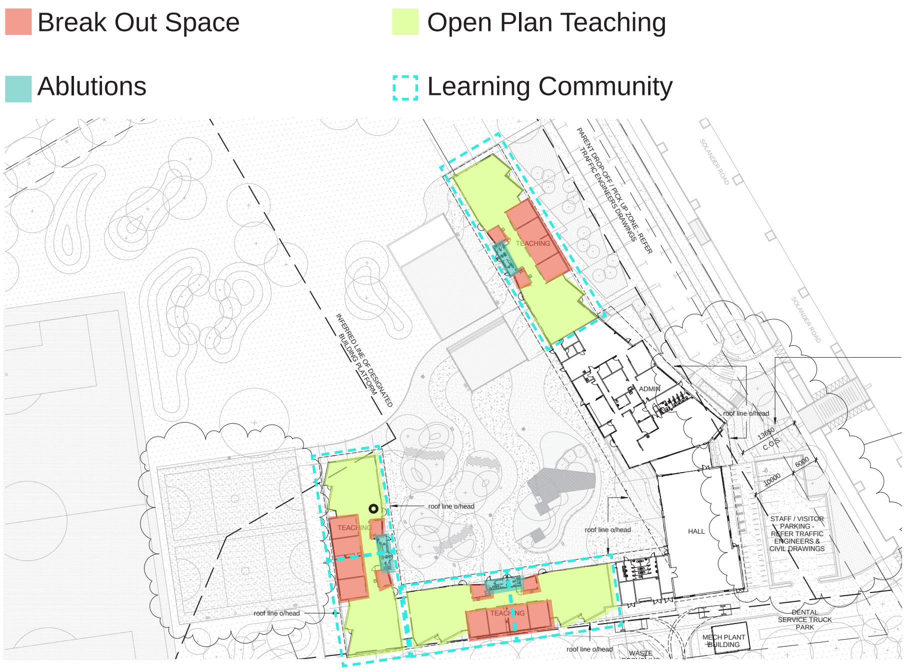


Fig 3.13. Pegasus Primary School: Site Plan

[35] Jasmax. "Pegasus Primary School." *Jasmax*. http://www.jasmax.com/work/pegasus-primary-school/sectors/education/1154, accessed 4th May 2016.
[36] Ibid
[37] Buchanan, Belinda, Interview by Author. *Pegasus Primary School*. June 2016.
[38] Jasmax. "Pegasus Primary School." *Jasmax*. http://www.jasmax.com/work/pegasus-primary-school/sectors/education/1154, accessed 4th May 2016.

The initial school roll consists of 450 students with a floor area of 2950m^2. A future expansion phase has been planned to allow for the predicted roll of 600 students.[38]

Summary

As one of the first Primary Schools in New Zealand to embrace the concept of Innovative Learning Environments, there are many areas which require attention in order for these spaces to continue to work effectively throughout the school lifetime.

Following site observation and survey analyses, results revealed that the users of ILE at Pegasus believe that the open plan interior works in terms of encouraging student-led learning, particularly in the new entrants, (Year. 1 - 2) and seniors (Year. 7 - 8). However in contrast, areas of concern were also outlined. These areas were particularly apparent in the middle school (Year. 3 - 6), where students found it hard to stay on task and lacked self-motivation.

Upon evaluation of the floor plan design, a disconnection is felt between the breakout spaces and open plan teaching spaces causing the areas to be inefficiently used, displaying a potential catalyst for student distraction (see Pegasus Primary School analysed floor plan, figure 3.15).

By initiating more accessible learning settings, breakout spaces and unique floor plans for the intended students occupying the space, student-led learning and acoustics within the classroom spaces could be catered to.

"There are things that I would modify, but overall this method has captured student interest."
- Teacher Survey, Pegasus Primary School, April 2016

Fig 3.14. Pegasus Primary School: Typical learning area

Reflection of Pegasus ILE Classrooms

What currently is working?
- Flexible interior
- Individual Learning
- Self-motivated Learning (Yr 1-2, Yr 7-8)

What currently is not working?
- Acoustics
- Disconnection to breakout spaces
- Child/Resource Storage
- Student Discipline
- Opportunity for focused work
- Self-motivated Learning (Yr 3-6)

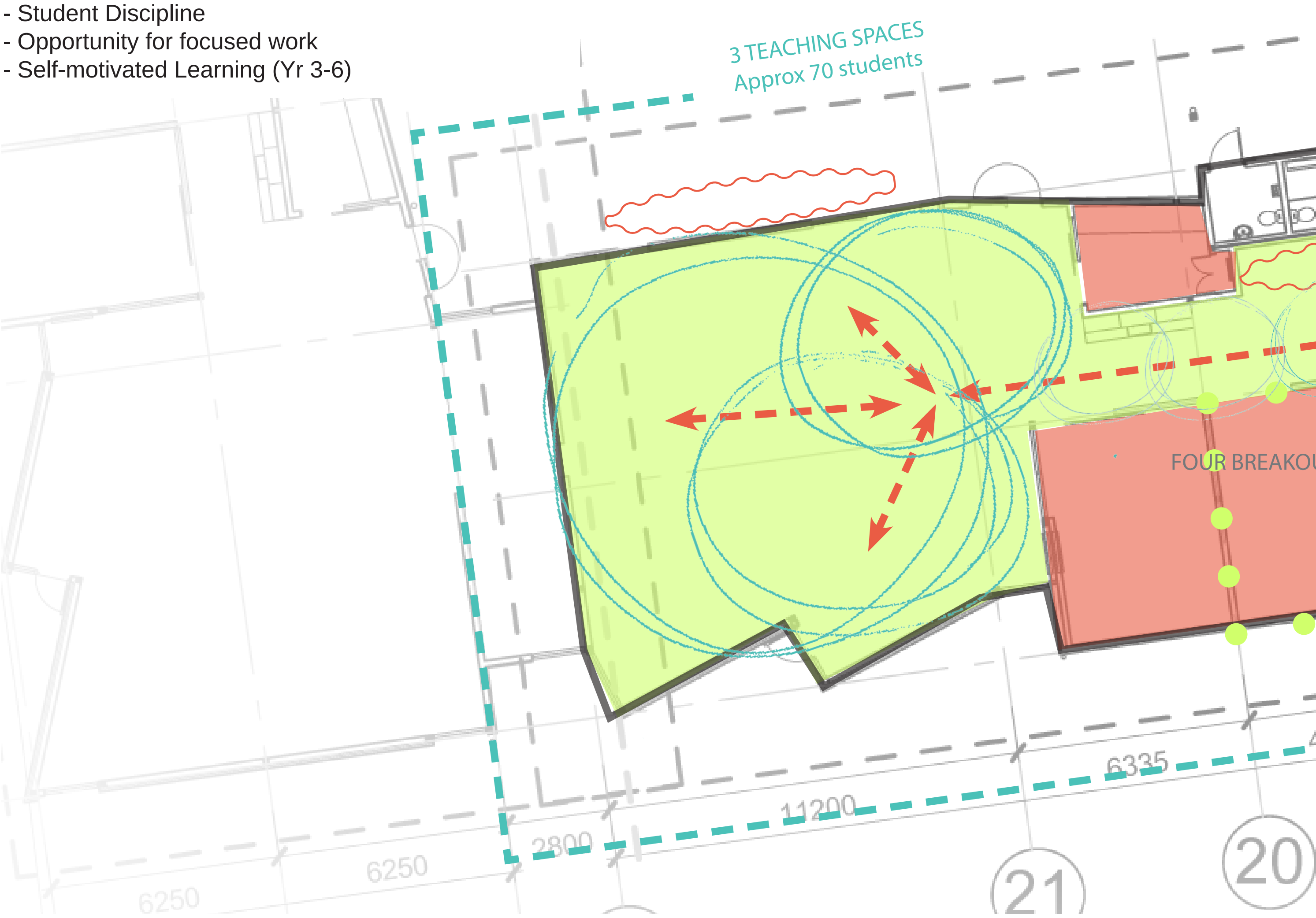
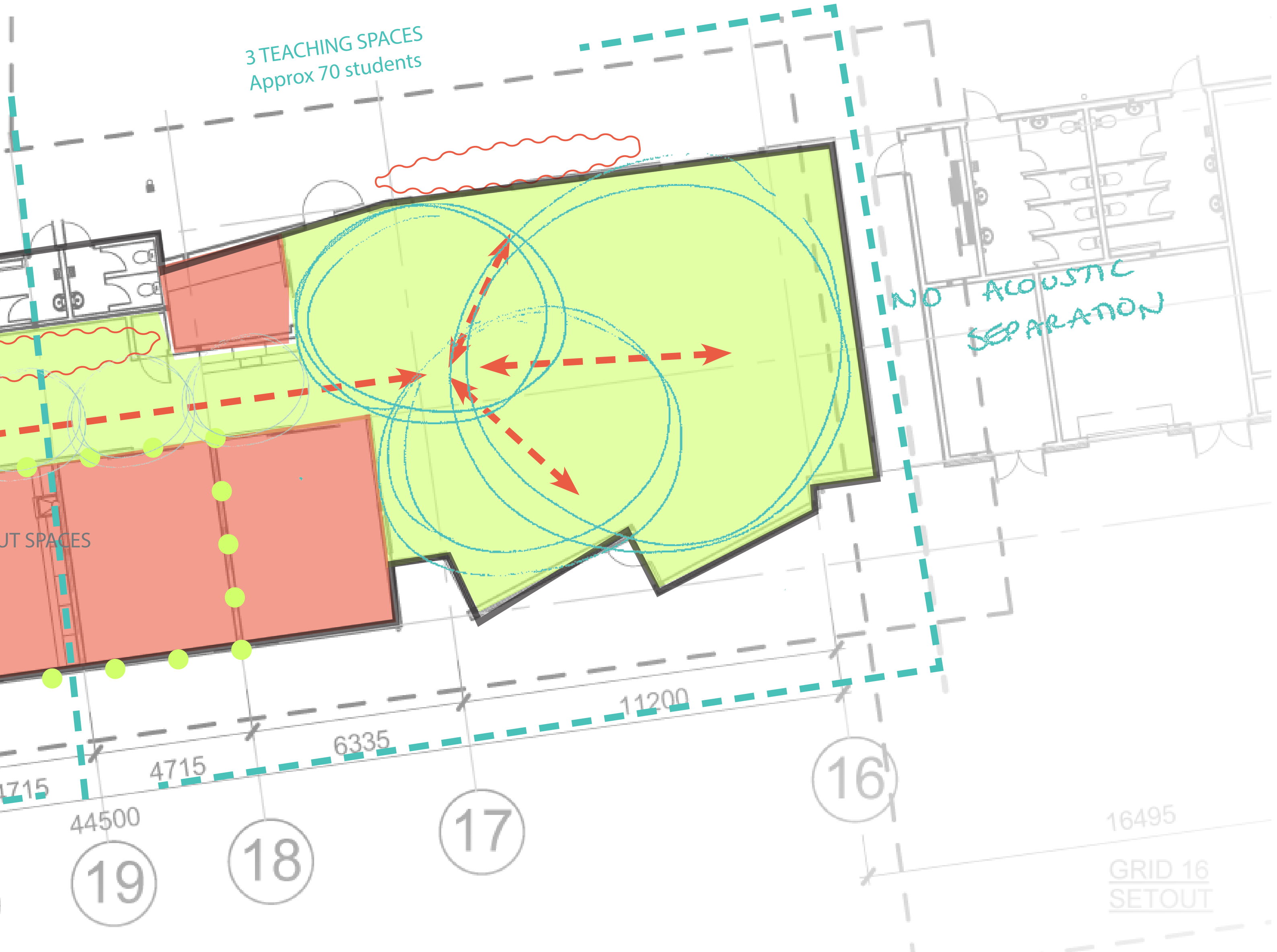


Fig 3.15. Pegasus Primary School: Analysed Floor plan


3 TEACHING SPACES
Approx 70 students
NO ACOUSTIC
SEPARATION
UT SPACES
1715
4715
6335
11200
44500
19
18
17
16
16495
GRID 16
SETOUT

3.5 Rangiora High School >

Jasmax
Canterbury, New Zealand.

Rangiora High School is located in the Canterbury region approximately thirty minutes' drive from Christchurch's CBD. The current school roll is approximately 1,200 students ranging from year nine to thirteen.[39]

Rangiora High School has been working with Jasmax architects to design and construct a new classroom block that consists of twenty eight teaching spaces which will be structured as Innovative Learning Environments (see new classroom block construction; LVL portal frame arrival, figure 3.16). This large scale Innovative Learning Environment will house a wide variety of specialised learning areas that cater to different secondary school subjects ranging from chemistry labs to common areas for students to 'hang out'.

Again, while not featuring prefabricated construction, Rangiora High has been selected as a case study to analyse the process of ILE and furniture testing which the school is currently working through.

Following site observation and survey analysis, Rangiora provided an insight into the different learning settings and furnishings that the students were most productive using, resulting in information that could be implemented into the Flexi-Ed design phases to follow.

Currently Rangiora are trialling the current Ministry of Education, Innovative Learning Environment design standards in a relocated building that was purchased and transported from Rangi Ruru Girls' High School in central Christchurch. The original layout of the purchased building consisted of two traditional classrooms, however Rangiora have created an opening in the intermediate internal wall, allowing the classrooms to transition into an open plan learning space.

Jasmax and Rangiora High are in the process of trialling this open plan space with year 9 students by performing two classes at a time. The furniture that is used within the classroom is constantly being rearranged and swapped out for alternatives based upon weekly surveys completed by the students (see flexible furniture trials, figures 3.18 - 3.19).[40]

The school has discovered that the teachers prefer not to have students working on equipment that has wheels, due to the distraction the students are causing for themselves and their peers. As for the students, they have noted in the surveys that the high tables and stools have been the most popular item of furniture to work with. This feedback is extremely important in preparation for the school as it begins the transition into a large scale innovative learning environment.

"I best envisage my learning environment as a space that is constantly evolving."

- Teacher Survey, Rangiora High School, June 2016

[39] Hays, Brian, Interview by Author. *Rangiora High School*. June 2016.
[40] Ibid

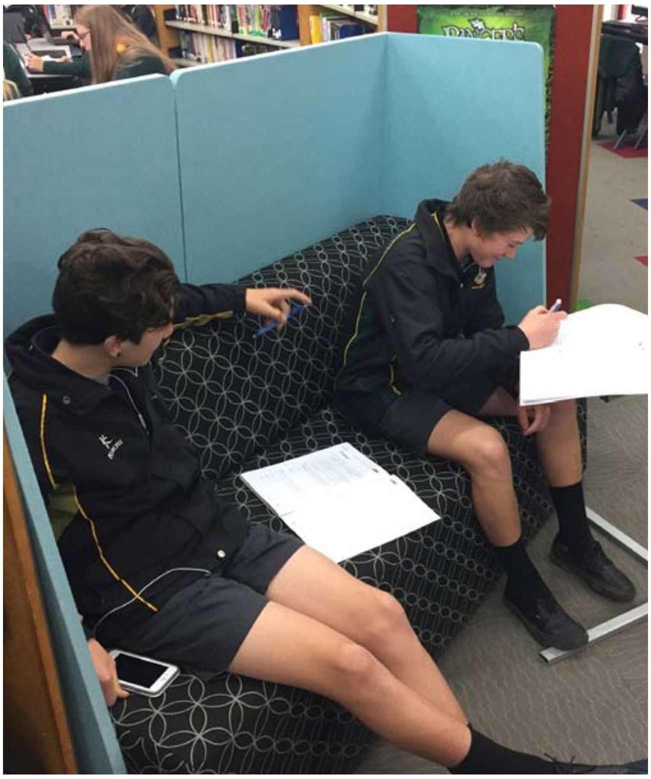


Fig 3.16. New classroom block construction; LVL portal frame arrival (top left)
Fig 3.17. New classroom block construction; LVL portal frame installation (top right)
Fig 3.18. Booth furniture trial (bottom left)
Fig 3.19. Flexible furniture trial (bottom right)

"Scientific observation has established that education is not what the teacher gives; education is a natural process spontaneously carried out by the human individual, and is acquired not by listening to words but by experiences upon the environment."
- Maria Montessori, 1947

4.0 THE DESIGN >

4.1 DESIGN APPROACH >

The prior sections discuss existing case studies along with the opportunities and constraints experienced by different construction techniques and products on the market relevant to the success of Flexi-Ed. By undertaking site observations and case study research the design phase began with a foundation of knowledge in an attempt to improve the existing situation for New Zealand schools.

This section, The Design, documents the process and approach that Flexi-Ed explored, taking in to consideration the initial research and findings, to produce a fitting system for the schools in need now and in the future.

The design approach for this thesis focused on achieving an Innovative classroom that conforms to, yet challenges aspects of the existing Ministry of Education design standards. Providing not only a more effective classroom space for the individual, but also addressing existing budget restraints.

The ILE movement attempts to address multiple learning settings that are undertaken within and around a typical teaching space. These learning settings encourage students to engage with different classroom activities and tasks using a student-led approach. These learning settings range from collaborative working paces, breakout nooks to outdoor learning spaces. In order to encourage a student-led environment which caters to the individual learner, these learning settings will be applied within the Flexi-Ed system.

Prefabrication has been selected to answer the question of flexibility that New Zealand Schools require, this observation is primarily due to the ability of being able to change more rapidly than traditional construction techniques, constantly catering to the different needs of the individual learner, and diverse sites.

The Canterbury Schools Rebuild Programme has been selected as a tool to test Flexi-Ed on differing sites across the greater Christchurch region, and challenge the system response to natural disasters and the repercussions this has caused to the enrolment numbers.

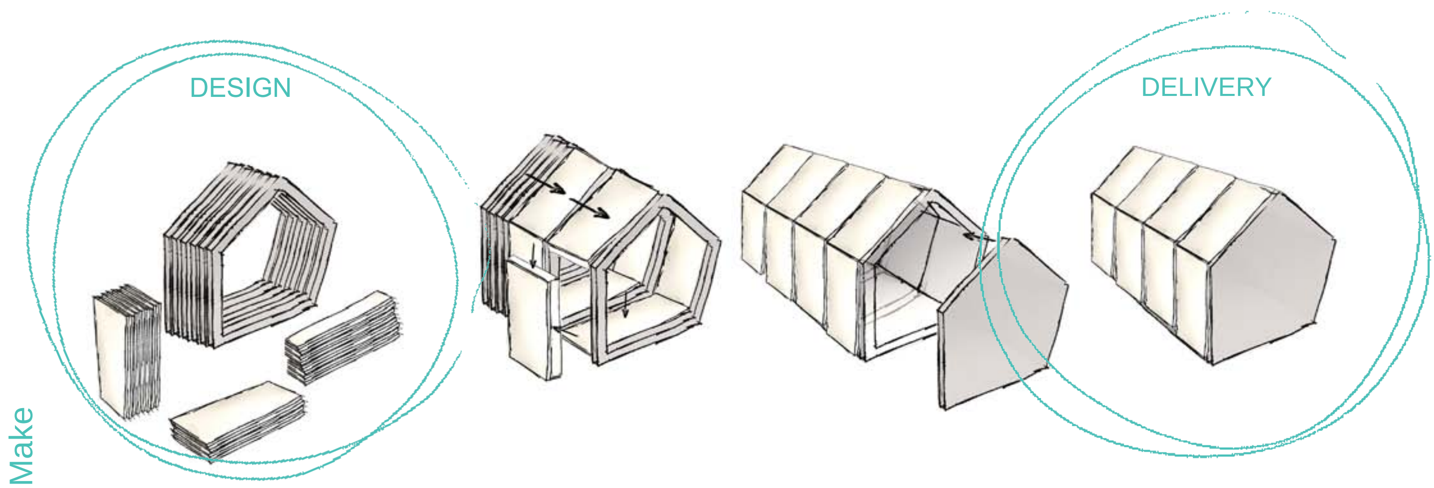


Fig 4.1. Prefabricated design approach illustration

4.2 DESIGN CONSIDERATIONS >

4.2.1 New Zealand Climate

Due to the unpredictable site and restricted transportation requirements for Flexi-Ed, there are some design considerations that must be outlined to ensure that this system is addressing the climate, transport and Ministry guidelines, prior to Preliminary Design.

In order to cater to the differing climates, research on the annual average rainfalls and temperatures has been undertaken to assess the different conditions across NZ, to allow Flexi-Ed to be effective across the country. Ultimately Flexi-Ed will address the differing New Zealand climates by providing unique designs that considers the control of light emitted into the interior, as well as the thermal comfort year round.

In order to efficiently cater to an array of sites, every proposed design will be assessed by the Flexi-Ed architect. An analyses of the thermal, solar and energy qualities of the classroom for the specific site will be undertaken and any concerns will be addressed before the project progresses into the construction phase.

Annual Averages for each region 1981 - 2010:
Resource from NIWA[41]

Region	Rainfall (mm)	Temp (‘C)
Northern	101.03	15.1
Central	115.48	13.7
Eastern	83.01	14.4
South-West	100.59	12.9
Northern	59.24	12.6
Inland	49.30	8.7
Eastern	51.51	12.2
Western	176.78	12.6
Southern	95.77	10.0

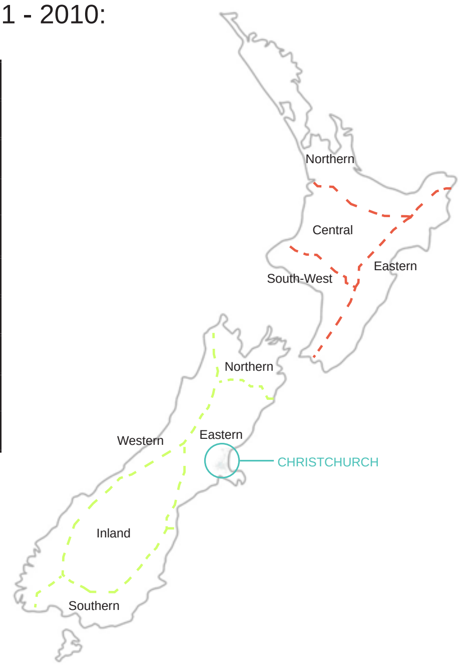


Fig 4.2. New Zealand region map

[41] National Institute of Water and Atmospheric Research (NIWA). “National and Regional Climate Maps.” *NIWA*. https://www.niwa.co.nz/climate/research-projects/national-and-regional-climate-maps, accessed 24th June 2016.

[42] Ministry of Education. “Space Entitlement.” *New Zealand Government*. http://www.education.govt.nz/school/property/state-schools/property-planning/space-entitlement/, accessed 14th April 2016.

[43] New Zealand Transport Agency (NZTA). “Land Transport Rule: Vehicle Dimensions and Mass 2002.” *Rule 41001/5* (2002): 21-25.

4.2.2 Size Restrictions

One restriction set by the Ministry of Education is the Space entitlement for classroom areas, this differs for primary and high schools.

Classroom Areas Entitlement[42]	
Max students/Class	25 Students/Teaching Space
Primary	87m^2 = 1 Teaching Space
Secondary	66m^2 = 1 Teaching Space

The area constraint will be implemented into Flexi-Ed, in order to produce an alternative option that caters to the existing Ministry of Education Space entitlement standards.

As prefabrication is the selected medium of construction, it is important to be aware of the constraints outlined for the transportation of panelised and volumetric buildings for site delivery.

Summary table of dimension limits:
Resource from NZTA[43]

Flatbed Truck Maximum Dimensions	
Height	4.8m
Width	11m
Building Length	27m
Overall Length	35m

By dimensioning the assigned classroom areas at a size that most efficiently uses the area of a flatbed truck, it allows the maximum number of teaching spaces to be transported at one time.

The selected dimensions for the school modules are as follows:

> High School: 11m x 6m
= 4 modules per flatbed truck

> Primary School: 11m x 8m
= 3 modules per flatbed truck

4.3 Materiality >

4.3.1 Material Options

Analyses of three different materials, reinforced concrete, timber and steel, were undertaken to determine the most suitable for the programme and application of Flexi-Ed.

Due to the aims and objectives set out by Flexi-Ed there a 4 key properties the selected material must provide in order to achieve an adequate learning environment:

> Excellent acoustic properties
> Good thermal qualities
> Light weight
> Low cost material

Although steel demonstrates a high strength to weight ratio and reduced construction time on-site, the increased cost due to maintenance and fire proofing made it an inappropriate material to apply to Flexi-Ed. As for reinforced concrete the high compressive strength and durable nature was let down by the heavy property of the material, therefore resulting in the selection of timber as the most adequate material for Flexi-Ed.[44]

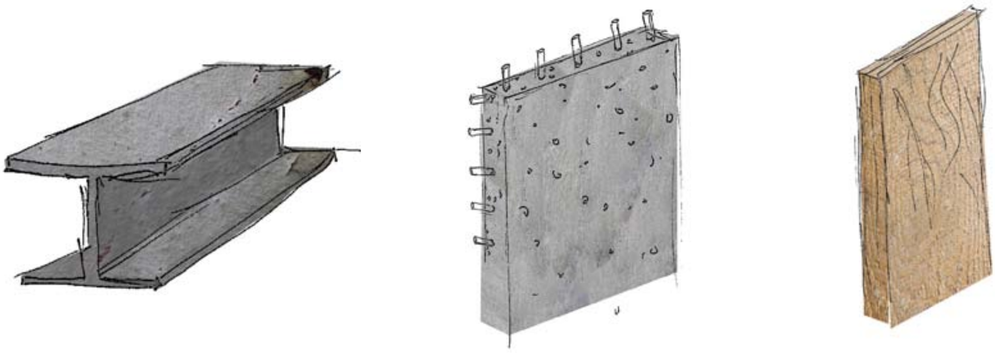


Fig 4.3. Illustration of assessed materials; steel, concrete and timber

4.3.2 Selected Material

Timber has been selected for Flexi-Ed due to the properties the material contains.

Acoustics:
As wood is a light material it is not suited for sound isolation, however it is ideal for sound absorption. Timber prevents the reverberation of noise by absorbing it.[45] In a classroom environment it is important to maintain an acoustic level with minimal reverberation to encourage students to concentrate and listen whether it be teacher led discussions or collaborative group work.

Thermal:
The thermal qualities of timber are approximately 400 times greater than steel and 14 times greater than concrete.[46] This high thermal performance of timber suits the classroom environment, as the teaching spaces are occupied

[44] Romie, Sheeraz. "Steel-Vs-Concrete and Timber." (2015): 6
[45] Romie, Sheeraz. "Steel-Vs-Concrete and Timber." (2015): 3
[46] Ibid
[47] Ibid
[48] Ibid

year round. Therefore timber will create the most comfortable thermal environment with the minimal amount of additional heating sources.

Cost:
The cost of timber structures are very low as the structures are often designed for low loads, strength and span.[47] The advantages of cost for timber assist in achieving a lower budget to meet client requirements and market competition.

Light Weight:
Timber has a high strength to weight ratio, which results in less structure required to brace the building against both seismic and wind loads.[48] The lightweight component allows the classrooms to be delivered with relative ease, and allows the teaching spaces to be more easily relocated as the school rolls require.

4.3.3 System Options

Three existing prefabricated systems were considered for Flexi-Ed and have been directly compared to the Portabuild modules to ensure that a more cost and energy efficient product is being used.

*The costing is approximate and based off of information researched from each company. Cost estimates are subject to change.

	Buy Cost	Panel/m^2	R Value
Welhaus	$44,928	$200	6.95
XLAM	$42,008	$159	2.5
Prefab 1	$47,443	$205	8.3
Portabuild	$50,185	n/a	n/a

After reviewing the appropriate prefabricated systems and directly comparing cost estimates, XLAM Cross Laminated Timber has been selected as the most cost effective system for the flooring, paired with Welhaus engineered wall panels and LVL timber trusses constructed within a CLT roof module. This choice has been selected based around the costing, acoustic analysis and the extremely high R values, which will ultimately reduce the life cycle costs of the building.

4.3.4 Selected Systems
Welhaus Engineered Welpanel

Welhaus is a Christchurch based company which specialises in prefabricated panelised technology. These panels are pre-manufactured from raw materials to panels in a factory environment within one week. Once delivered to site, it takes approximately 12 - 36 hours to gain a weatherproof structure.[49]

Welhaus have been selected as the system for Flexi-Ed wall panels based upon cost comparison along with two key properties which address the aims and objects for this thesis.

The first is the proposal of a much faster construction period (as much as 50%), helping to achieve a shorter construction time frame.[50] The reduced time frame allows the off-site production to become reduced, mirroring the on-site time reduction caused by the nature of prefabrication. By compressing the total construction period, clients are able to occupy the required classrooms almost immediately, addressing the unpredictable fluctuation in school rolls more effectively than other prefabricated panel providers.

Secondly, when joined together the timber engineered Welpanels achieve an airtight interior, ultimately reducing the life cycle costs for schools and provide comfortable internal environments year round (see Welhaus interior prototype example images, figures 4.5 - 4.7). The efficiency of the Welhaus design is primarily due to the thickness of the panels. Typical walls built to NZBC are 114mm thick whereas the average Welhaus wall is 238mm thick(see Welhaus engineered Welpanel make up, figure 4.4).[51] Thus resulting in superior R Value and a structure that gains 6+ stars on the Homestar Rating System (Typical home = 3.5+ stars).[52] It is important to achieve a high R value paired with an interior that is enjoyable and healthy for every season, due to the required occupation year round in a school environment.

Through both cost comparison and improved environmental conditions Welhaus Welpanels have demonstrated that they are the most suitable option for Flexi-Ed. The Welpanel will be developed through the design phase to enhance the panel, and allow the system to directly address a classroom environment, paired with enhancing the concept of Innovative Learning Environments.

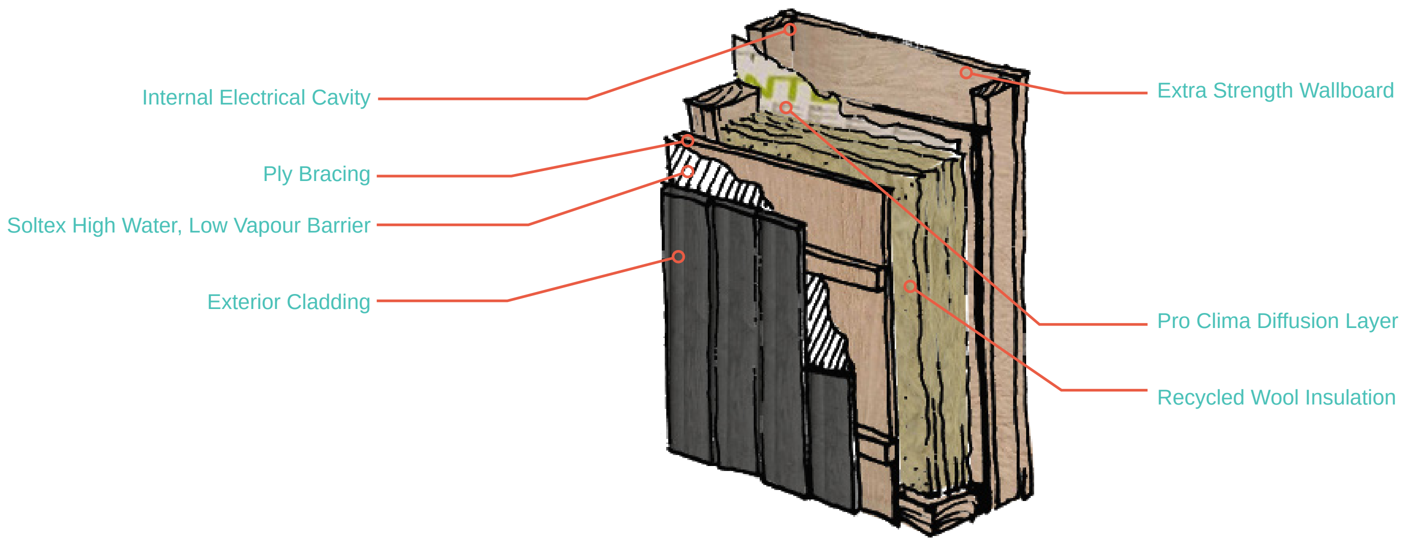


Fig 4.4. Welpanel illustration

[49] Tremewan, Dan, Interview by Author. *Welhaus*. May 2016.
[50] Ibid
[51] Tremewan, Dan. “Welhaus Hybrid Construction System, Green Tech Pre-Engineered Panels.” *Welhaus*
[52] Ibid

CLT Floor and Roof System

In New Zealand Cross Laminated Timber, also known as CLT, is made from NZ Radiata. Each panel is fabricated by alternating the grain orientations of each layer of wood veneer when bonded together, improving the structural properties by distributing the along-the-grain strength of timber in both directions.[53]

CLT is the best solution for Flexi-Ed primarily due to the Innovative Learning Environment application, requiring open plan interior spaces, resulting in a demand for a system that has the ability to span long distances.

CLT addresses the flexibility objectives of this thesis through both the material weight and recyclable properties. The system is approximately 20% the weight of concrete, as well as being recyclable, allowing the classrooms to be more easily transported and then disassembled when necessary.[54]

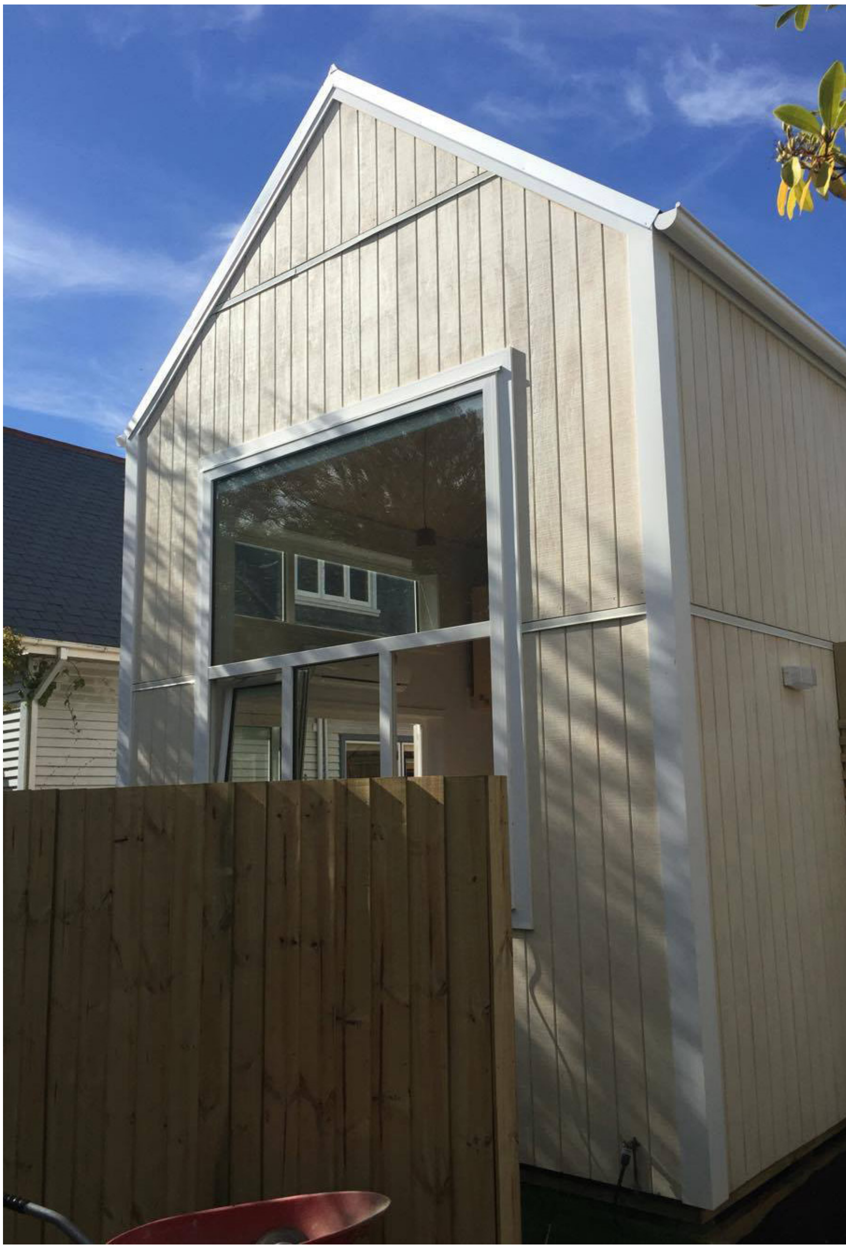
CLT also contains improved acoustic and thermal performance, reducing the need for additional insulation and aid in controlling the interior acoustics of an open plan classroom. Along with the improved performance, the panels have the opportunity to have wiring pre-installed, reducing on-site construction time and providing a structure that is ready to go almost instantly after being delivered to site.[55]

Finally the structural stability of the timber system has the properties to span a width of 3.45m and length of 15.1m, with a range of panel thickness from a 60 to 350mm.[56] This significant material property is ideal for open plan classrooms as they have the ability to span the required distance without the interference of vertical structural elements.

As outlined earlier the selected teaching spaces consist of 11m x 8m for primary schools and 11m x 6m for High Schools to align with transportation requirements. The spanning capabilities of CLT requires a maximum of one CLT joint in the floor and roof cassettes, reducing additional structural elements required and limiting the joints in the Flexi-Ed system.

[53] Scmidt, J., and C.T Griffin. "Barriers to the Design and Use of Cross-Laminated Timber Structures in High-Rise Multi-Family Housing in the United States." *Portugal, July 24, 2013.* ICSA, 2013.
[54] Tretheway, Warren, Interview by Author. *XLAM*. July 2016.
[55] Scmidt, J., and C.T Griffin. "Barriers to the Design and Use of Cross-Laminated Timber Structures in High-Rise Multi-Family Housing in the United States." *Portugal, July 24, 2013.* ICSA, 2013.
[56] Tretheway, Warren, Interview by Author. *XLAM*. July 2016.

From Left
Fig 4.5.   Welhaus: Manchester Street; Skylight
Fig 4.6.   Welhaus: Manchester Street; Roof panel
Fig 4.7.   Welhaus: Manchester Street; Stairway
Fig 4.8.   Welhaus: Manchester Street; Exterior



4.4 PRELIMINARY DESIGN >

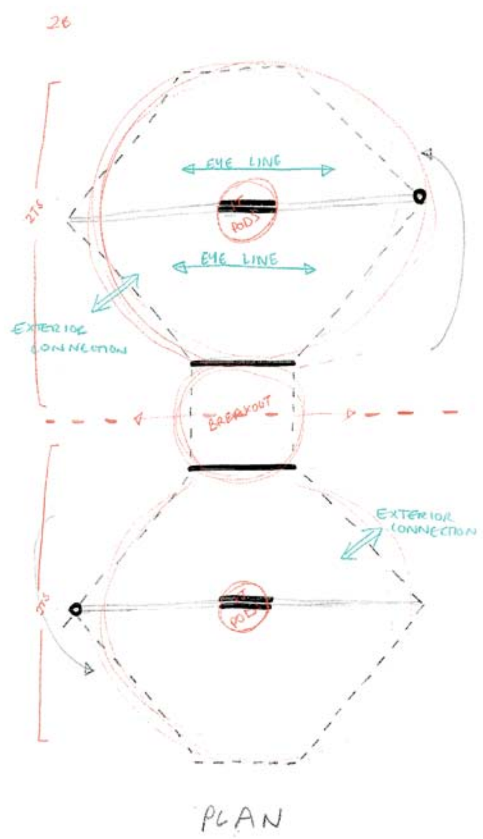
4.4.1 (A) Preliminary Sketches

The preliminary research into New Zealand schools demonstrates that the concept of Innovative Learning Environments is being embraced, however they are currently not operating to the maximum efficiency with the existing ILE design standards outlined by the Ministry of Education.

The primary area of improvement focuses on the desire to control acoustics in an open plan environment. Flexi-Ed will challenge the standards that have been highlighted as issues during the research phase, to produce a heightened standard of learning environments.

The design phase of Flexi-Ed began by using the methodology of layering, using sheets of butter paper on top of one another to collectively analyse a collation of Innovative Learning Environments in action across the country.

After highlighting the physical areas of concern, five quick fire concept sketches were produced, using multiple layers of butter paper to test the contribution surface and form have within a classroom environment (see Preliminary concept sketches, figure 4.9). From these quick fire concepts, the module and panel concepts were selected to progress and develop into concept design (see module and panel concept, figures 4.10 - 4.11).



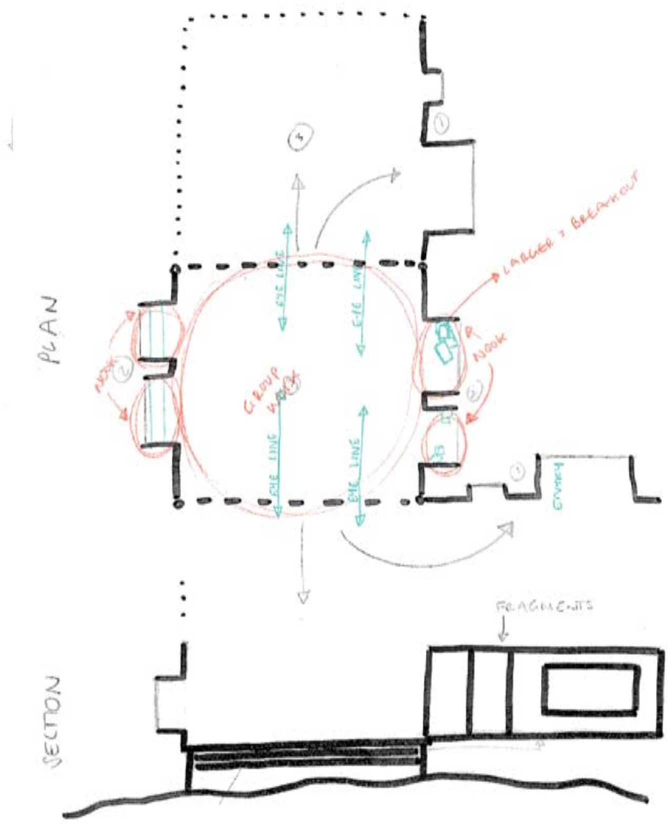
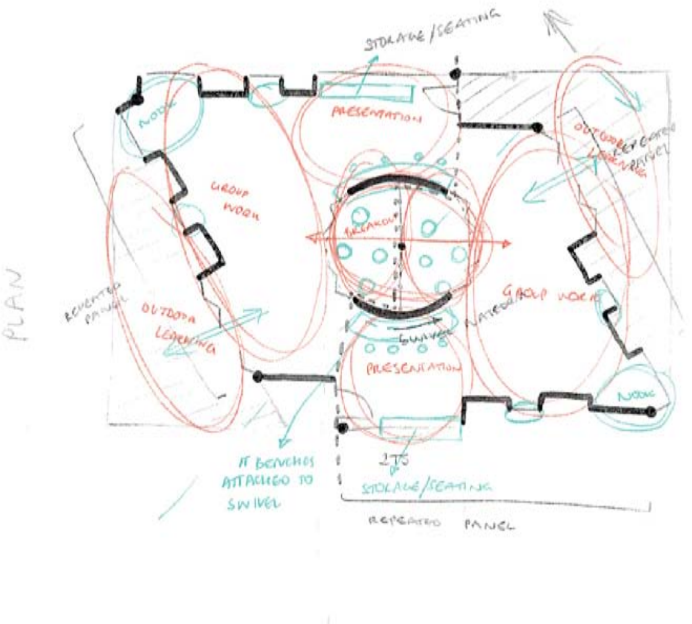
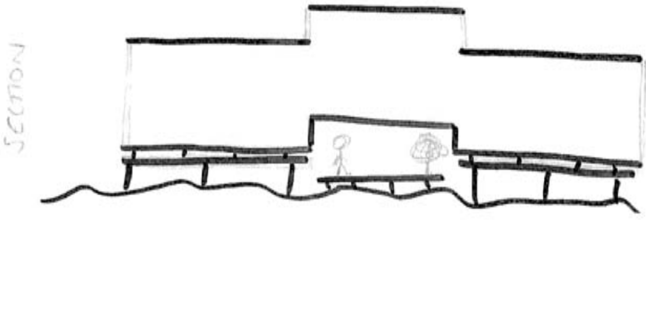
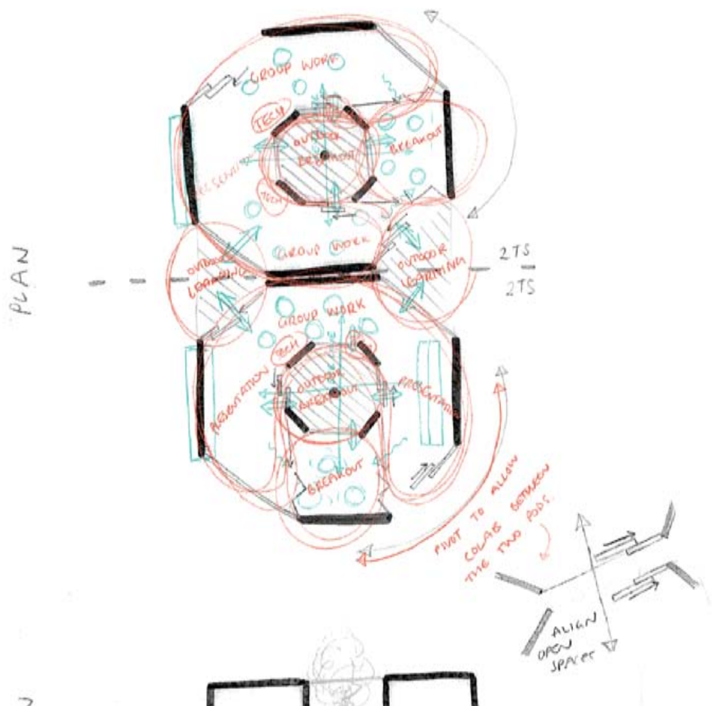
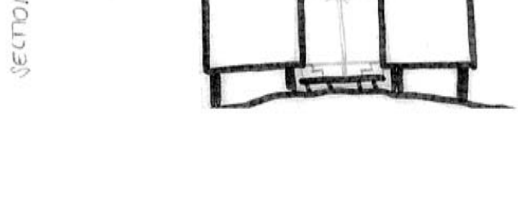


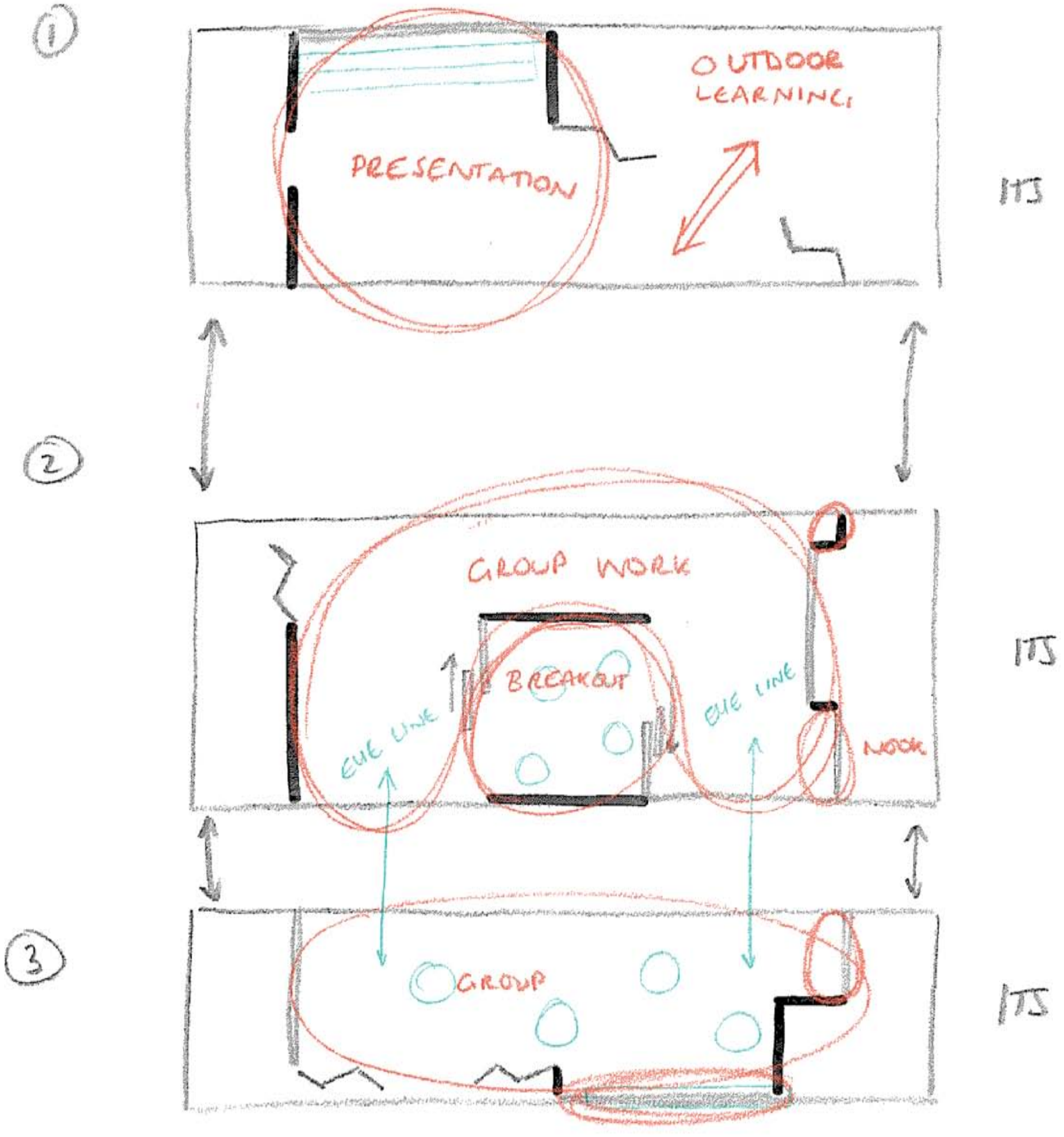
Fig 4.9. Preliminary concept sketches
Fig 4.10. Preliminary sketch - Module concept (over page left)
Fig 4.11. Preliminary sketch - Panel concept (over page right)

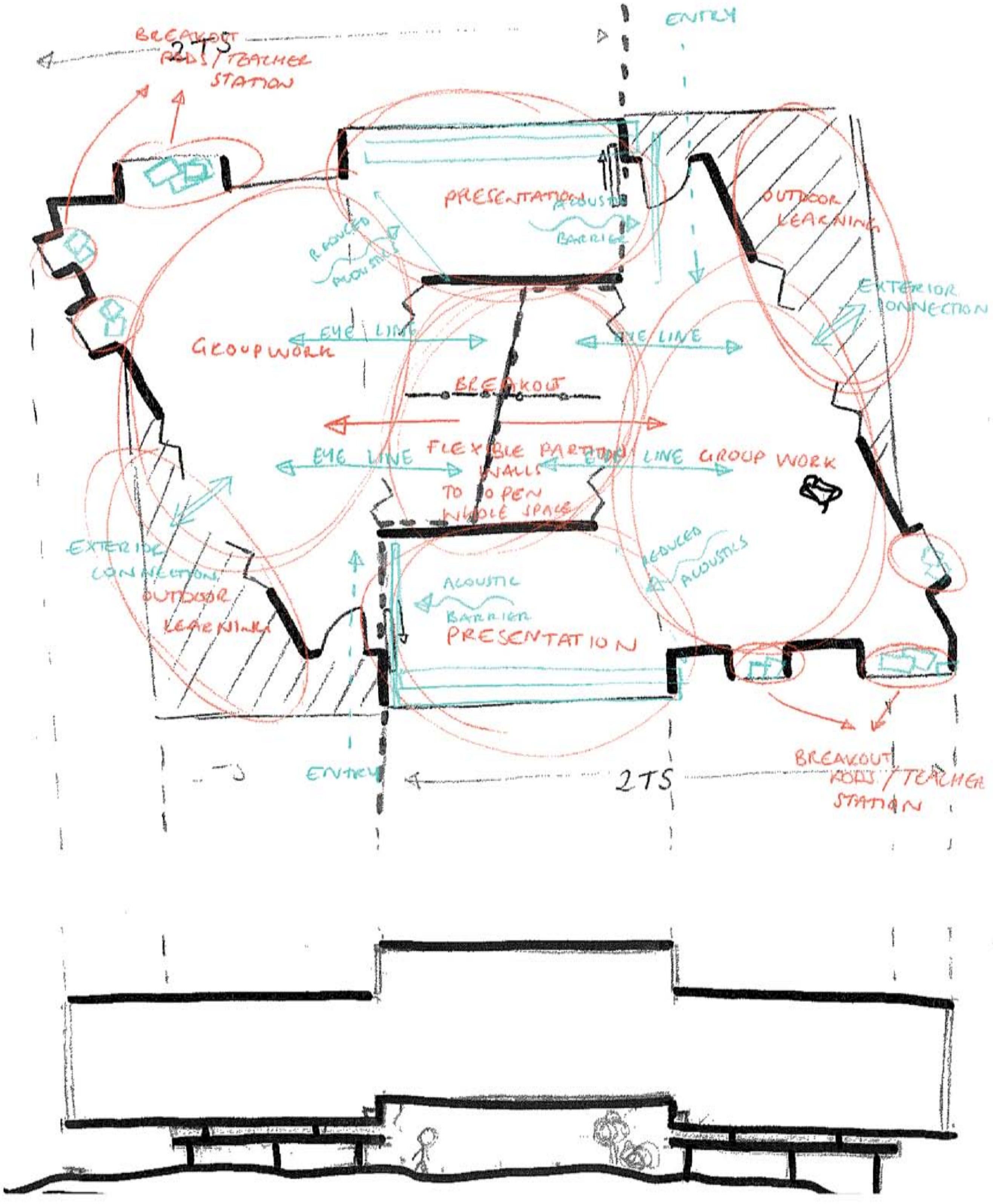

STORAGE/SEATING
PRESENTATION
GROUP WORK
BREAKOUT
OUTDOOR LEARNING
PLAN
PRESENTATION
STORAGE/SEATING
REPEATED PANEL


SECTION

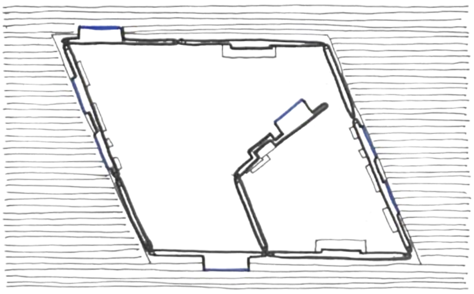

GROUP WORK
BREAKOUT
OUTDOOR LEARNING
PLAN
GROUP WORK
BREAKOUT
ALIGN OPEN SPACES

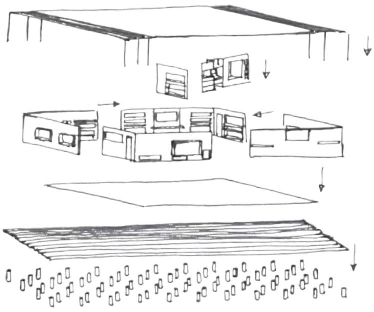

SECTION

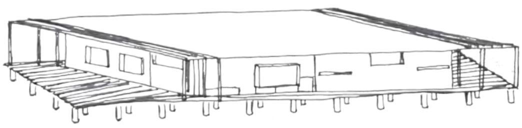

1
OUTDOOR LEARNING
PRESENTATION
2
GROUP WORK
BREAKOUT
EYE LINE
EYE LINE
NOOK
3
GROUP


ENTRY
BREAKOUT PODS / TEACHER STATION
2TS
PRESENTATION
ACOUSTIC BARRIER
REDUCED ACOUSTICS
OUTDOOR LEARNING
EXTERIOR CONNECTION
EYE LINE
GROUP WORK
BREAKOUT
EYE LINE
EYE LINE
FLEXIBLE PARTITION WALLS TO OPEN WHOLE SPACE
EYE LINE
GROUP WORK
EXTERIOR CONNECTION
OUTDOOR LEARNING
REDUCED ACOUSTICS
ACOUSTIC BARRIER
PRESENTATION
ENTRY
2TS
BREAKOUT PODS / TEACHER STATION

4.4.2 (B) Panel Concept







After preliminary design, a developed panel system was explored. The panel concept consists of six different panel types which have been sized to fit within the dimension restrictions of a flatbed truck as well as the outline floor cassette sizes for both primary and high schools.

Each panel has been designed with a specific programme application that addresses the needs of the everyday classroom environment.

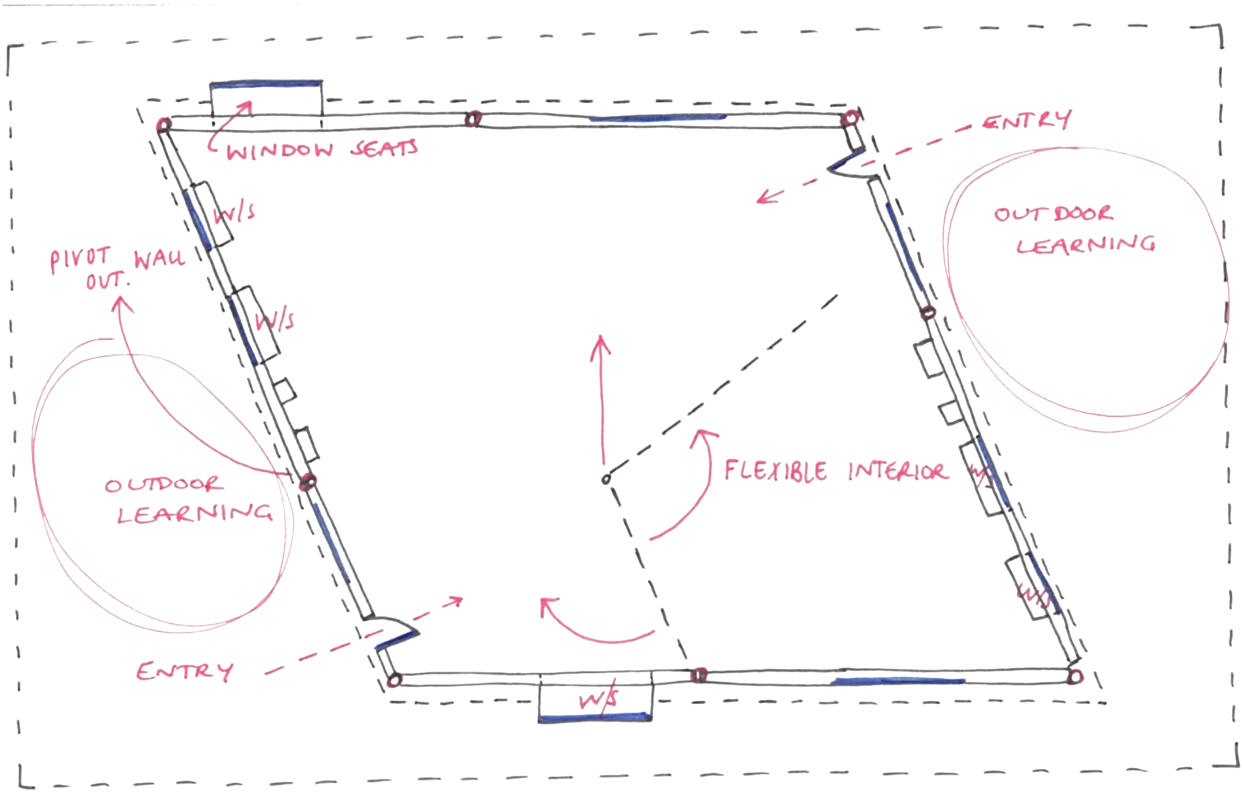
These programmed panels consist of:
> Storage/exterior access panel that enhances the connection to outdoor learning environments.
> Interactive panel that houses electrical and data points catering to the transition to paperless classrooms.
> Study Nook panel that attempts to provide segregated areas for individuals and small group work.

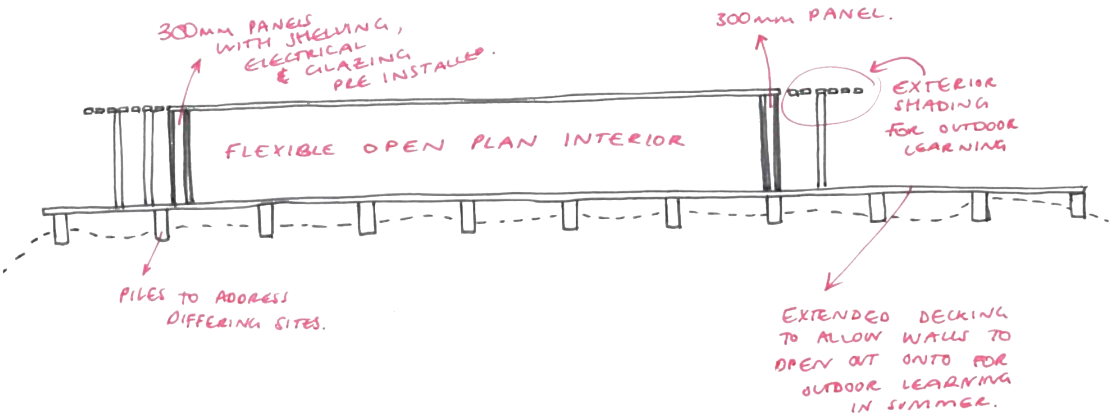
The panels are designed to provide hourly flexibility within the classroom, using interior pivot points which allow the internal panels to swivel within the learning environment, adjusting to the ever changing needs of the classroom (see panel concept; floor plan sketch, figure 4.14).

It is intended that the panels have the ability to be exchanged, rearranged and re-cycled on a school term or annual basis to address the different students expected to occupy the classroom during the buildings' lifetime (see demonstration of panel removal, figure 4.19).

An assessment was made on the limitations and concerns of the panel concept. The physical model raised concerns of the structural stability and whether the interchanging panels would be a feasible concept for a school. The treatment of acoustics within the interior is also limited and does not address the alterations that the existing MoE design standards needs.

Fig 4.12. Exploded axonometric (top)
Fig 4.13. Physical Model: Panel concept (bottom)
Fig 4.14. Floor plan sketch (top left)
Fig 4.15. Section sketch (bottom left)


WINDOW SEATS
ENTRY
OUTDOOR LEARNING
PIVOT WALL OUT.
W/S
W/S
FLEXIBLE INTERIOR
OUTDOOR LEARNING
ENTRY
W/S


300mm PANELS WITH SHELVING, ELECTRICAL & GLAZING PRE INSTALLED.
300mm PANEL.
EXTERIOR SHADING FOR OUTDOOR LEARNING
FLEXIBLE OPEN PLAN INTERIOR
PILES TO ADDRESS DIFFERING SITES.
EXTENDED DECKING TO ALLOW WALLS TO OPEN OUT ONTO FOR OUTDOOR LEARNING IN SUMMER.

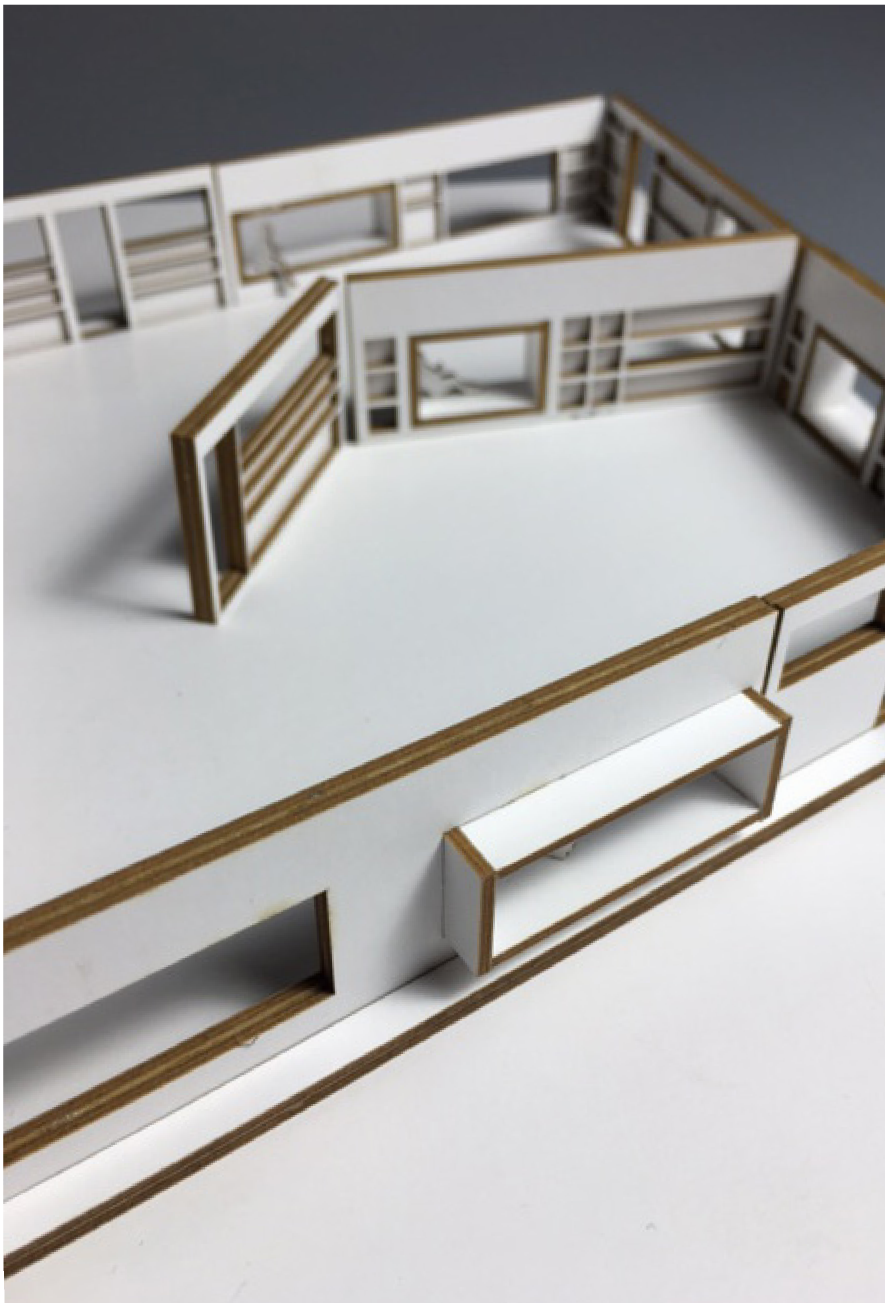
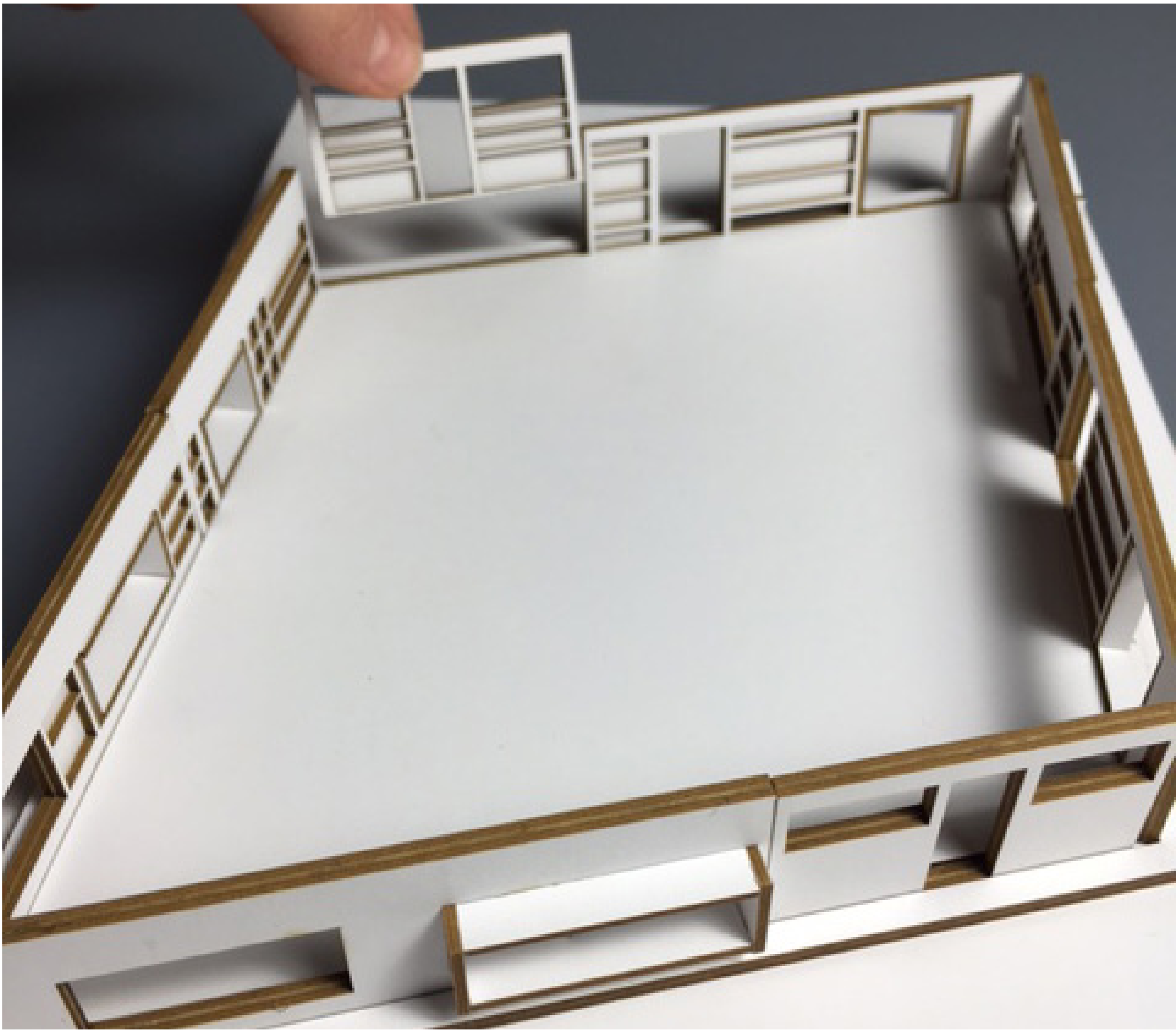
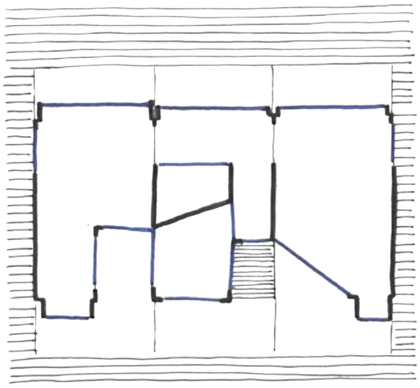
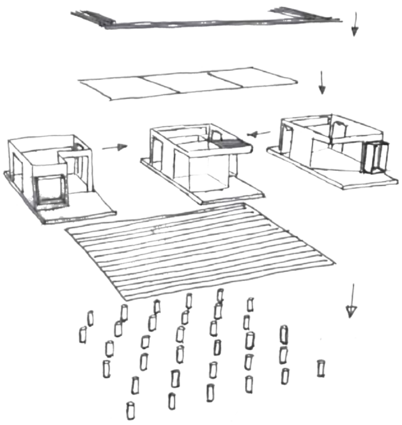


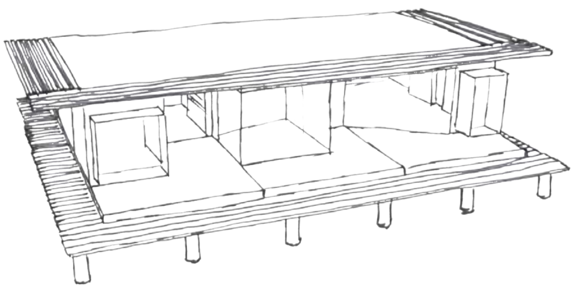
Fig 4.16. Interior view study nook (top left)
Fig 4.17. Interior view of flexible panels (bottom left)
Fig 4.18. Overview
Fig 4.19. Demonstration of panel removal (far right)



4.4.3 (C) Module Concept







Following the panel system concept design, a second concept design was developed, based on modules. Modules were selected to assess the different constraints and opportunities the volumetric prefab typology produces to provide a direct comparison to the previous panel concept.

The module concept consists of three different module types that have been sized to align with the Space Entitlement Areas outlined by the Ministry of Education.

The three modules have been specifically designed to cater to three different programmes required in a classroom environment, similar to the panel concept.

These three programmes consist of:
> Breakout pod for small group and individual learning.
> Open Plan pod for large group collaboration.
> IT pod to align with the current transition to paperless classrooms.

The module design follows a grid system, allowing each pod to align with one another in multiple configurations. It is intended that the arrangement of the modules have the capacity to be reconfigured on-site on a termly or annual bases (see Module concept; Floor plan sketch, figure 4.22).

This flexibility in arrangement provides schools with a system that can be configured by the school, for the school, allowing the education community to gain some control over the classroom composition and design prior to site installation and during the classrooms life time.

The physical model reinforces the flexibility of this modular concept, demonstrating the multitude of configurations that can be applied (see possible configurations, figures 4.26 - 4.27), as well as the opportunity for mass customisation reducing construction costs long term.

The limitations of this concept is seen in the lack of site flexibility and climate adaptation which the different schools sites across New Zealand require, limiting the market that the module concept would be applicable to.

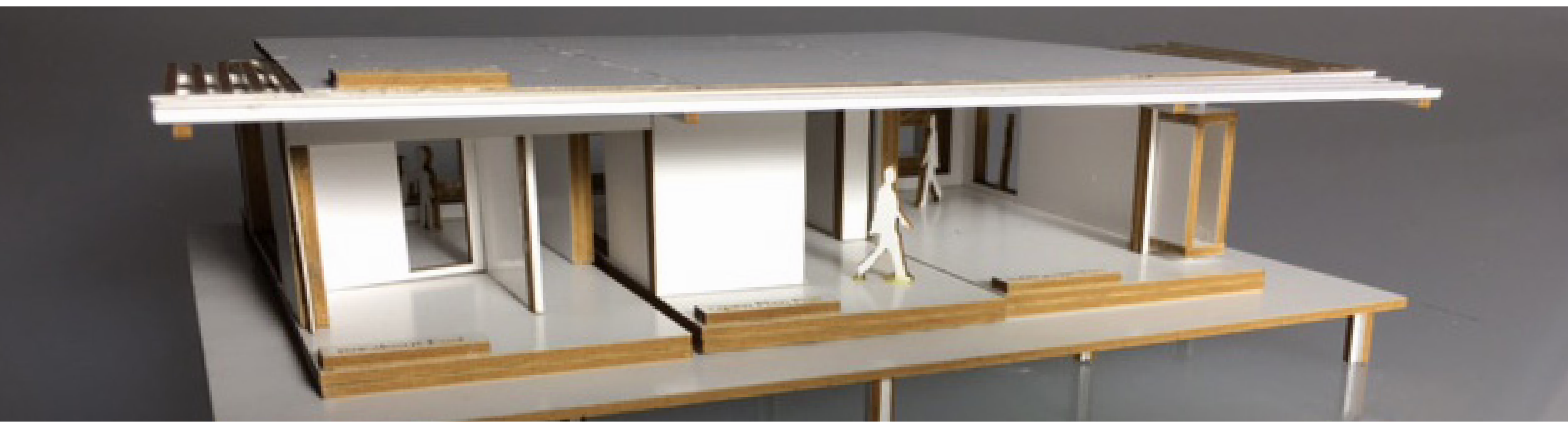
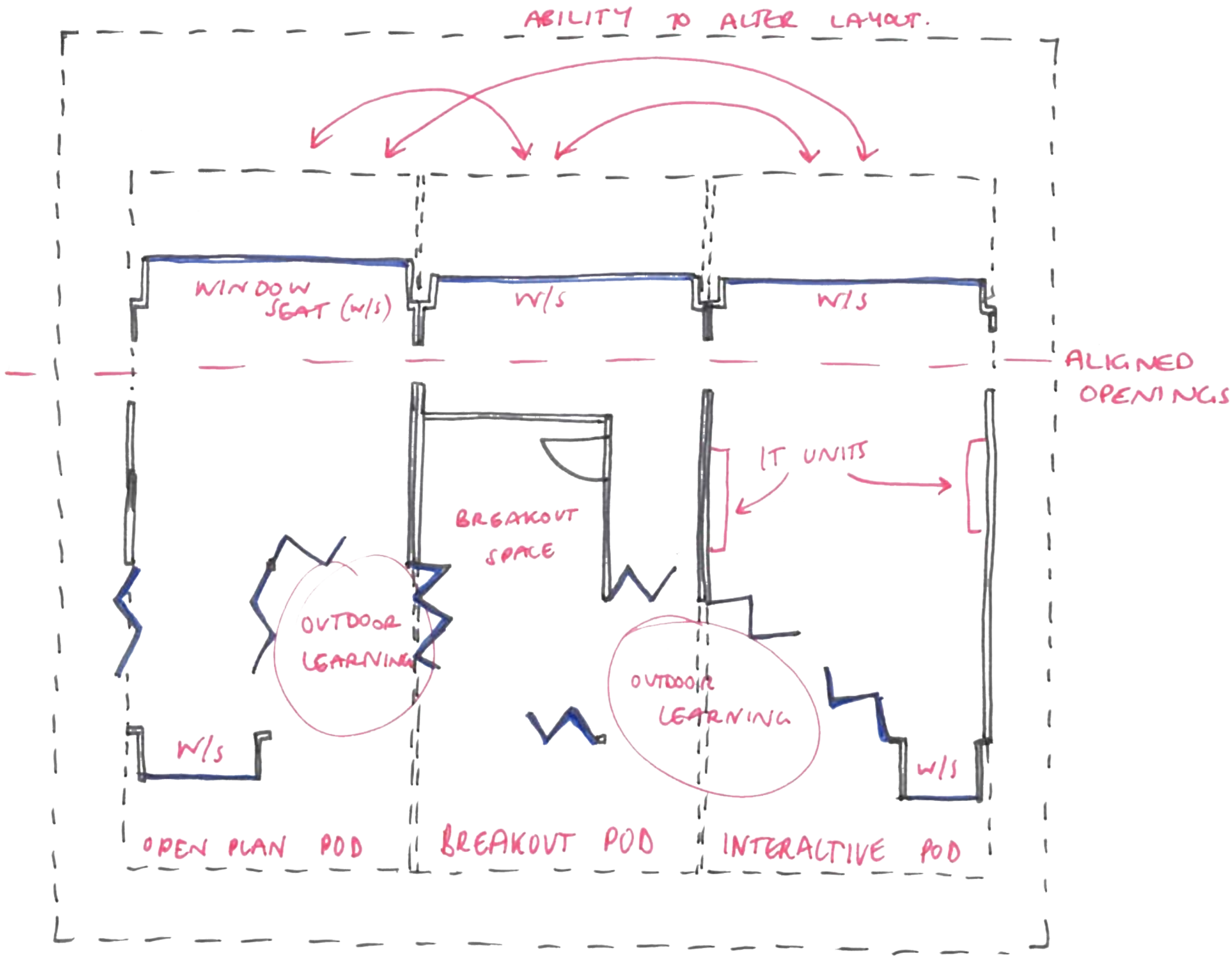


Fig 4.20. Exploded axo (top)
Fig 4.21. Physical Model: Module concept (bottom)
Fig 4.22. Floor plan sketch (top left)
Fig 4.23. Section sketch (bottom left)


ABILITY TO ALTER LAYOUT.
WINDOW SEAT (W/S)
W/S
W/S
ALIGNED OPENINGS
IT UNITS
BREAKOUT SPACE
OUTDOOR LEARNING
OUTDOOR LEARNING
W/S
W/S
OPEN PLAN POD
BREAKOUT POD
INTERACTIVE POD

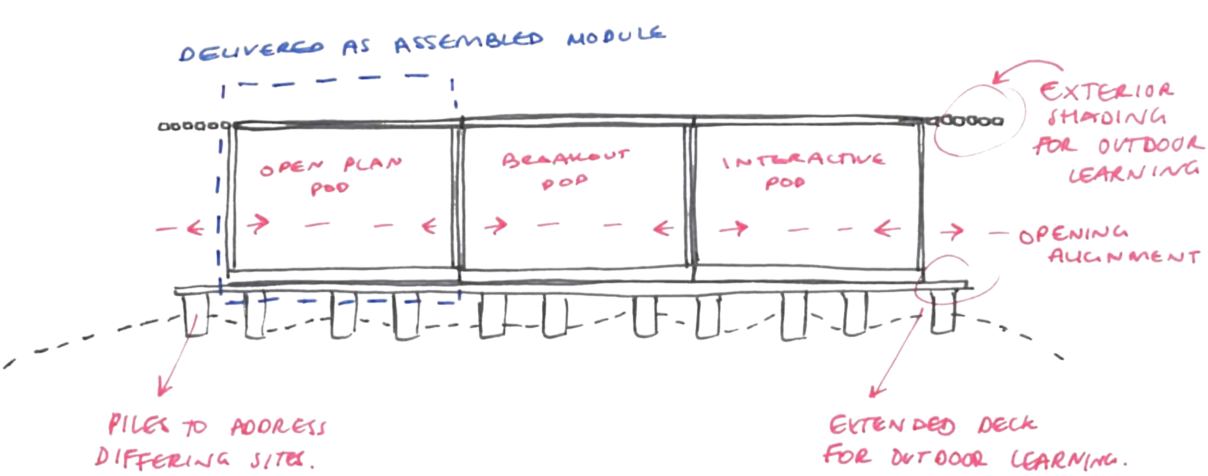
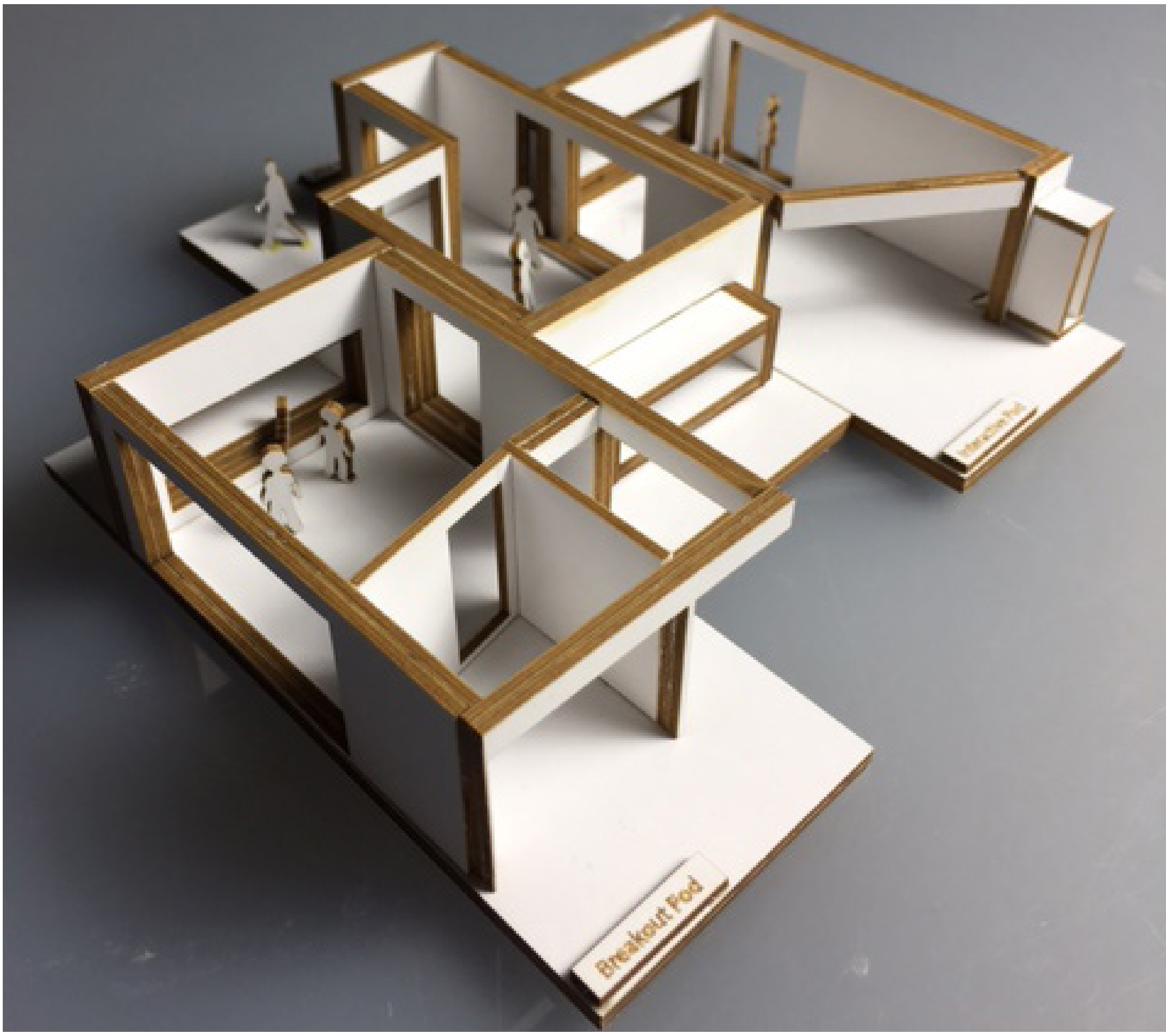

DELIVERED AS ASSEMBLED MODULE
EXTERIOR SHADING FOR OUTDOOR LEARNING
OPEN PLAN POD
BREAKOUT POD
INTERACTIVE POD
OPENING ALIGNMENT
PILES TO ADDRESS DIFFERING SITES.
EXTENDED DECK FOR OUTDOOR LEARNING.

Fig 4.24. Interior connection (top left)
Fig 4.25. Interior connection and study nook (bottom left)
Fig 4.26. Possible configuration options
Fig 4.27. Alternative configuration options (far right)


Breakout Pod

4.5 CONCEPT DESIGN >

4.5.1 (D) Hybrid Design
Preliminary Design Analysis

In June, these preliminary design concepts were presented for critique at an architecture firm heavily involved in school design. The response encouraged more thought into the site specifics of the design and questioned how the concept could progress forward by catering to each and every school.

As a result of the feedback received, the design process progressed into a Hybrid design approach of both the Panel and Module concept, maximising the different opportunities seen within both and eliminating the constraints; attempting to provide a more customisable design that caters to the differing sites across New Zealand.

Hybrid Design Approach

The Hybrid design is a developed product which builds on critical self-analysis and utilizes the feedback received up to this point in the Flexi-Ed design phase.

The Hybrid design system consists of (see Hybrid approach collection, figure 4.28):

CLT Floor Cassette

> Two cassettes have been produced, sized to the space entitlement equivalent of one teaching space for both primary (11m x 8m) and high school (11m x 6m)

Welhaus Engineered Welpanels

> Four individually programmed Welpanels that apply to a specific learning setting of an ILE classroom.
These programmes consist of:
> IT wall
> Make Space
> Breakout Nook
> Gateway to outdoor learning

These panels are manufactured in three different lengths to apply to the specified floor cassette parameters.

CLT Monopitch Roof Module

> Four different designs to address the direction and percentage of light emittance for differing sites across New Zealand.

Flexi-Ed is to be designed by the client using a step-by-step selection process (see market approach 4.5.2, page 74). This process has been set up via a user friendly website which guides the client through the design from floor cassette sizes, all the way through to interior and exterior panel finishes.

Therefore each pre-designed panel is selected by the schools, for the school site. Ultimately giving clients the ability to take partial control of the design configuration, whilst being streamlined by the pre-designed panels. This will encourage classroom designs that are both site specific and cater to the unique pedagogies of the schools.

Once the design selection process has been completed, the panels are constructed off-site and then configured as modules along with the floor cassettes ready for site delivery, each equivalent to one teaching space.

Each module has the ability to be added and subtracted with relative ease on-site, to cater to the required number of teaching spaces within a school. On-site a single module can be removed and replaced with a panel to reduce the number of teaching spaces by one, or vice versa if the roll increases. The removed modules then have the opportunity to be transported to nearby schools on a flatbed truck or dismantled into panels and recycled for other schools working with Flexi-Ed.

By providing a system that is designed as panels and delivered as modules, it will maximise the design customisation whilst promoting a reduced on-site period, primarily due to the module application.

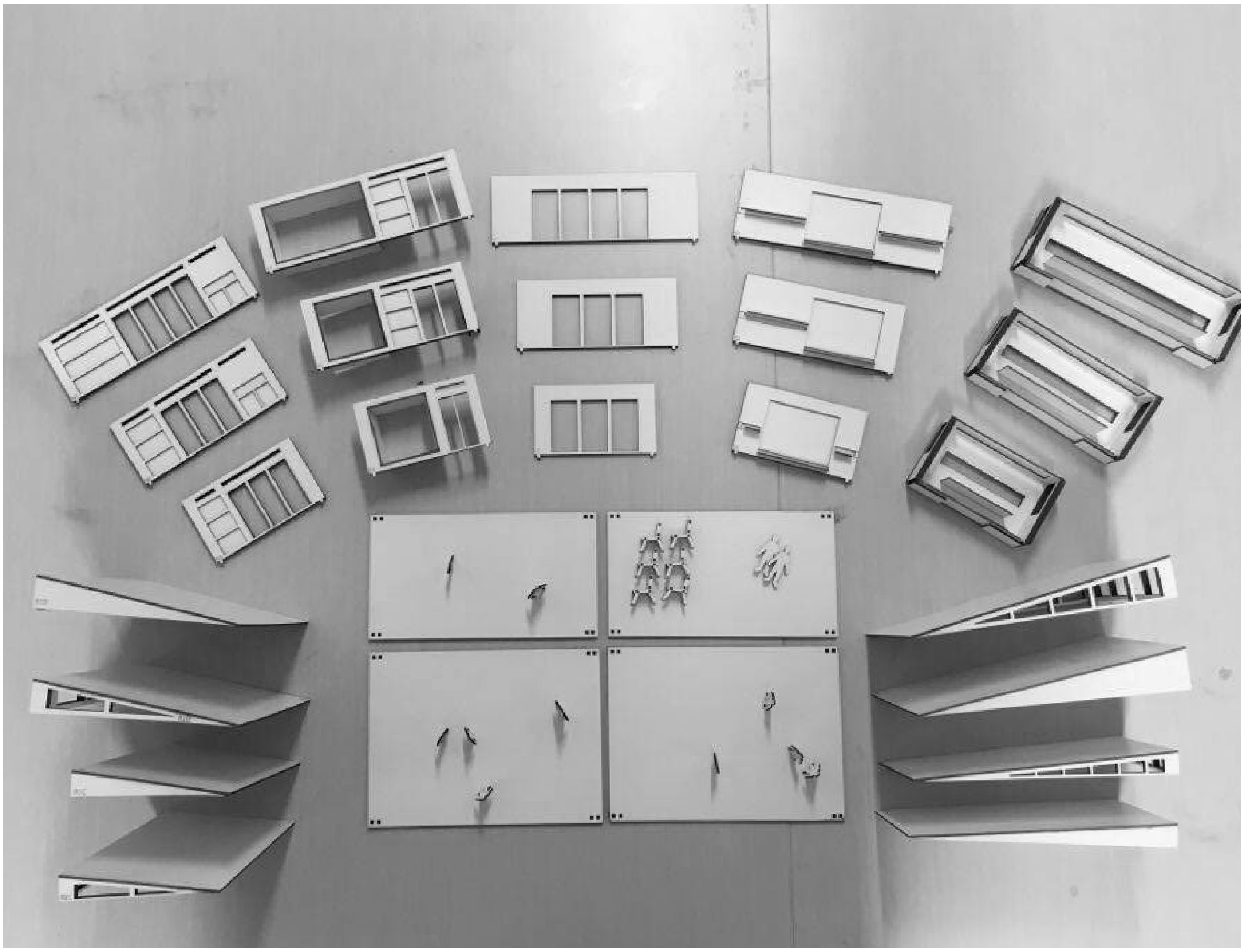


Fig 4.28. Hybrid approach collection

Hybrid Approach Considerations

The Hybrid design focuses on two key areas of consideration which will affect the success and marketability of Flexi-Ed, these are addressing the site specific climates nationwide and the altering budgets experienced from project to project.

The climate has been a key driver for the design of the individual panels, as well as a catalyst for addressing the budget. Each panel has been designed specifically for an orientation, North, East, South or West, by considering the solar and thermal qualities of each direction as a singular element. This analyses and orientation specific process allows Flexi-Ed to produce a design that attempts to allow for passive lighting, heating and ventilation of the interior, and as a resultant reduces the life cycle costs of the building.

Each panel has been designed with a specific orientation and programme in mind. The selected programme for each panel has been designated to address the solar and thermal qualities that the orientation requires.

North Panel: Outdoor Learning

The North face has been designed to maximise the amount of natural light emitted into the interior by installing a high percentage of glazing, thus also enabling passive cooling and heating.

As a panel which contains a high percentage of glazing the designated programme of an access way to exterior learning spaces is well suited. Including bi-folding exterior doors along with a variety of storage nooks, encouraging students as they enter the classroom to store their belongings away.

South Panel: IT Wall

The South face has been designed with a minimal percentage of glazing to increase the thermal insulation for the coldest orientation of the classroom.

As a panel that requires a small amount of glazing the panel has been programmed as an interactive wall. Providing the classroom with a panel that has data and electrical all pre-installed within the panel service cavity, enabling students to use electronic devices and tools.

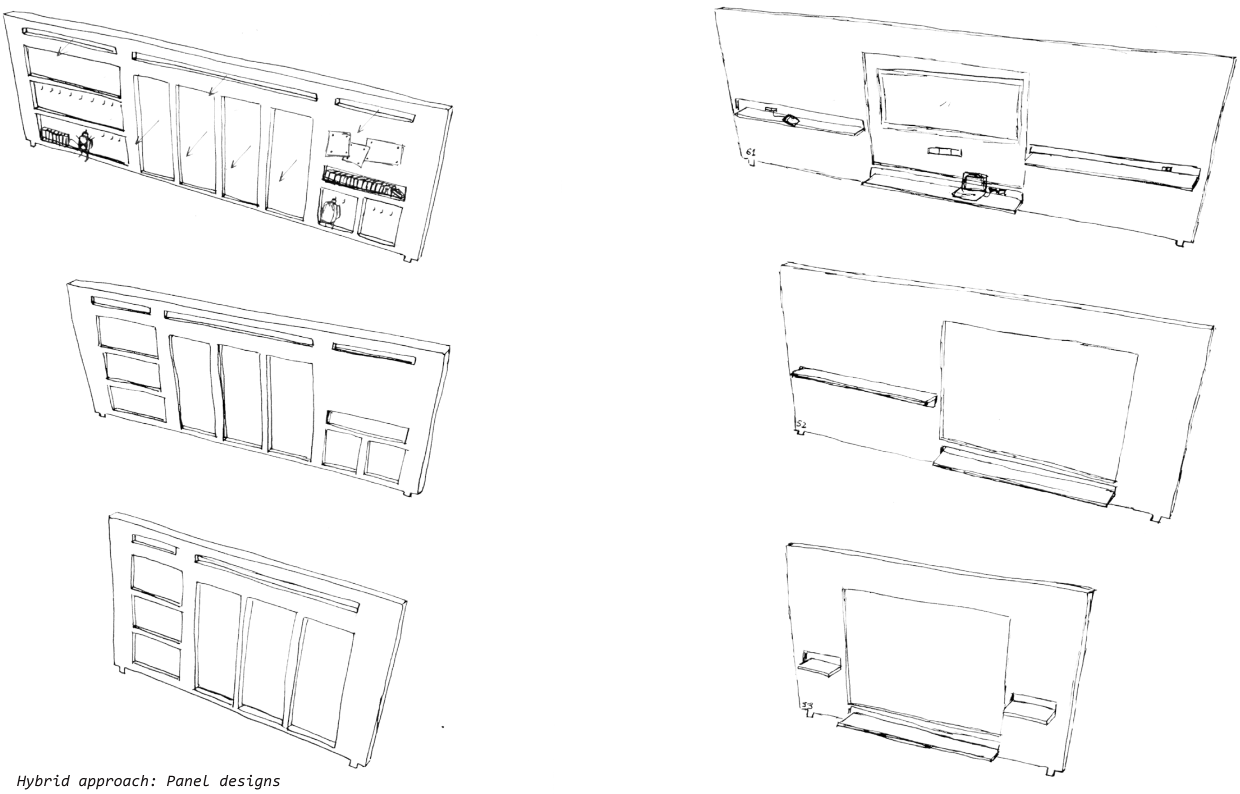
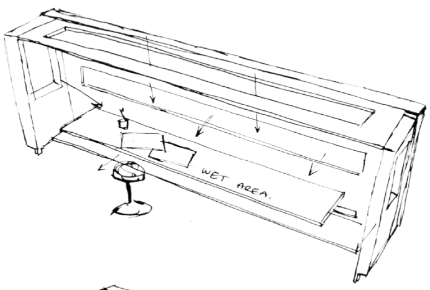


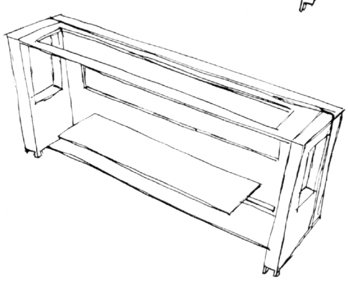
Fig 4.29. Hybrid approach: Panel designs

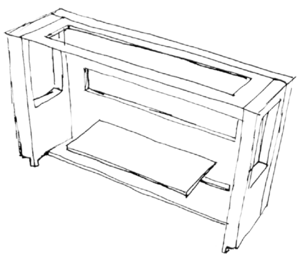
West/ East Panel: Make Space

The East and West panels have been deemed suitable for two different programme applications, the Make Space and the Breakout Nook.

The Make Space has been designed with differing window heights to activate both the floor and desk plane, providing students with various work spaces and levels to address the individual learner. The panel caters to kinaesthetic activities where students are likely to make mess, such as painting, drawing and modelling.

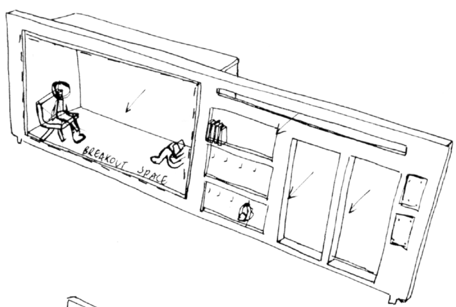


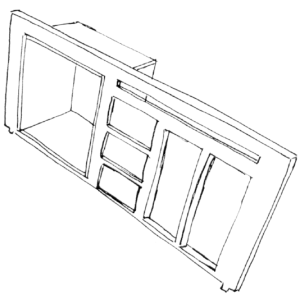


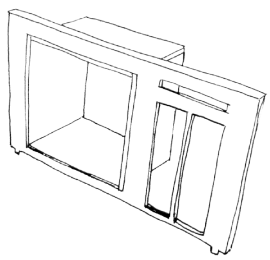


West/ East Panel: Study Nook

The study nook has been designed to provide students with a ‘breakout’ nook for smaller group study, which is segregated from the main learning space. The nook has been elevated above the central learning hub plane to differentiate the learning settings between the two areas, encouraging students to engage with the spaces with an appropriate style of learning.







As part of the design analysis and testing, a physical prototype was produced, accentuating the multitude of options that are available for schools nationwide.

The vast array of potential design solutions reflected in the physical model indicate the high level of site adaptability Flexi-Ed contains relative to any other products on the market.

Fig 4.30. Hybrid approach: System collection (over page)

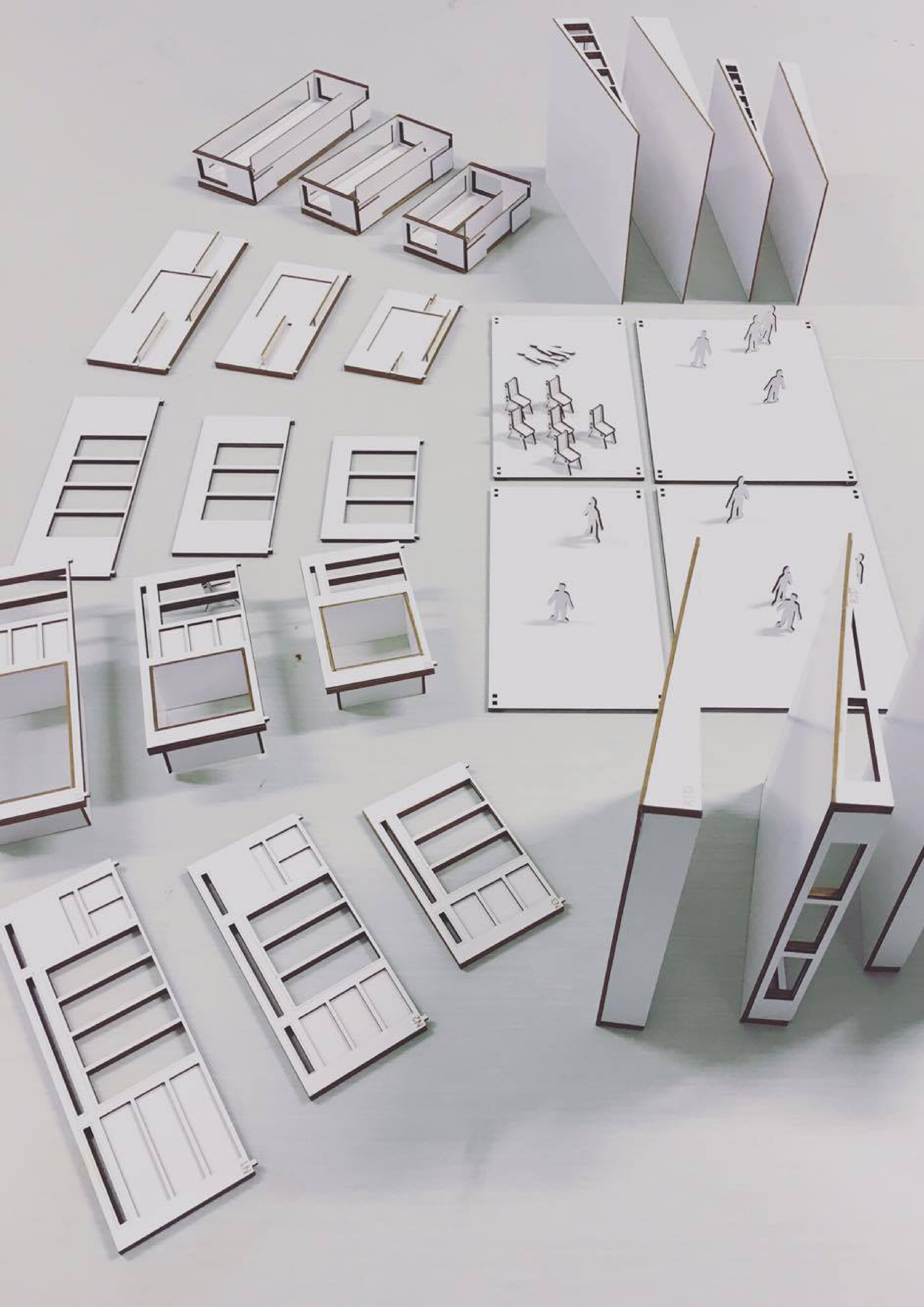
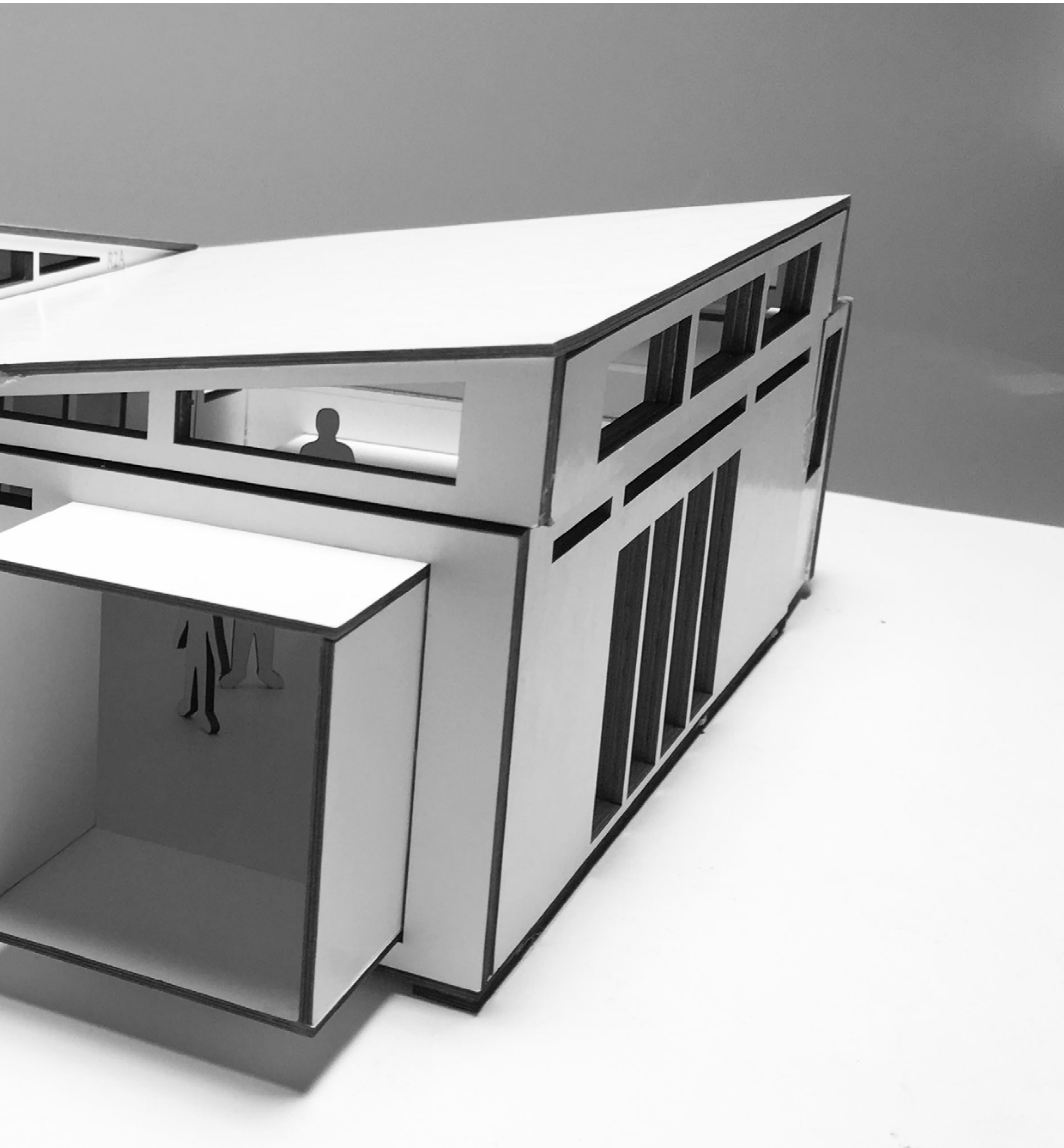


Fig 4.31. Hybrid model exterior view



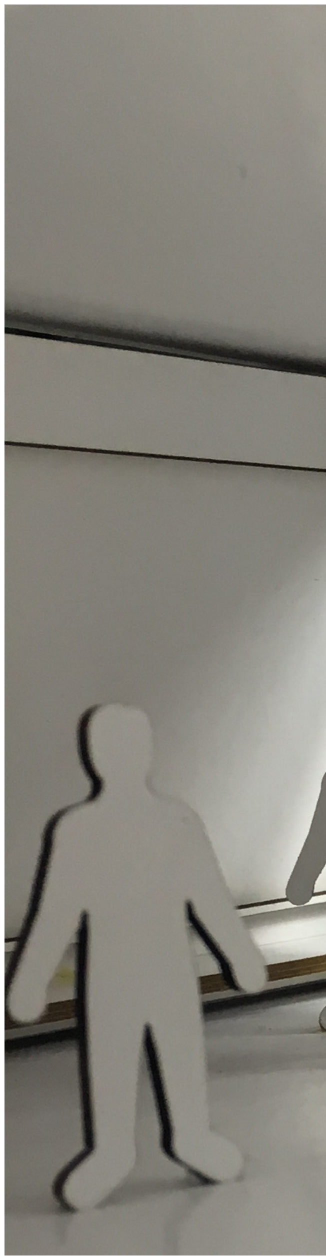


Fig 4.32. Hybrid model interior view (left)
Fig 4.33. Hybrid model alternative configuration; Interior view (right)

4.5.2 Market Approach

The success of this thesis largely rests on the marketability; the response and engagement of the public.

The term prefabrication can often be depicted as a concept that is mass produced, without the imprint of individuals and communities on the product. However Flexi-Ed approaches prefabrication from an angle where mass-customisation is utilized.

By providing potential clients with a tool that they have the opportunity to engage with, the flexibility and specificity of Flexi-Ed will become widely known. By using a marketing approach that is universally understood and visually driven the marketability will increase and will become more appealing nationwide.

The Flexi-Ed proposal has been supported with a graphic website and/or application which visually guides users through the design process (see website example, over page).

This application takes the users through the whole design journey. The process begins with the uploading of the proposed site and progresses all the way through to the selection of interior and exterior finishes.

This linear process directly inputs the data into a three dimensional view of the users proposed site throughout the process, with the ability to push, pull and rotate the view so users fully understand the design decisions being made and allow for self-assessment.

From here the proposed design is sent through to Flexi-Ed for consultation regarding the appropriateness for site and analyses of the energy efficiencies including solar and thermal qualities. This step of the process is where the Flexi-Ed architect steps in, ensuring that efficient classrooms are being produced as well as addressing areas of concern or making any recommendations before the design is signed off for the construction phase.

"Tell me all and I forget, teach me and I remember, involve me and I learn"
- Benjamin Franklin

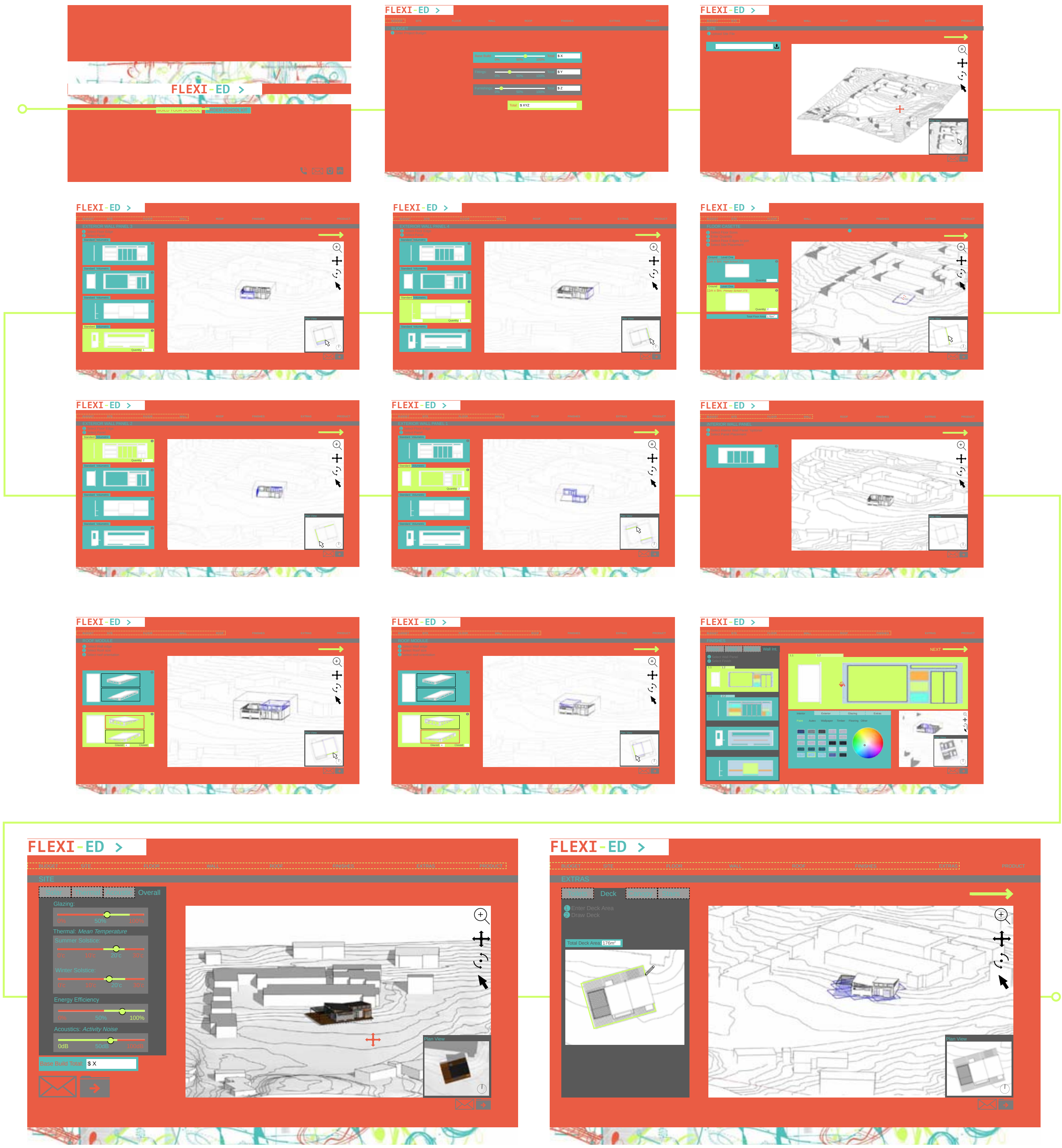


Fig 4.34. Flexi-Ed Market Approach; Website process

4.5.3 MoE Testing
Alteration of Design Standards

In order to provide a solution that improves and addresses the areas of concern in the existing MoE design standards for Innovative Learning Environments, it is important to directly analyse the designed parameters for Flexi-Ed.

Flexi-Ed has attempted to challenge the current ILE design standards in the following areas:

Breakout spaces:

The research phase demonstrated an inefficiency within the design specifications for breakout spaces. The areas of concern were raised around the efficiency of appropriate occupation, primarily due to the disconnection from the main learning hub in an attempt to reduce acoustics within these small spaces.

Flexi-Ed displays an alternative approach to breakout spaces by introducing breakout nooks. These nooks are freely accessed from the main learning hub, promoting the movement to student-led learning by giving the students the choice as to where they deem an appropriate learning setting to work in for the classroom task being undertaken.

Alternatively Flexi-Ed includes an interior partition wall in the collection of system panels. This interior partition wall includes large glazed sliding doors which allows parallel teaching spaces to either join together as one or segregate off, depending on the classroom tasks. This teaching space flexibility has the opportunity to address the acoustics on the interior accordingly, and with the opening or closing of a door can completely change the experience of the learning space

Teacher Work Spaces:

Teacher work spaces are specified in the ILE design standards as small nooks which appear to be underutilized around schools, with hordes of paper and files inadequately stored away.

Flexi-Ed proposes an alternative which was influenced by the school observations performed in June 2016. One school in particular demonstrated a successful approach to teacher work spaces through the introduction of mobile teaching units. These units on wheels allow the teachers to move freely throughout the teaching space, with the ability to constantly move the ‘front of the classroom’. These units contain draws for essential teaching equipment and student work, with a flat surface on top for laptops and workbooks to work as a fully functional mobile ‘desk’. As the Education Industry transitions to paperless classrooms, promoting interactive and collaborative learning the teachers should too be included in this movement.

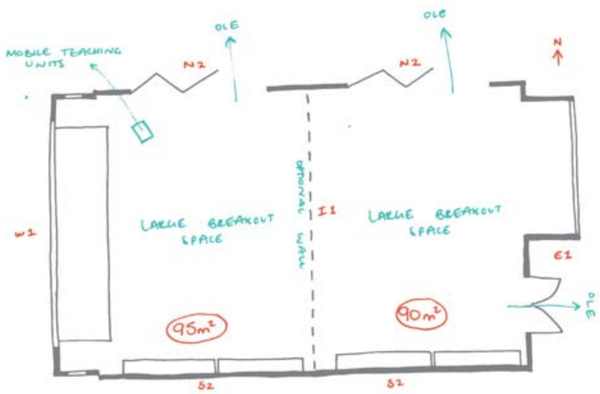
Flexi-Ed Testing

After taking into consideration the alterations outlined above and the existing Ministry of Education ILE design standards (seen on Page 12), a Primary and High school version of Flexi-Ed was analysed.

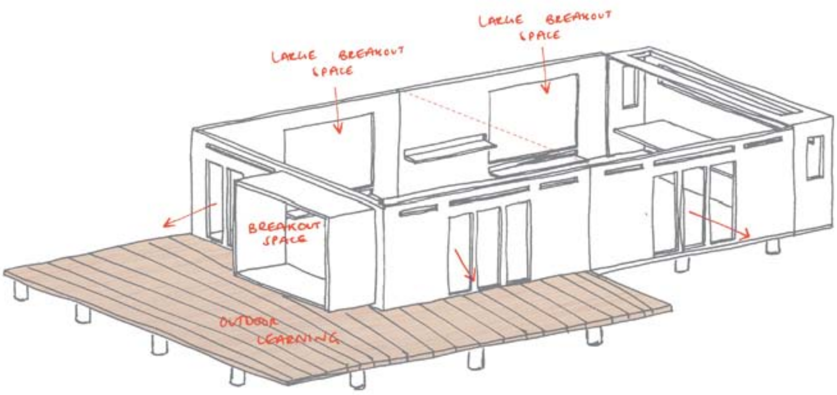
The analyses (see Flexi-Ed design standard analyses, figures 4.35 - 4.36) revealed that through the use of both prefabricated panels overlaid with specific orientation and interior learning setting, Flexi-Ed demonstrates an efficient, effective and innovative approach to classrooms in alignment with the revised MOE design standards.

Primary School Concept

Floor Plan

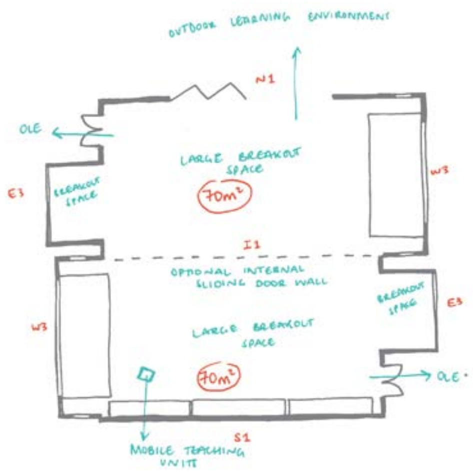


Axonometric



High School Concept

Floor Plan



Axonometric

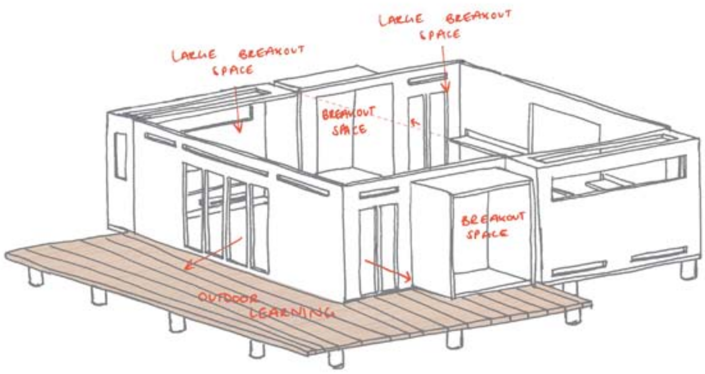


Fig 4.35. Primary School Floor plan and axonometric MoE analyses (top)
Fig 4.36. High School; Floor plan and axonometric MoE analyses (bottom)

4.5.4 Structural Analysis

The Flexi-Ed Hybrid design concept has been analysed by a Structural Engineer at Victoria University, using the computer programme RESIST. The results produced from the programme RESIST demonstrate that the concept design is of a sufficient structural standard, that it will be able to withstand both wind and earthquake forces.

These assessments provided recommendations and structural considerations that need to be applied in the development of Flexi-Ed.

These recommendations are as follows:

Roof Module
Material:
> Metal roofing over insulated CLT twin skin roof.
Structure:
> Timber trusses to ensure that earthquake and wind forces are able to have an efficient load path through one classroom module.

Wall Panels
Selected Material:
> Plywood cladding over insulated timber framing with ply bracing layer and GIB lining.
Structure:
> Studs used in the timber frame to transfer the wind pressure up and down, along with sufficient mullions to transfer face loads.
> Wall thickness to be greater than 150mm to prevent the wall panels from buckling.

Floor and Foundations (see structural analyses diagrams, figure 4.37)
Selected Material:
> CLT Floor Panel (maximum size 15.1m x 3.3m)
Structure:
> CLT floor cassette on top of bearers, design specified by 3604. The bearers are to take the weight of the shear walls and transfer the load into the specified piles.
> Diagonal cross braced square pad piles to counteract earthquake forces and the differing ground conditions of the sites.

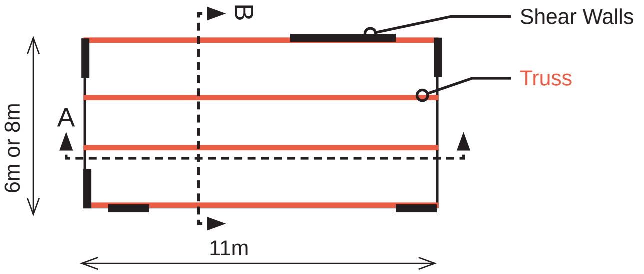
One Classroom Structures (see structural analyses diagrams, figure 4.37)
Section A:
In the longitudinal direction the wind and earthquake forces will be transferred up the shear walls and along the horizontal cross bracing into the roof diaphragm. From here the load will be transferred down the opposite shear wall into the foundations.

Section B:
In the short section the trusses allow the load to transfer up to the roof diaphragm and evenly distribute down the sheer walls below through the horizontal cross bracing.

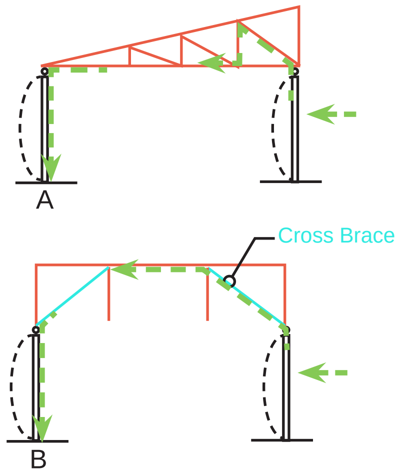
Two Classrooms Structures (see structural analyses diagrams, figure 4.37)
Section C:
The different orientation of roof planes require to be tied back to effectively transfer inertia forces. A two bay diaphragm is required at the bottom of the roof truss using timber or steel which can be fabricated as part of the roof module.

One Classroom

PLAN

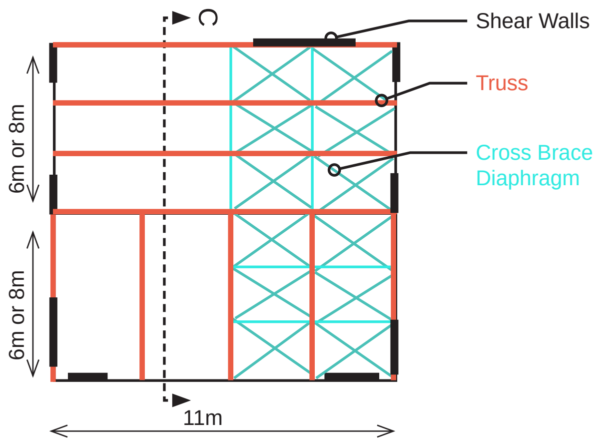


SECTION



Two Classrooms

PLAN



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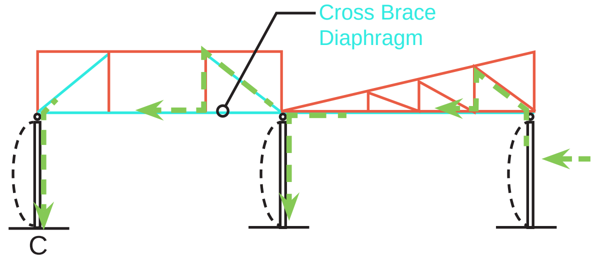
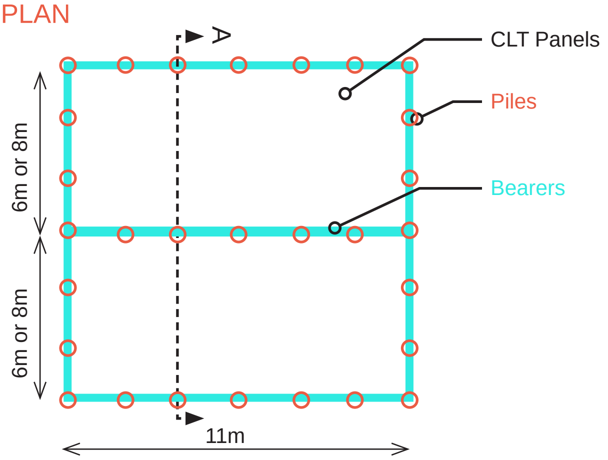


Foundations

PLAN



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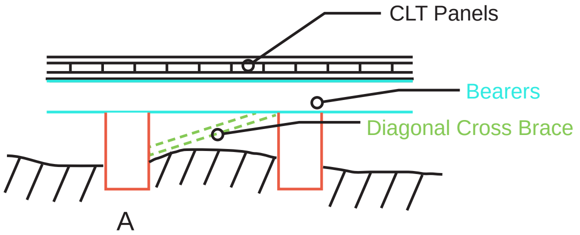


Fig 4.37. Structural analysis diagrams

4.5.5 Site Analysis

Three different school sites (see selected Canterbury Schools map, figure 4.38) in the Canterbury Region have been selected to test the adaptability and flexibility of Flexi-Ed. The site analysis will determine whether the current design has the ability to cater to varying challenges and constraints of each site.

Fig 4.38. Selected Canterbury schools map

Urban Site:
Hagley Community College

Hagley Community College is located in the heart of Christchurch City, opposite the well known Hagley Park.

The existing school is made-up of approximately thirty five buildings, varying from an array of historic brick classroom blocks to stand alone relocatable Portacom classrooms.

The High school sustained damage to multiple blocks during the February 2011 earthquake, including one teaching block that has been deemed as a rebuild.

This High School has been chosen as my urban site due to the damage that the school community are still coping with post-earthquake along with the current use of relocatable classrooms, to demonstrate a more effective alternative solution for classrooms in their rebuild process.

Fig 4.39. Hagley Community College site analysis

Motorway Site:
Addington Primary School

Addington Primary School is located adjacent to Brougham Street, one of the busiest multi lane roads in Christchurch. Similar to the selected urban site, Addington contains an array of buildings ranging from relocatable Portacom classrooms to an historic brick building.

Currently Addington Primary are in the process of the Canterbury Schools Rebuild Programme. The engaged architects have begun the concept design phases, with the proposal of one classroom block renovation to ILE and another specialist teaching block to be rebuilt.

This site has been chosen as it is located in close proximity to Brougham Street and the Christchurch motorway and therefore will challenge the acoustic approach of Flexi-Ed, by requiring a site specific design that addresses to this.

Fig 4.40. Addington Primary School site analysis

Exposed Site:
Mt Pleasant Primary School

Mt Pleasant Primary School is located on a steep site amongst the Banks Peninsula, approximately twenty minutes away from the CBD of Christchurch. Due to the bedrock that forms the mountain, damage was seen throughout the streets of Mount Pleasant, along with neighbouring hillside suburbs.

This site has been chosen as it is located on an exposed site with challenging topography, therefore the site will test Flexi-Ed's approach to weather exposure and foundation treatment.

Fig 4.41. Mt Pleasant Primary School site analysis

4.5.6 Site Specific Design 1
Hagley Community College

Hagley Community College requires one new classroom block to replace the existing earthquake damaged building. This new classroom block requires:
> Eight teaching spaces
> Potential to build up to two storeys to reduce building footprint
> Mixture between open and segregated interior spaces
> Flexibility within the function of each teaching space

The following design decisions have been made to cater to the brief (see Hagley floor plan example, figure 4.43):

> Array of eight ILE teaching spaces that have the ability to be closed off, introducing a combination of learning settings to cater to a variety of group tasks.

> The North faces have been selected to encourage exterior learning as well as allow natural light to emit into the building.

> The southern faces focus on a balance between connection to the surrounding blocks and thermal control within the interior.

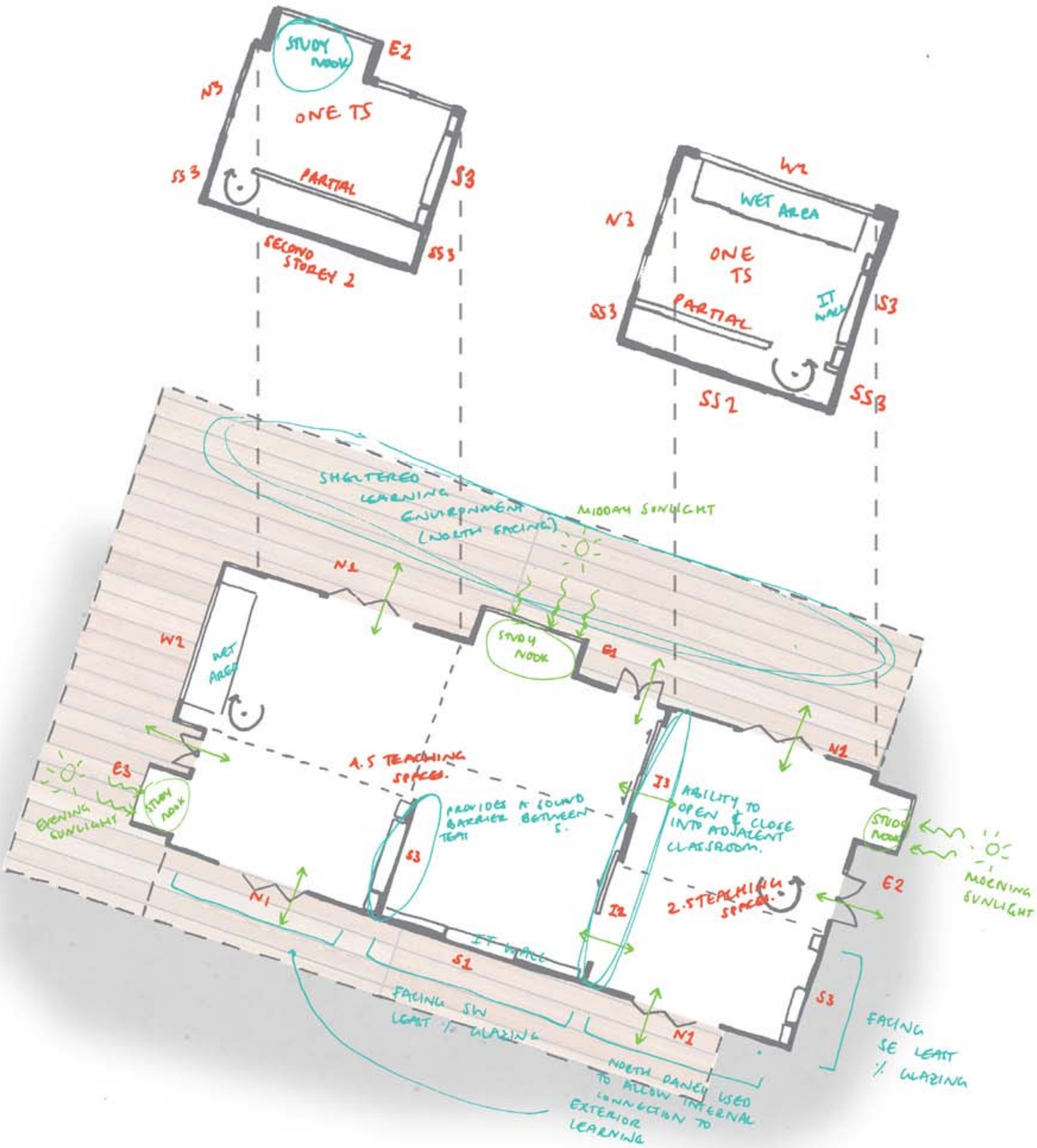
> The possibility for a Second storey is a demonstration of how Flexi-Ed may develop in the future, providing an additional two teaching spaces which can be accessed using internal stairs.

Existing School Buildings

Flexi-Ed Classroom Block

Surrounding Buildings

Fig 4.42. Hagley Community College proposed design site analysis



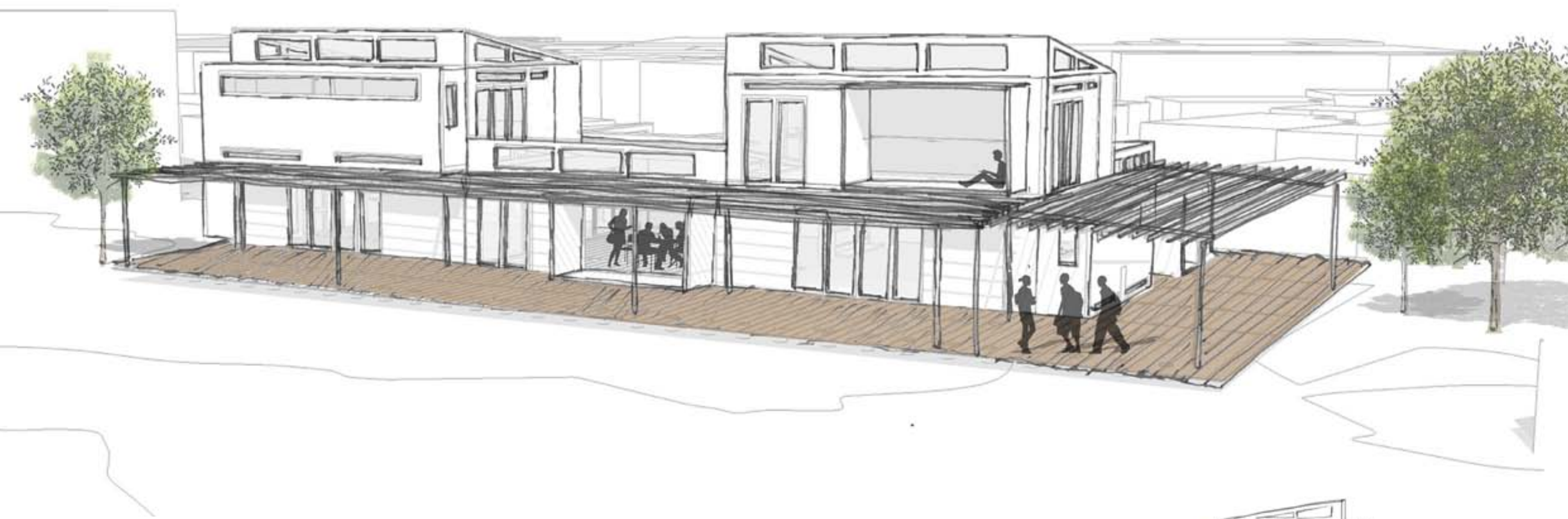


Fig 4.43. *Proposed floor plan (top)*
Fig 4.44. *Proposed design exterior view*
Fig 4.45. *Proposed design section (bottom)*

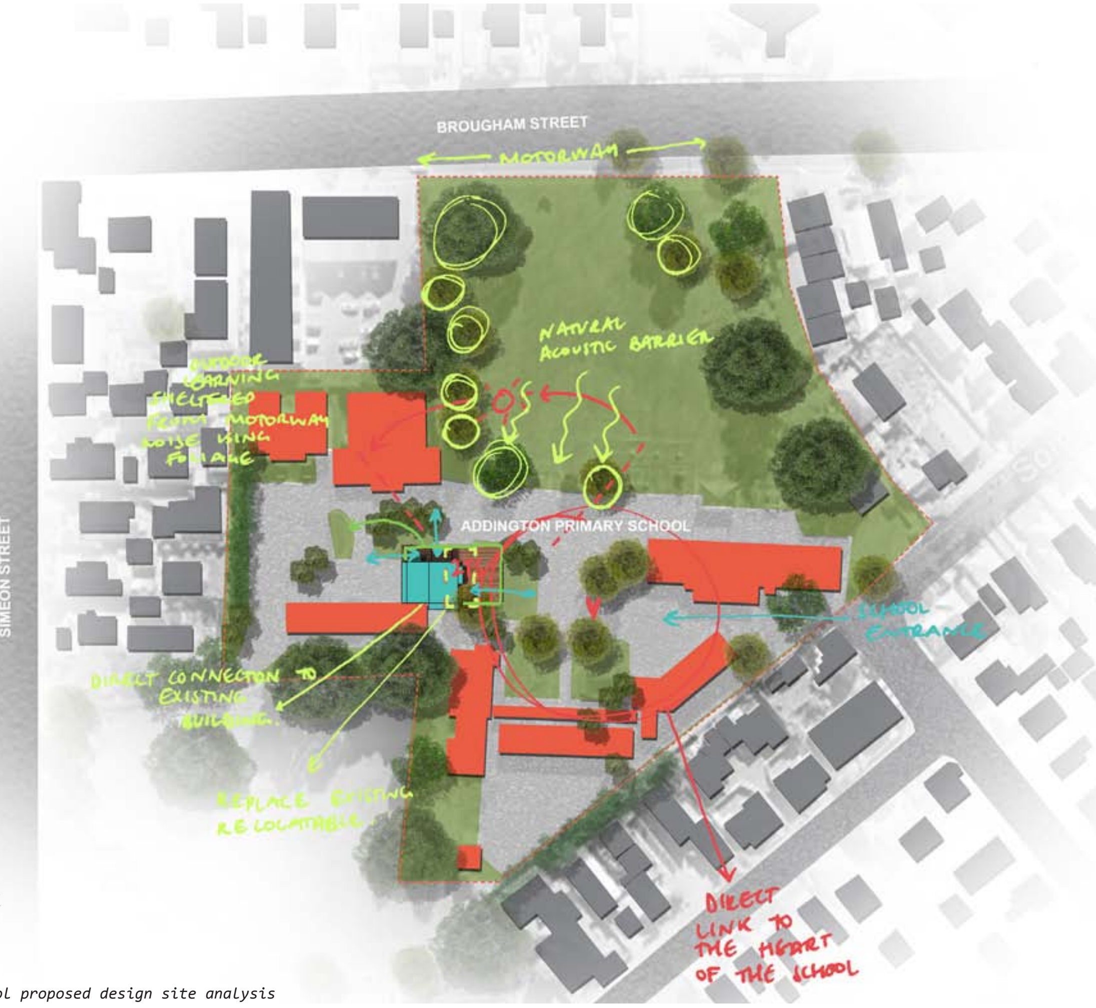
4.5.7 Site Specific Design 2
Addington Primary School

Addington Primary School require the replacement of an existing relocatable classroom, to provide additional ILE teaching spaces that can work collaboratively with the proposed ILE block for the Canterbury Schools Rebuild Programme. The new classroom requires:
> Two teaching spaces
> Classroom space that can be closed off
> Connection to existing buildings on-site
> Access to exterior environment and central courtyard
> Existing Toilet facilities adequate for number of teaching spaces

The following design decisions have been made to cater to the brief (see Addington floor plan example, figure 4.47):
> The acoustics have been considered through the interior teaching spaces as they have the ability to be completely segregated or open plan with the integration of an interior wall panel. The panels selected facing the motorway have been chosen with the consideration of the acoustic transmittance from the motorway.

> Both teaching spaces have used each different panel type to provide the two teaching space with the ability to work collaboratively or as individual teaching spaces.

> The East orientation has a strong focus on the exterior sheltered learning environment that extends away from the motorway to the central courtyard and the heart of the school.



Existing School Buildings
Flexi-Ed Classroom Block
Surrounding Buildings

Fig 4.46. Addington Primary School proposed design site analysis

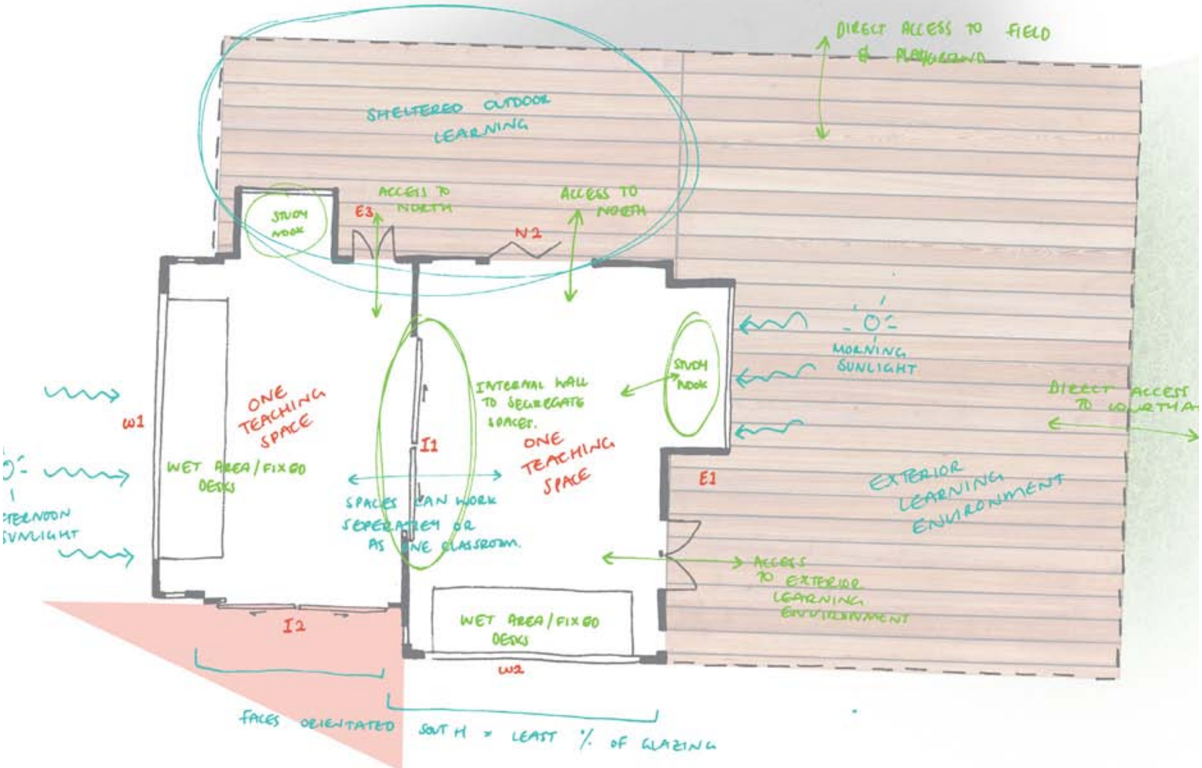


Fig 4.47. Proposed floor plan (top)
Fig 4.48. Proposed design exterior view
Fig 4.49. Proposed design section (bottom)

4.5.8 Site Specific Design 3
Mt Pleasant Primary School

Mt Pleasant primary school require one additional standalone classroom block to cater to the increased roll numbers as a repercussion off the Canterbury Earthquake causing a shift in residential addresses. The new classroom block requires:

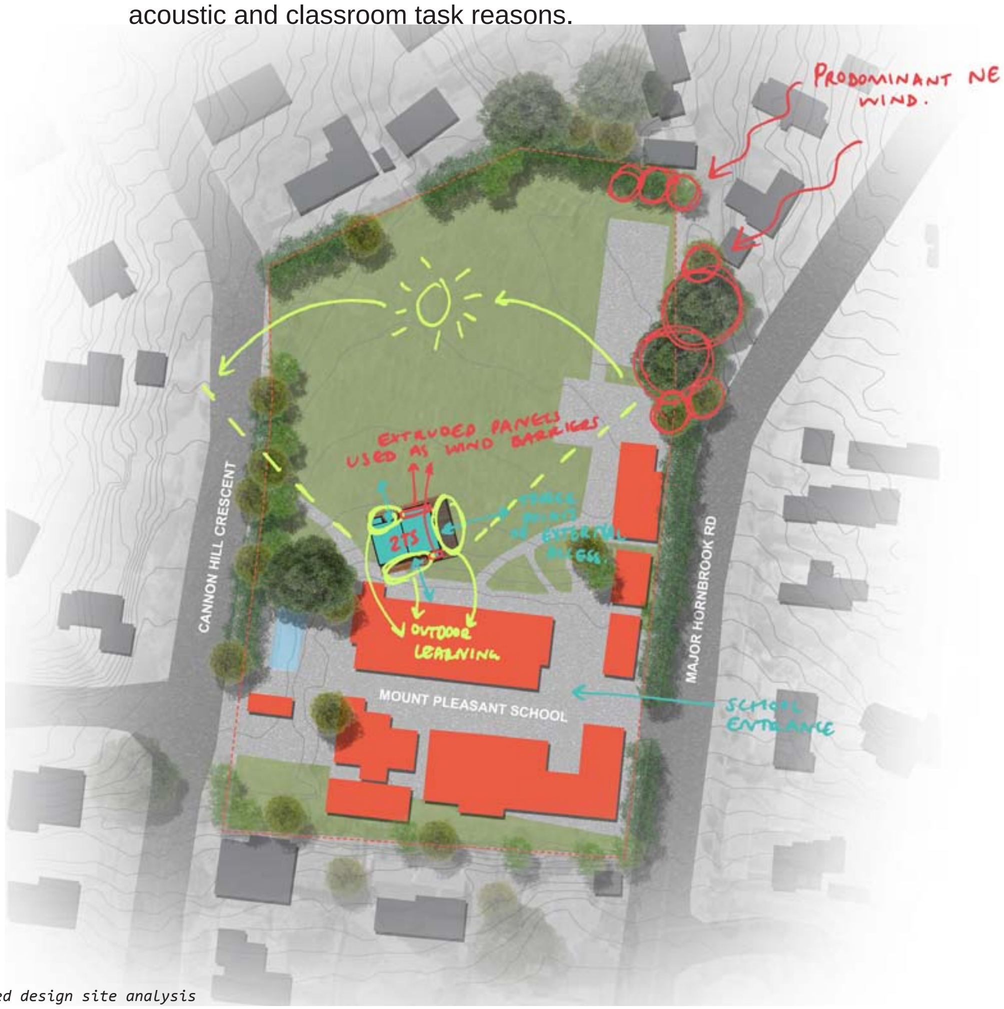
> Two teaching spaces
> Ability to segregate the teaching spaces
> Sheltered exterior learning environment
> Consideration of wind exposure
> Existing Toilet facilities adequate for number of teaching spaces

The following design decisions have been made to cater to the brief (see Mt Pleasant floor plan example, figure 4.51):

> The exterior learning environment orientated to the north-east is sheltered using a breakout nook panel that allows the extruded forms to provide shelter from weather conditions and elements for outdoor learning.

> The south-west face has been appointed an Interactive panel with minimal a percentage of glazing, whilst the north-east and north-west orientation have a higher percentage of glazing for thermal and passive heating reasons.

> The interior space has been designed open plan with a partial internal wall that allows the two teaching spaces to have a degree of separation for acoustic and classroom task reasons.

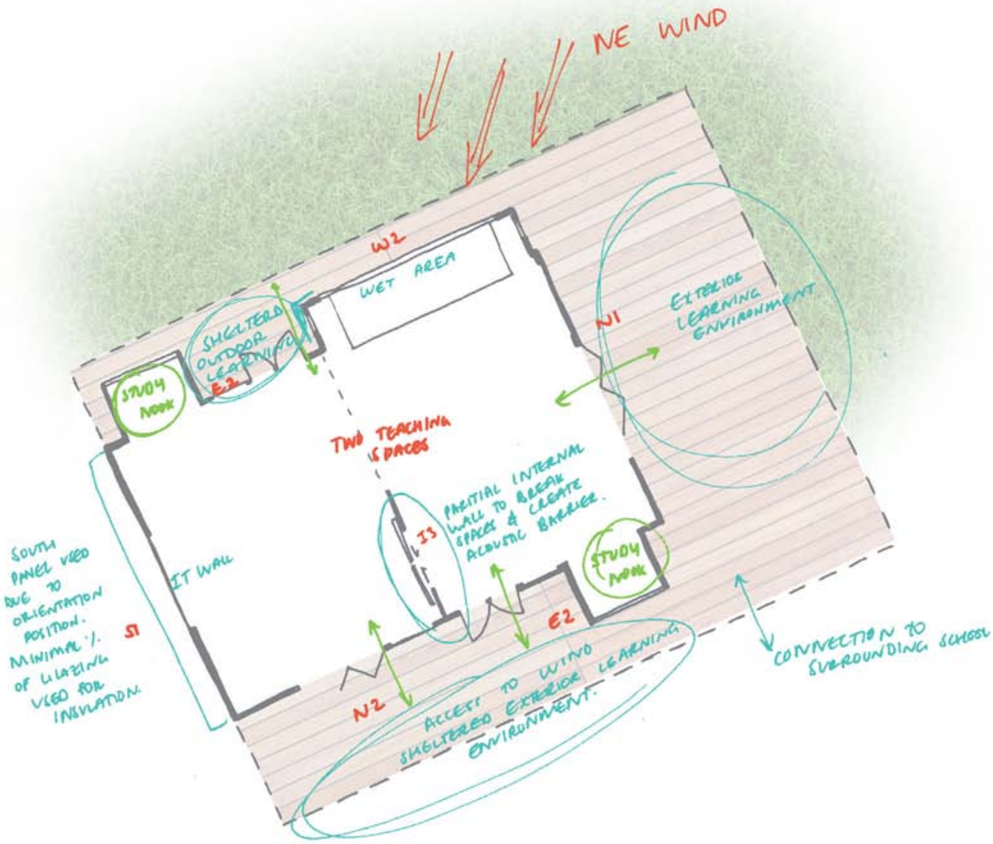


Existing School Buildings

Flexi-Ed Classroom Block

Surrounding Buildings

Fig 4.50. Mt Pleasant Primary School proposed design site analysis



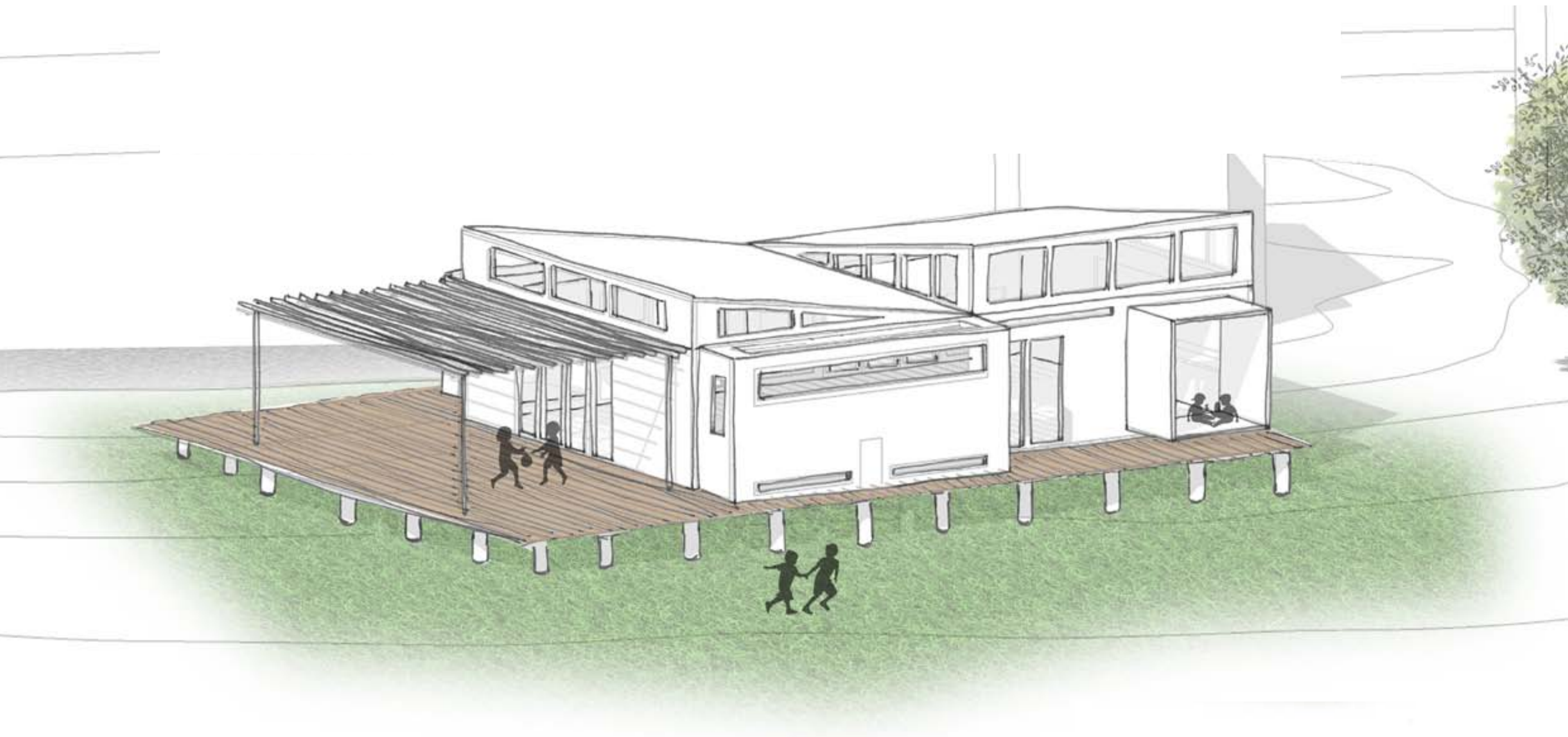


Fig 4.51. Proposed floor plan (top)
Fig 4.52. Proposed design exterior view
Fig 4.53. Proposed design section (bottom)

4.6 DEVELOPED DESIGN >

4.6.1 Panel Modification

After the site analysis and testing, the panel design has been re-evaluated to maximise classroom efficiency and increase the potential floor plan options along with the standard of Innovative Learning Environments.

The introduction of a volumetric panel has been included into the programmed wall panel series (see volumetric and standard panel diagrams, figure 4.54). The New Zealand Classroom Acoustics guide recommends open plan and rectangular classrooms be avoided.

However these volumetric panels challenge the current recommendation by demonstrating through considered architectural form, open plan classrooms

Breakout Nook

"Allowing for student collaboration, whether it be small, medium or large"

> 6 - 12 students
> Quite breakout space
> Ability to acoustically seal off
> Medium, small or individual work

Outdoor Learning Gateway

"The gateway to learning"

> 4 - 6 students
> Entrance foyer including bag and jacket storage
> Resilient flooring catering for the expected foot traffic and dirty footwear
> Bi-folding doors accessing the external learning environment

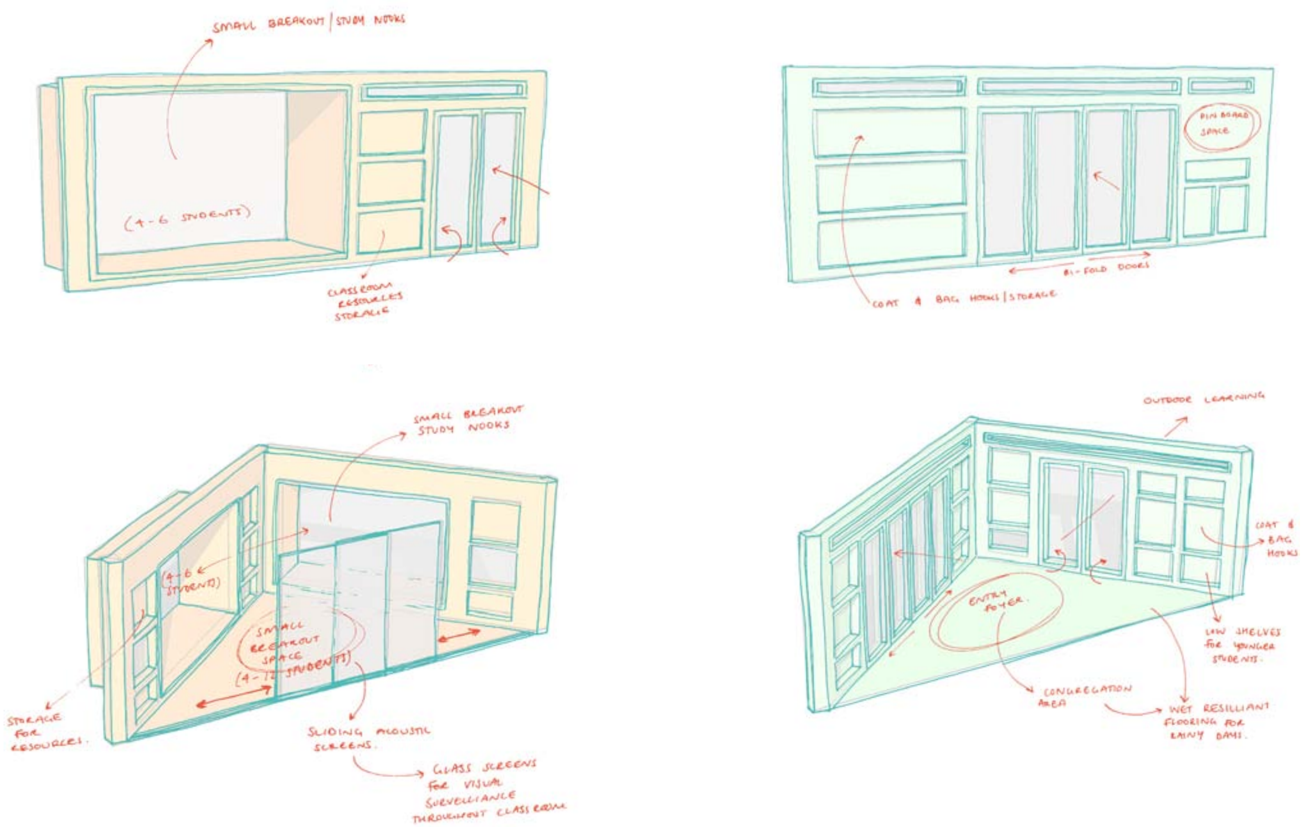


Fig 4.54. Volumetric and standard panel diagrams

[57] Wilson, Oriole. *Classroom Acoustics : A New Zealand Perspective*. Wellington, N.Z. : Oticon Foundation in New Zealand, 2002. Pg 30

can be successful.[57] The volumetric panels will help reduce the reverberation time within the classroom environment, as well as defining different learning settings.

This development enables the aesthetic of Flexi-Ed to move away from the rectilinear form of the Portabuild modules and likewise products, creating a new identity for relocatable classrooms.

These additional volumetric panels will be of a higher cost to the standard panels, however the client can select how many they wish to use, if any at all.

Make Space

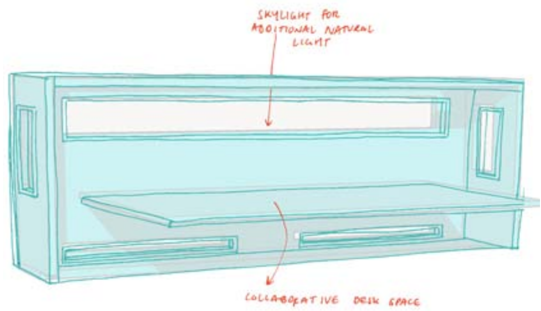
"Encouraging creativity in every individual"

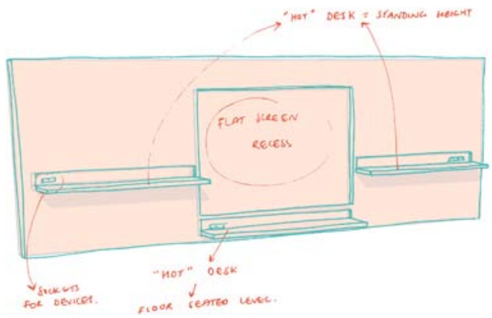
> 6 - 12 students
> Creative work
> Resilient flooring to cater to the expected mess
> Exterior access to allow students to transition between the interior and exterior for different projects.

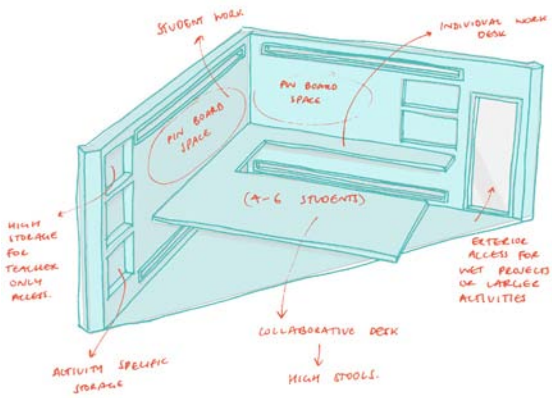
Tech Centre

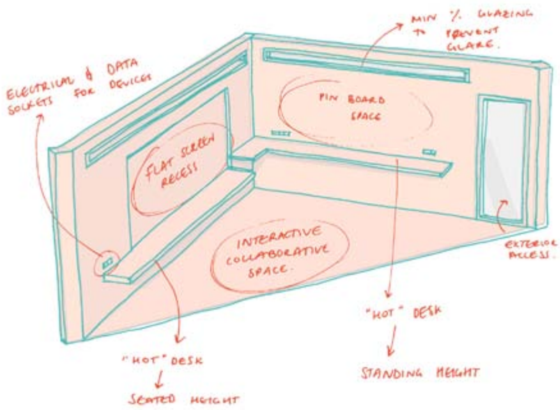
"The transition to a paperless classroom"

> 4 - 6 Students
> Technology Space
> Data Points
> "Hot" Desks
> Different height desks to cater to an array of learning styles, seated or standing.









4.6.2 Roof Modification

The Flexi-Ed Hybrid system contains roof modules that consist of monopitch forms, with the opportunity to select the slope direction and the percentage of glazing.

The monopitch modules have been analysed to assess the practicality for a classroom, along with recommendations made by the Ministry of Education. In order to eliminate the possibility of internal gutters and inadequate drainage (see two teaching space monopitch roof module example, figure 4.55), the roof types have been reconfigured and streamlined to specific classroom floor plans.

The monopitch roof is intended to be used for a one teaching space classroom (see one teaching space monopitch roof module example, figure 4.56), whilst two teaching space builds will be encouraged to use a gable roof module (see two teaching space gable roof module example, figure 4.57). Any teaching spaces three and above will require a specifically designed modular roof system to ensure a suitable roof option is being used.

These design decisions have been made to reduce construction costs, on-site maintenance and the risk of leaky buildings often associated with internal gutters.

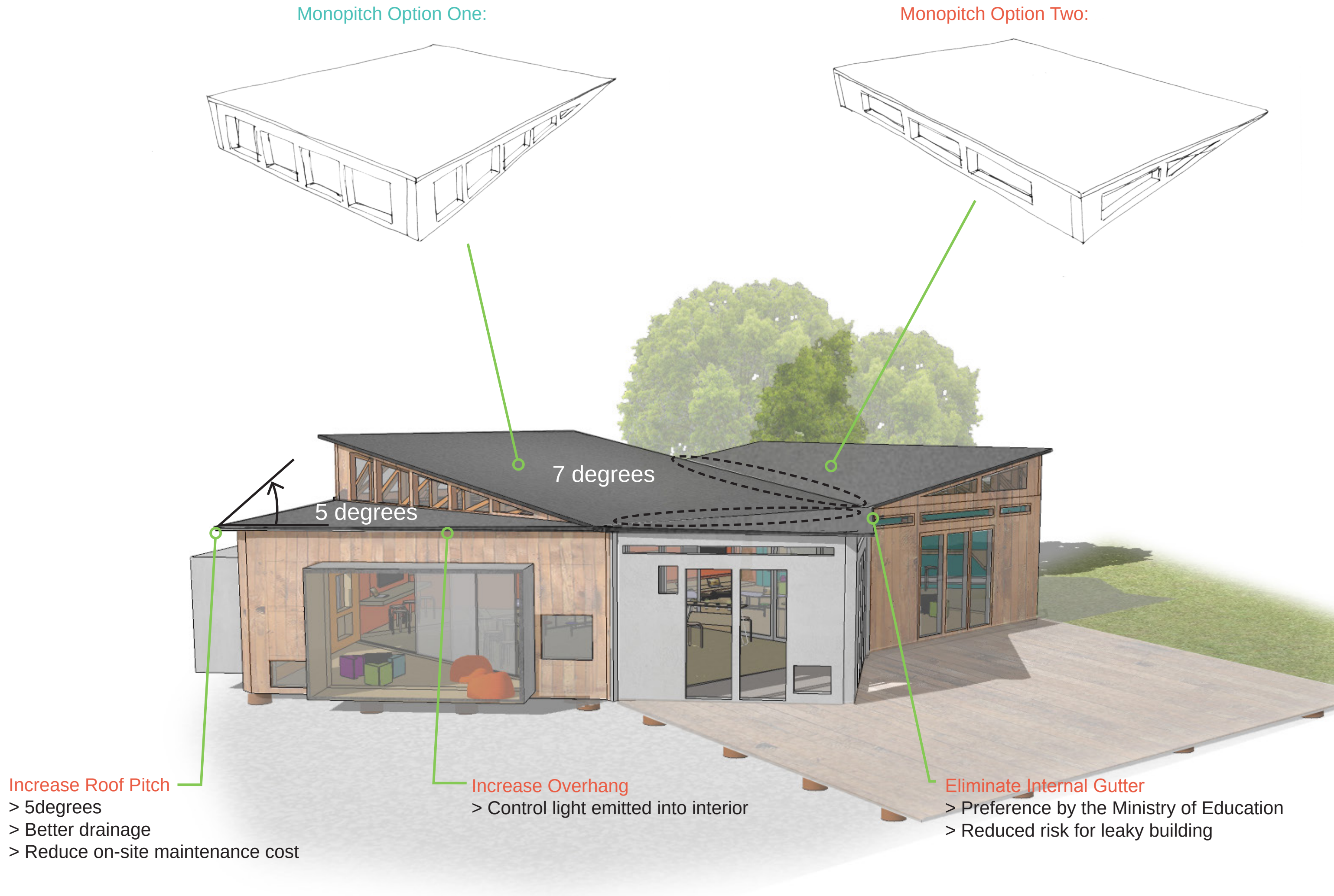
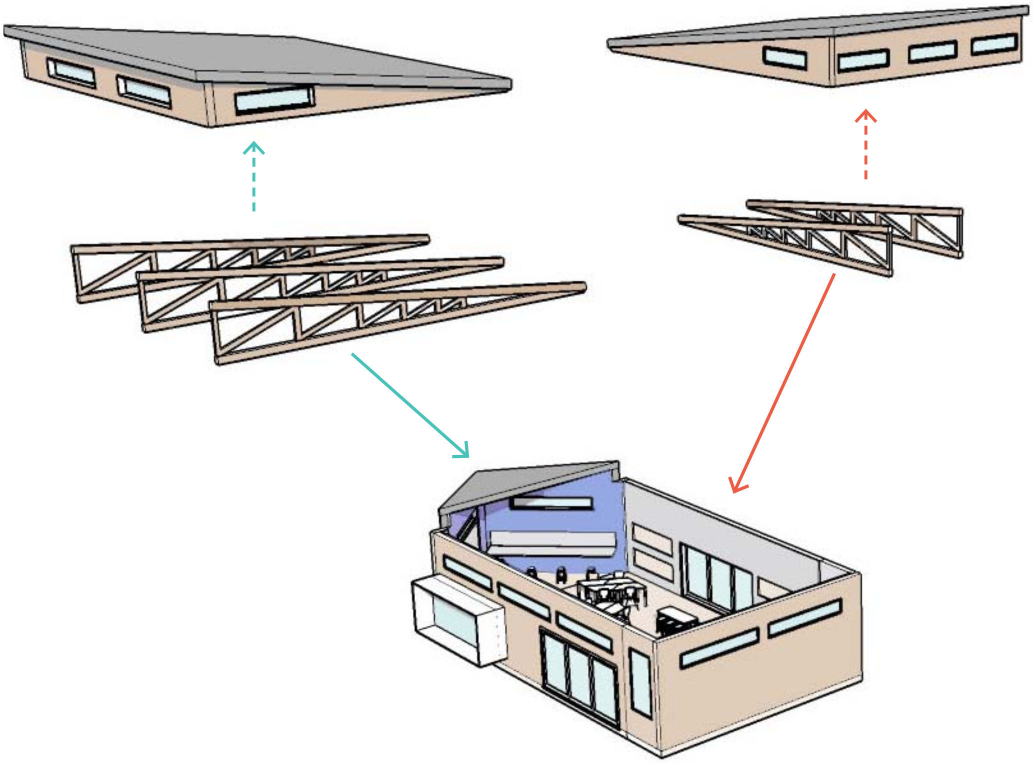


Fig 4.55. Two teaching space monopitch roof module

One Teaching Space:

Monopitch Option One: OR Monopitch Option Two:



Two Teaching Spaces:

Gable Option:

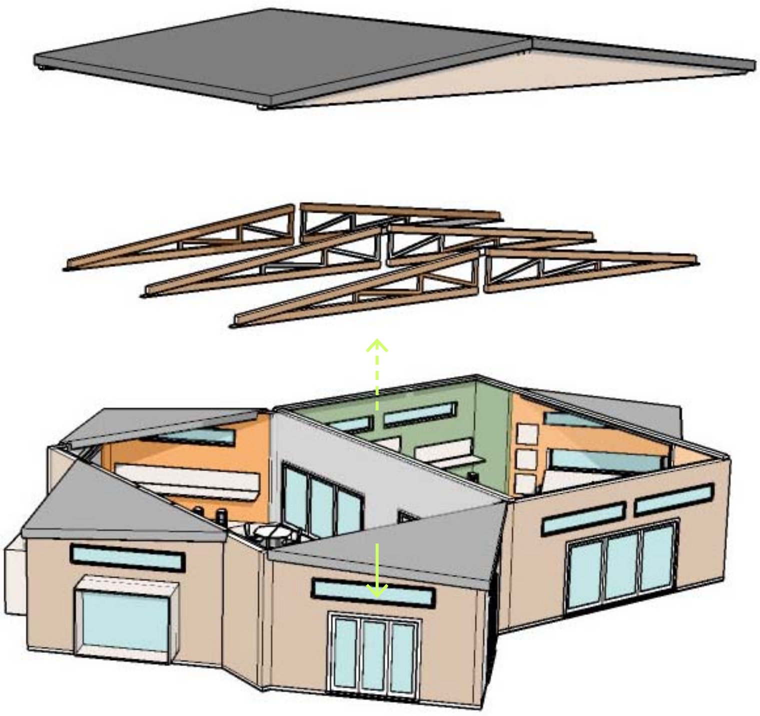
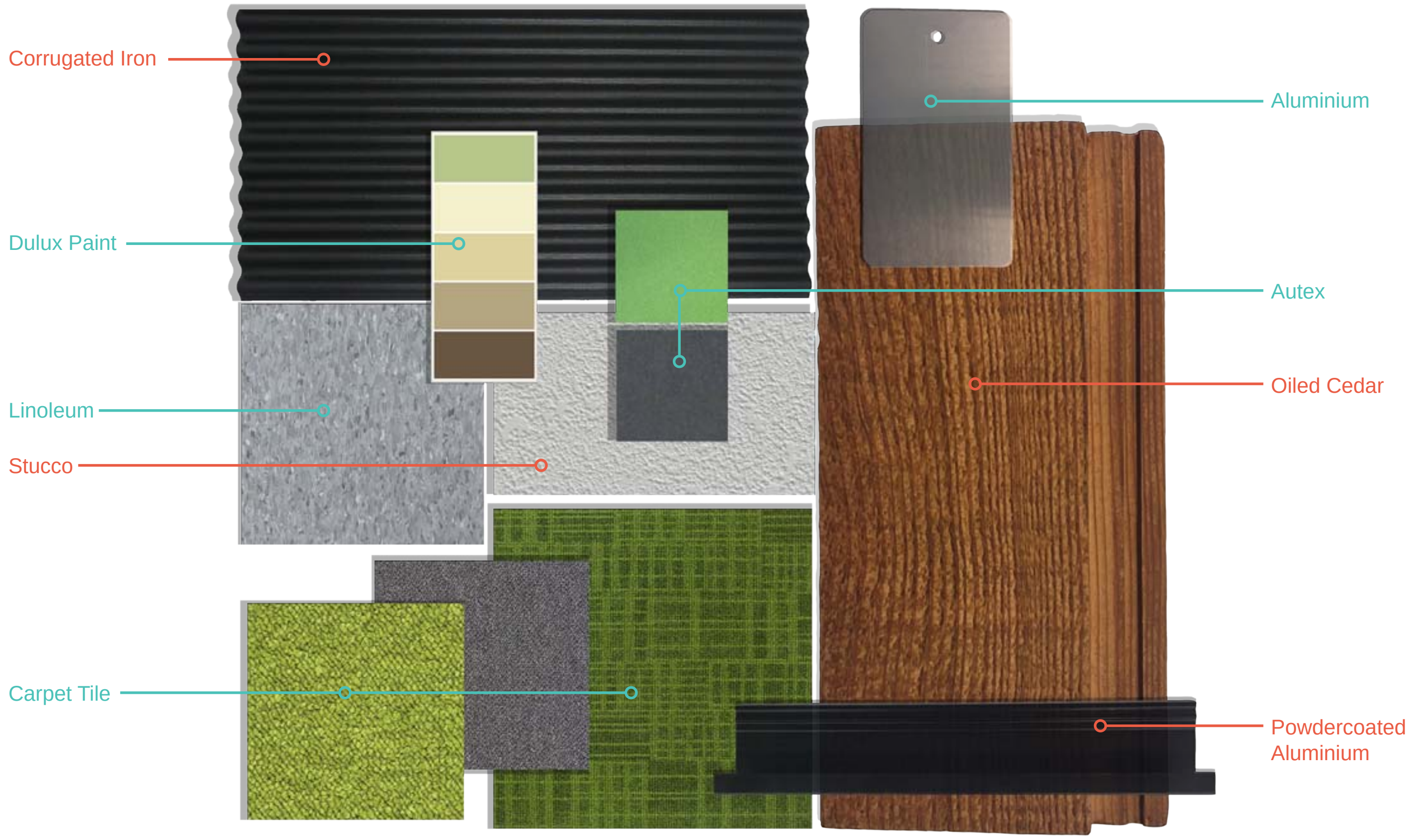
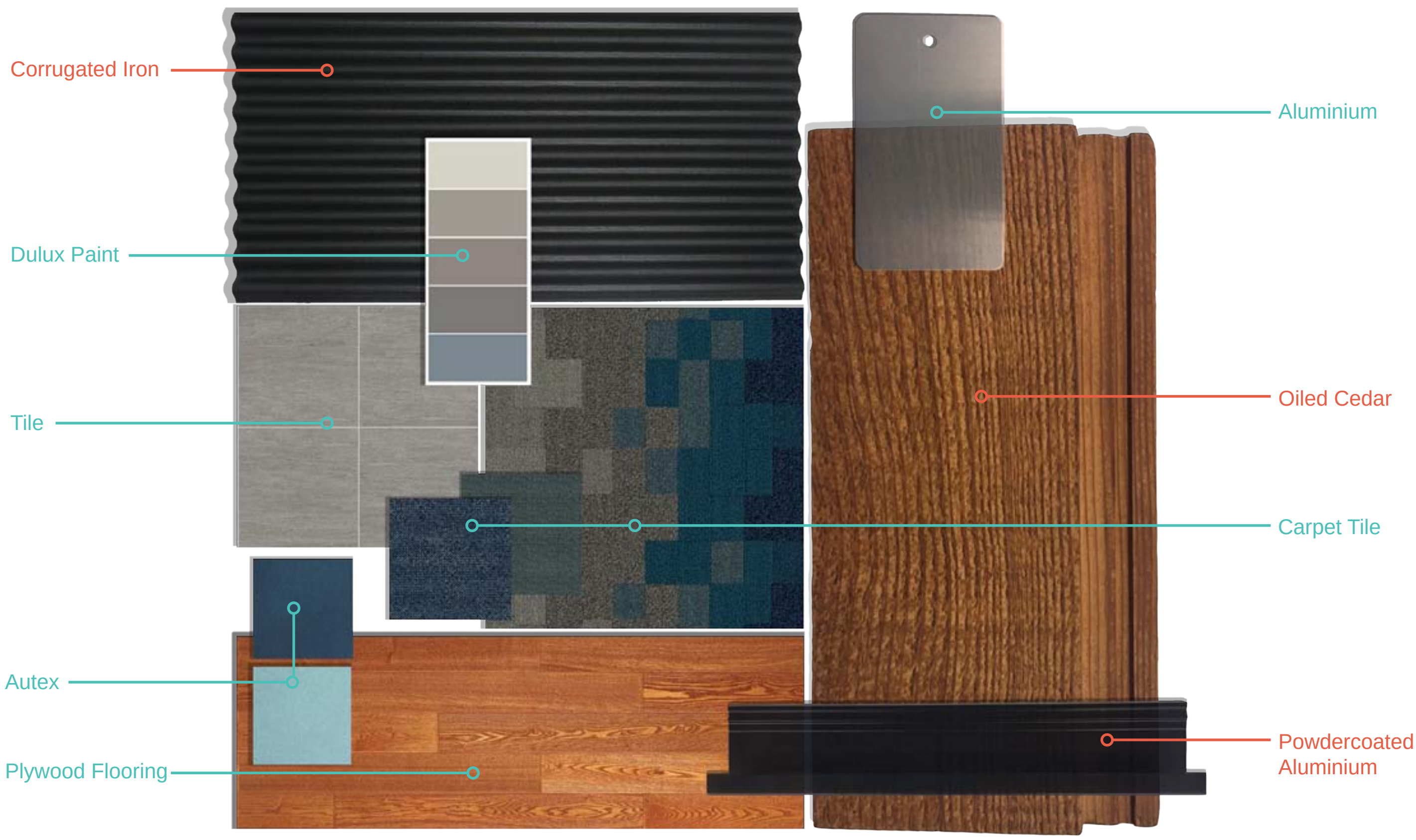


Fig 4.56. One teaching space monopitch roof module (top)
Fig 4.57. Two teaching space gable roof module (bottom)





Interior Finishes
Exterior Finishes

Fig 4.58. Materials palette example mood board: Standard design (top)
Fig 4.59. Materials palette example mood board: Deluxe design (bottom)

4.6.3 Material Application

In order to allow each client to imprint their own individuality on the design, Flexi-Ed has selected a list of approved material options with a minimum performance standard that contributes to the control of classroom acoustics and withstands the general wear and tear expected within the classroom environment.

These finishes are as follows (see Materials palette mood board examples, figures 4.58 - 4.59):

Flooring:
Learning Hub:
> Thick carpet tile (Acoustic recommendation)
> Plywood Flooring

Make Space/Entry Foyer:
> Lineoulm
> Tiles

Interior Walls:
> Autex (Acoustic recommendation)
> Paint
> Wallpaper
> Aluminium (glazing)

Exterior Walls:
> Cedar
> Stucco
> Powdercoated Aluminium (glazing)

Roof:
> Corrugated Iron

4.6.4 Client Control

The control is now handed over to the client, allowing them to select a design that is relevant to their budget and specific to their school site.

Two examples have been included on the following pages to demonstrate a possible 'standard' and 'deluxe' Flexi-Ed build, illustrating the vast array of options, aligning with many client needs and requirements without compromising the interior spaces or students .

4.6.5 Budget Approach: *Standard Design Option*

The 'standard' option demonstrates lower budget finishes along with standard panel options (see deluxe design floor plan and material application example, figures 4.60 - 4.61).

This proposed configuration is suited to clients with lower budgets.

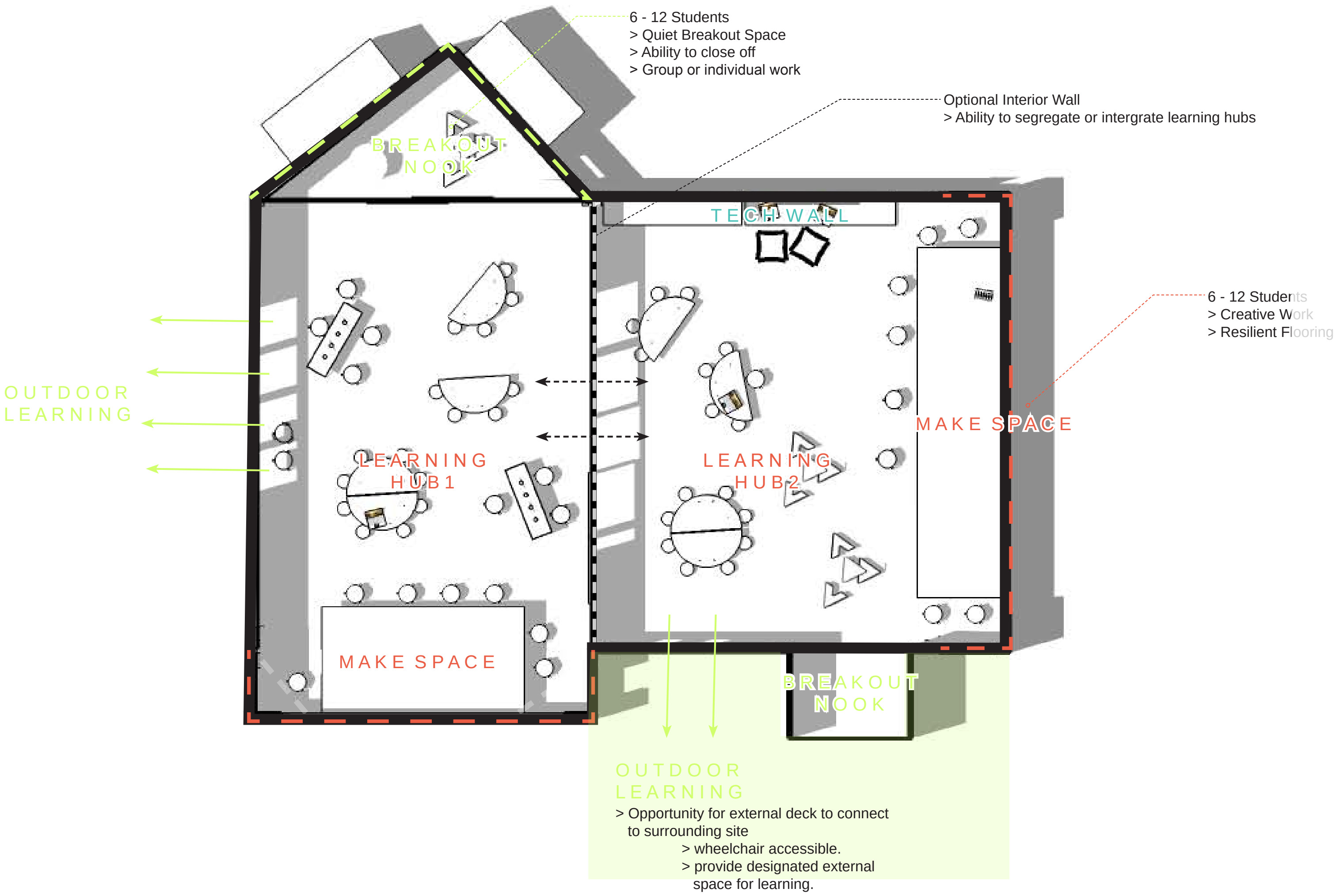


Fig 4.60. Budget Approach; Standard design option floor plan

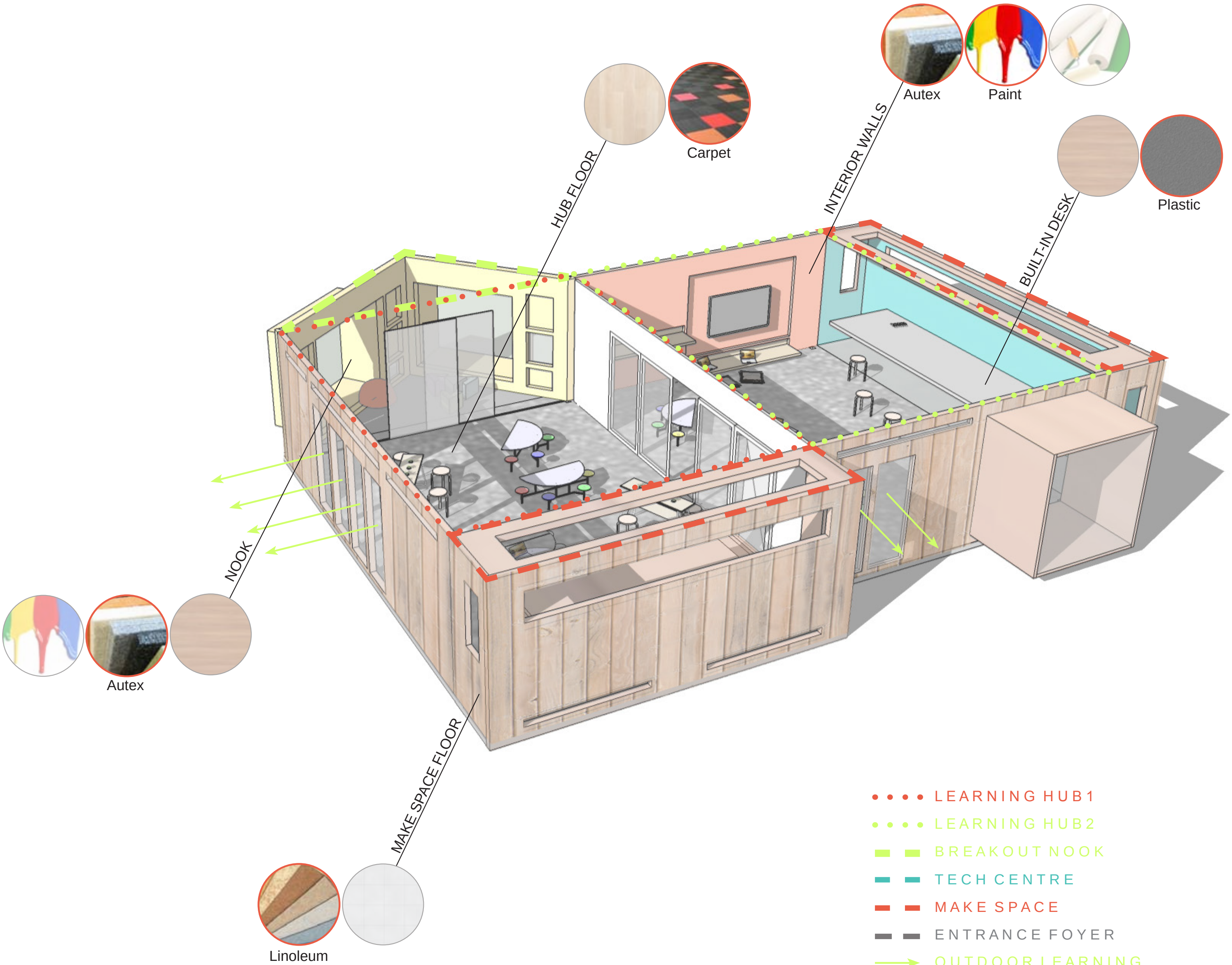


Fig 4.61. Budget Approach; Standard design option axonometric material application

Deluxe Design Option

The 'deluxe' option demonstrates top range finishes along with varied panel options, shifting between volumetric and standard (see deluxe design floor plan and material application example, figures 4.62 - 4.63).

This proposed configuration is suited to clients with more flexible budgets.

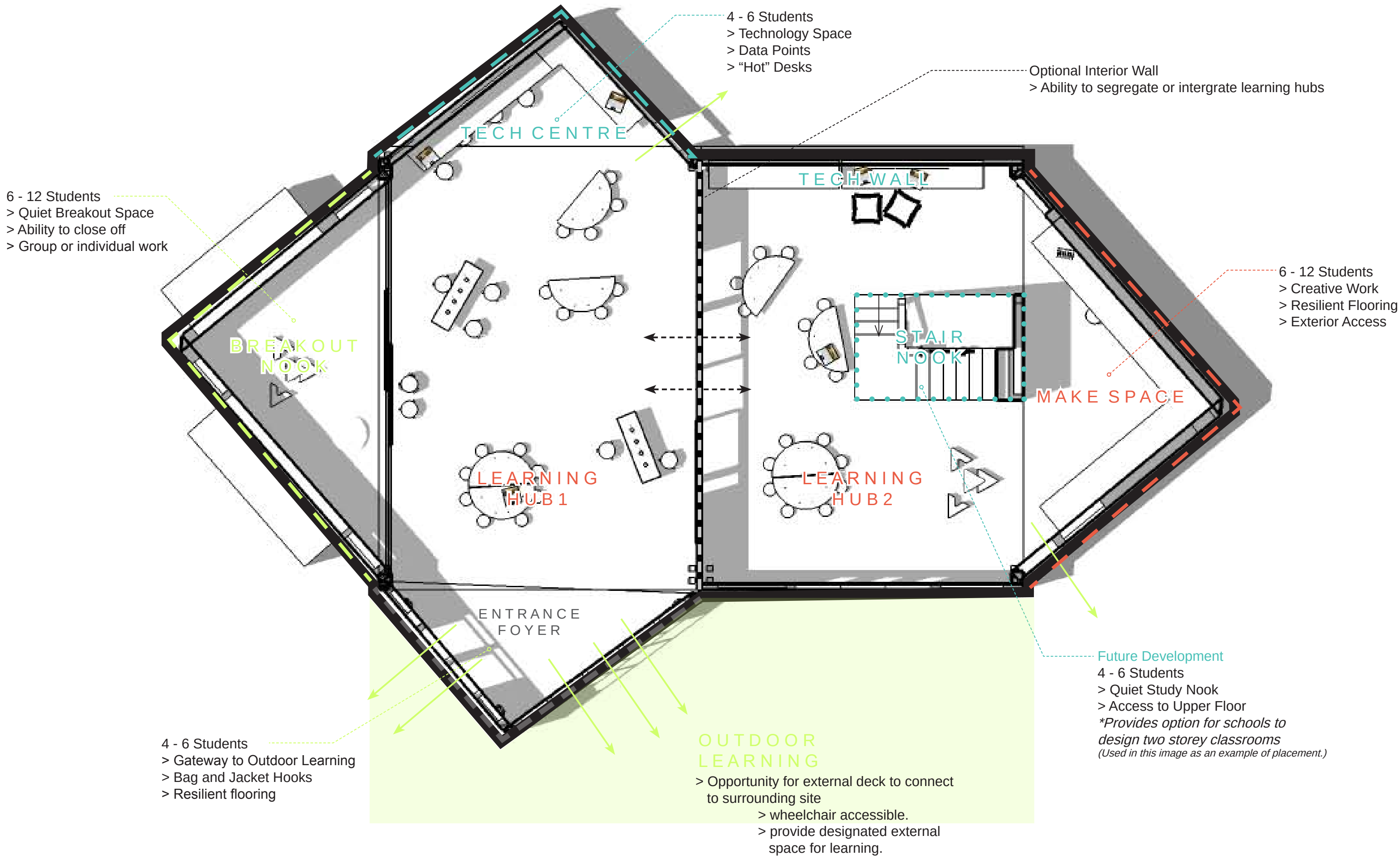


Fig 4.62. Budget Approach; Deluxe design option floor plan

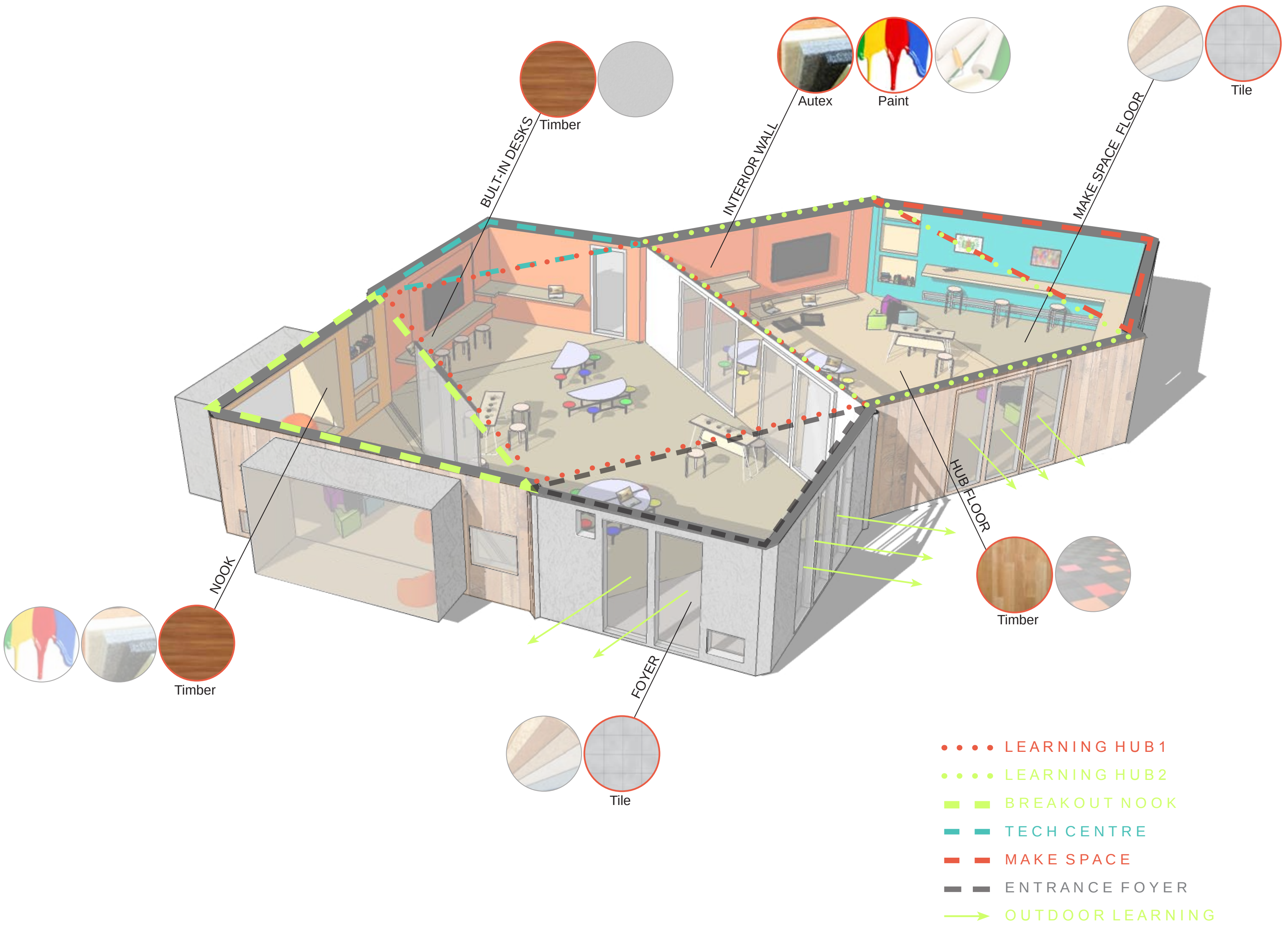


Fig 4.63. Budget Approach; Deluxe design option axonometric material application

4.6.6 Acoustic Treatment

One of the principle challenges of ILE is acoustics; the change in teaching style has led our classrooms of today to become too noisy.

Student led learning has caused around 38% of class time spent doing group work and 31% mat work, resulting in a staggering 71% of teachers reporting that noise from within the classroom has become a problem.[58]

The acoustic issues have primarily risen from relocatable classrooms with low pitched ceilings, along with concrete floors. The New Zealand Classroom Acoustics guide recommends that soft materials such as carpet with underlay for floor finishes and Autex for walls will help aid in improving the acoustics. Not surprisingly the guide recommends that open plan classrooms be avoided, however Flexi-Ed challenges the current recommendation by demonstrating through both architectural form and material qualities, open plan classrooms can be successful for the students of the future.[59]

As outlined previously the panel series includes both standardised panels as well as volumetric panels. By including an array of forms within the interior space, the rectangular structure is no longer present, increasing reverberation time and improving classroom acoustics.

Another panel within the series which provides significant acoustic improvement is the interior partition wall. This internal wall encourages clients to place an intermediate acoustic barrier between parallel teaching spaces to acoustically contain the individual learning hubs, giving the option to either open or close the glazed partitions depending on the classroom task.

Flexi-Ed allows schools to select the finishes for the interior teaching spaces from a list of pre-approved materials. These materials have been selected based upon a minimum performance standard specifically based upon acoustic recommendations. Thus allowing the school to have a direct effect on the aesthetics as well as acoustic qualities within the interior and exterior spaces.

During the design process clients will have their selected design run through an energy and acoustic analysis screening to ensure that clients are selecting appropriate panels for an effective design. It is important that the selected client designs are analysed to ensure that New Zealand is producing efficient classrooms that have the capabilities to reduce building life cycle costs, and house comfortable learning areas year round.

Fig 4.64. Primary school example of interior finishes A

[58] Wilson, Oriole. *Classroom Acoustics : A New Zealand Perspective*. Wellington, N.Z. : Oticon Foundation in New Zealand, 2002. Pg 30

[59] Ibid

Fig 4.65. High school example of interior finishes

4.6.7 Construction Timeline

The process of Flexi-Ed can be seen outlined in figure 4.66, supported by a construction timeline demonstrating the stages of the prefabricated build in figure 4.67. The timeline demonstrates the linear process of the Flexi-Ed system along with a compressed construction phase due to the simultaneous off-site and on-site works as a resultant of a prefabricated build.

Once Flexi-Ed is up and running it is intended that the timeline will be compressed, due to having access to both machinery and storage. This will allow the production of both panels and components up to the material application stage to be readily available in advance and stored until required. The compressed timeline aims at a two week turnaround from client order to site installation.

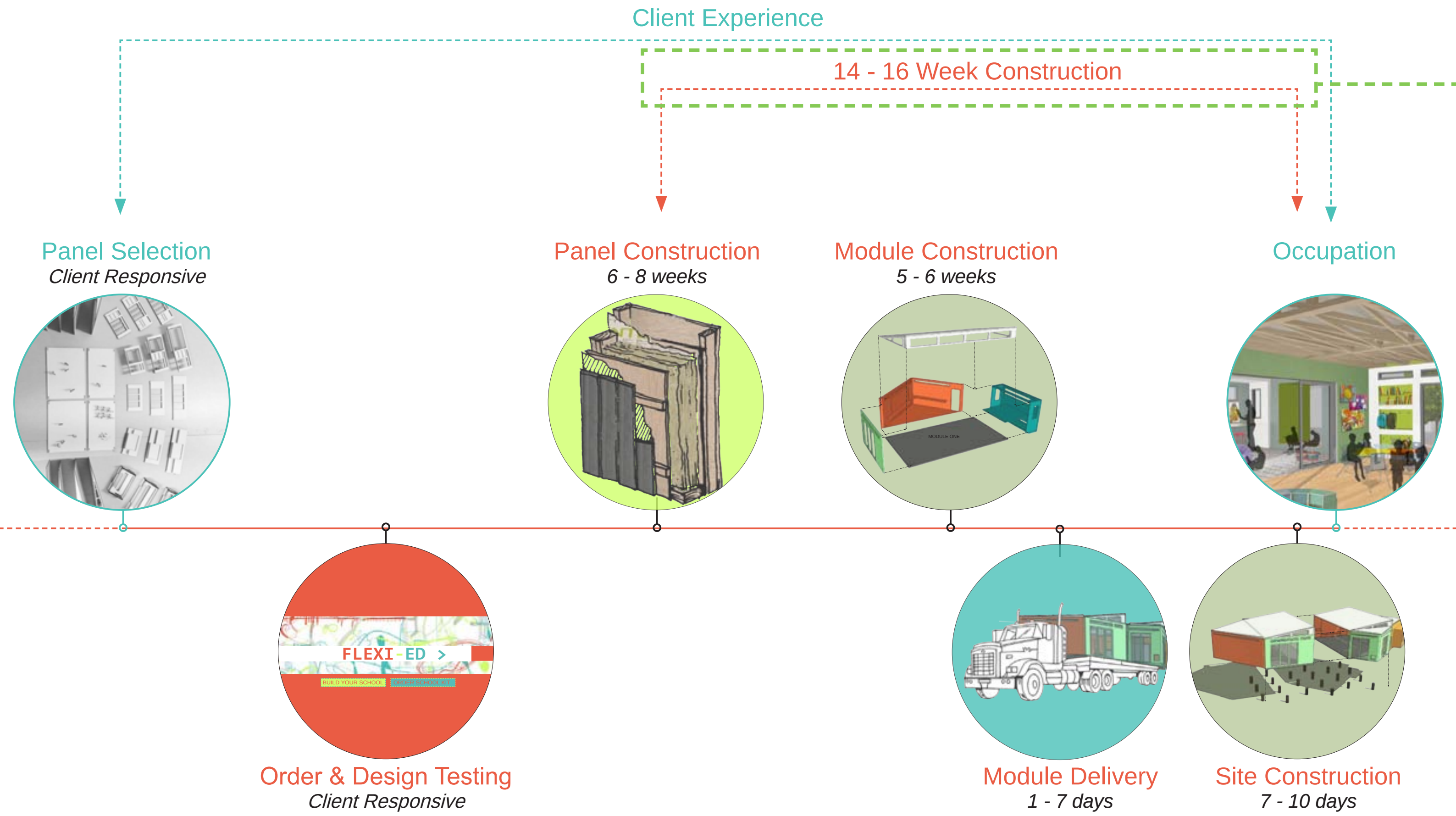


Fig 4.66. Flexi-Ed timeline overview

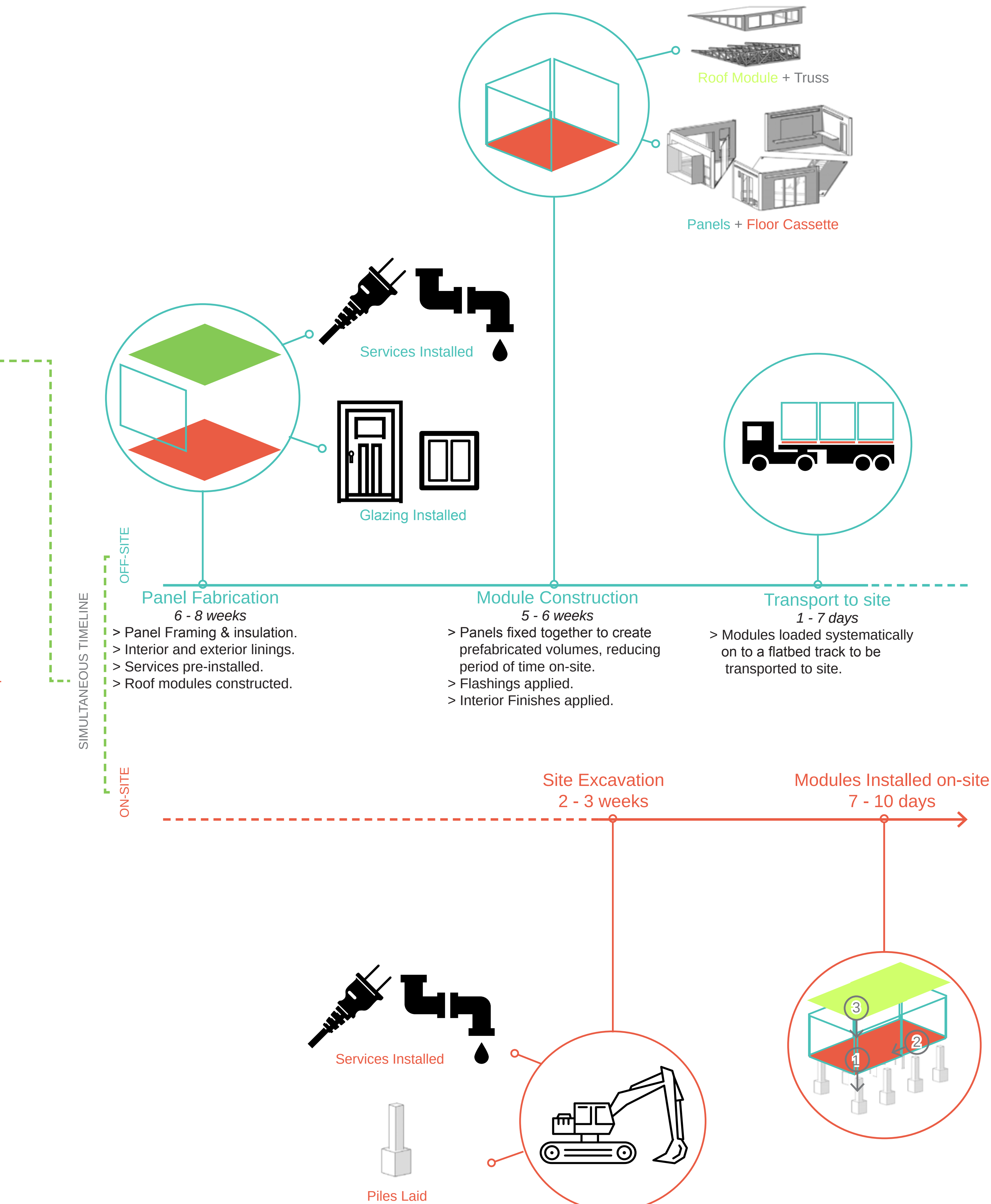


Fig 4.67. Flexi-Ed detailed prefabrication timeline

...Prefabrication is “modern architecture’s oldest new idea”
- E.Harker, 2007

5.0 THE BUILD >

5.1 PHYSICAL MODEL >

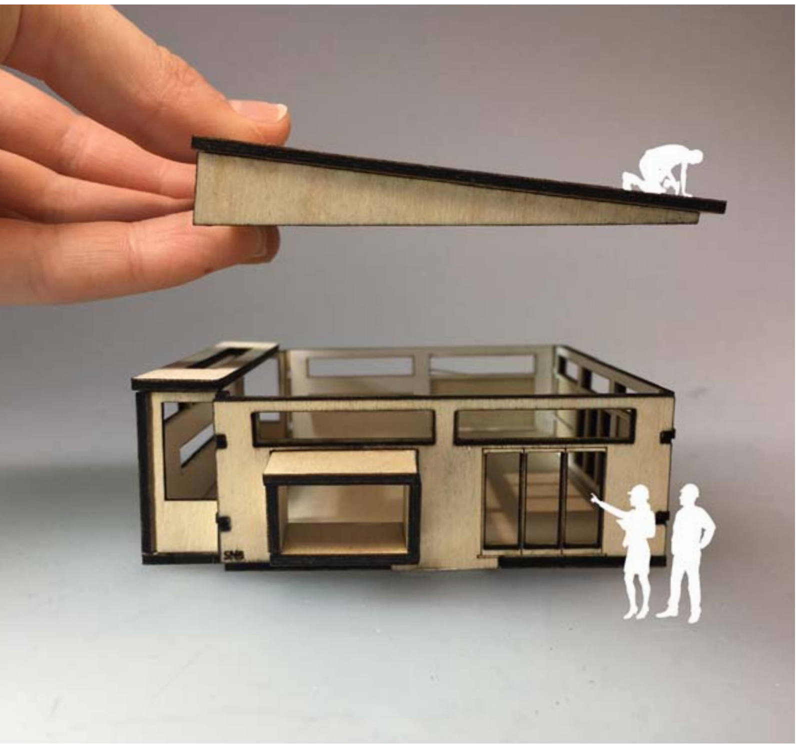
In the previous section, 4.0 The Design, the design process and the assembly of the system was discussed.

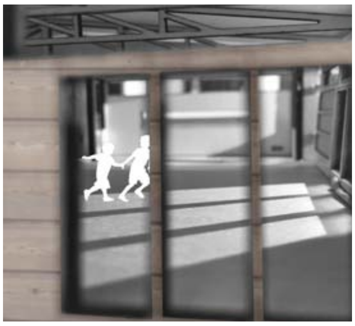
This section documents the detailing of each panel in the Flexi-Ed collection and documents the fabrication and assembly process of how a typical floor plan build would be carried out.

The Build section discusses the realities of the construction system and reflects on the occupation of a Flexi-Ed build.

A final physical model was constructed (see Flexi-Ed model collection, figures 5.1 - 5.6) to test and evaluate the developed design, demonstrating the success and ability to interchange different panels. This process displayed the success in establishing a system that caters to a wide diversity of clients, ultimately enhancing learning for the students of our future in New Zealand.

Fig 5.1. Collage of Flexi-Ed system





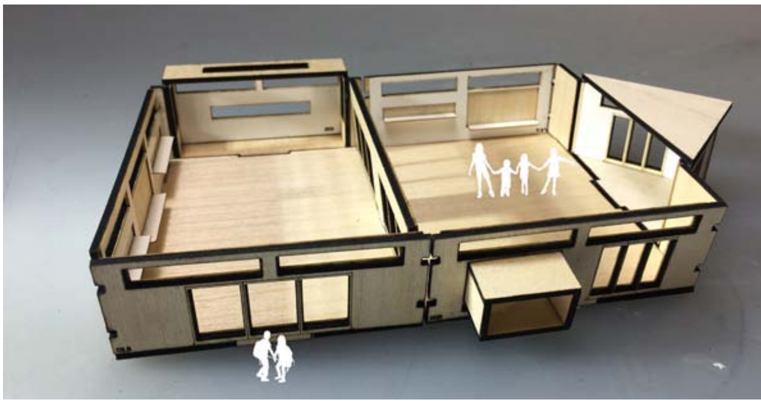


Fig 5.2. Exterior view (top)
Fig 5.3. Roof model installation (bottom left)
Fig 5.4. Interior views of learning hubs (right)
Fig 5.5. Axonometric view of possible plan configuration (bottom right)

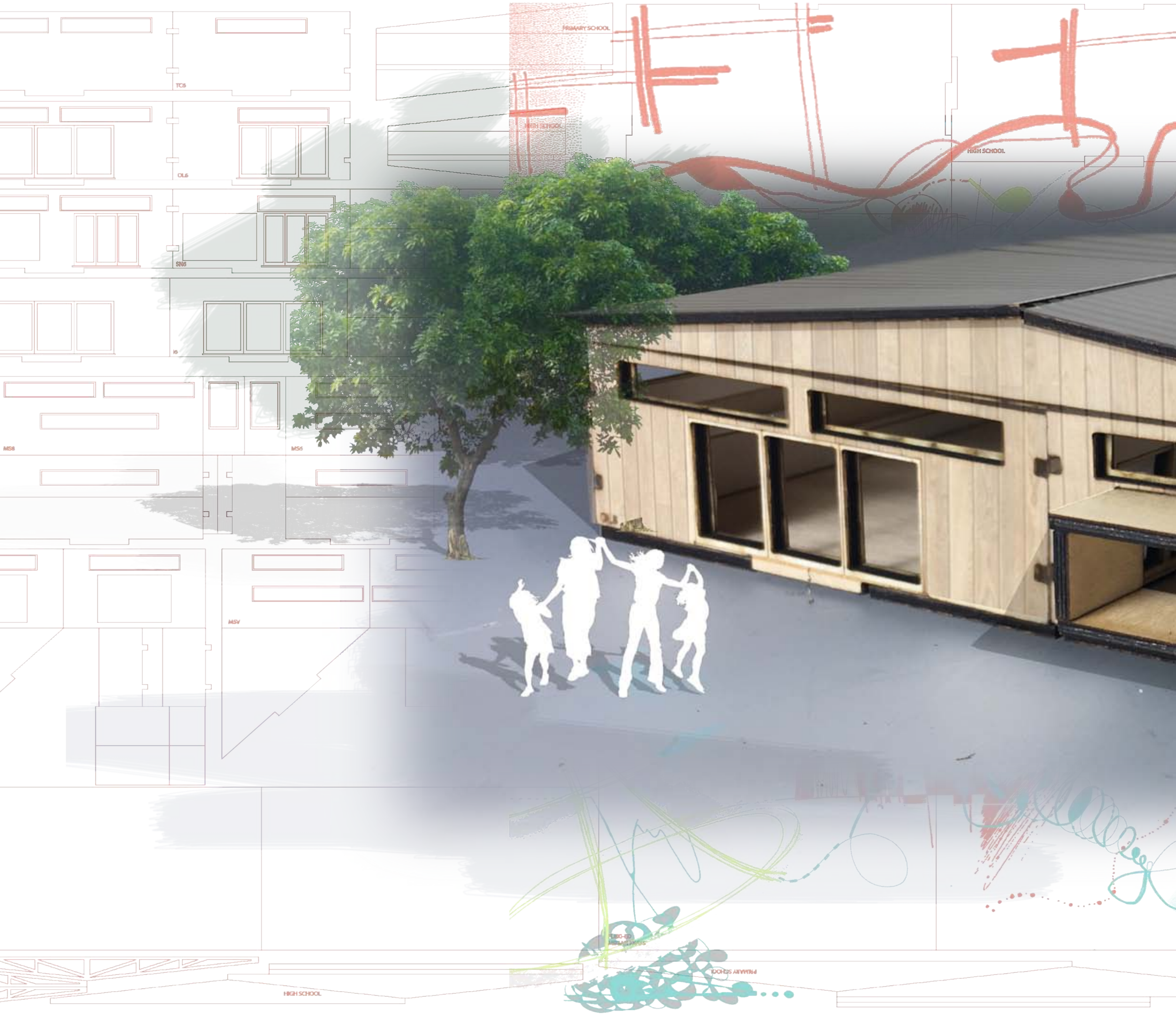
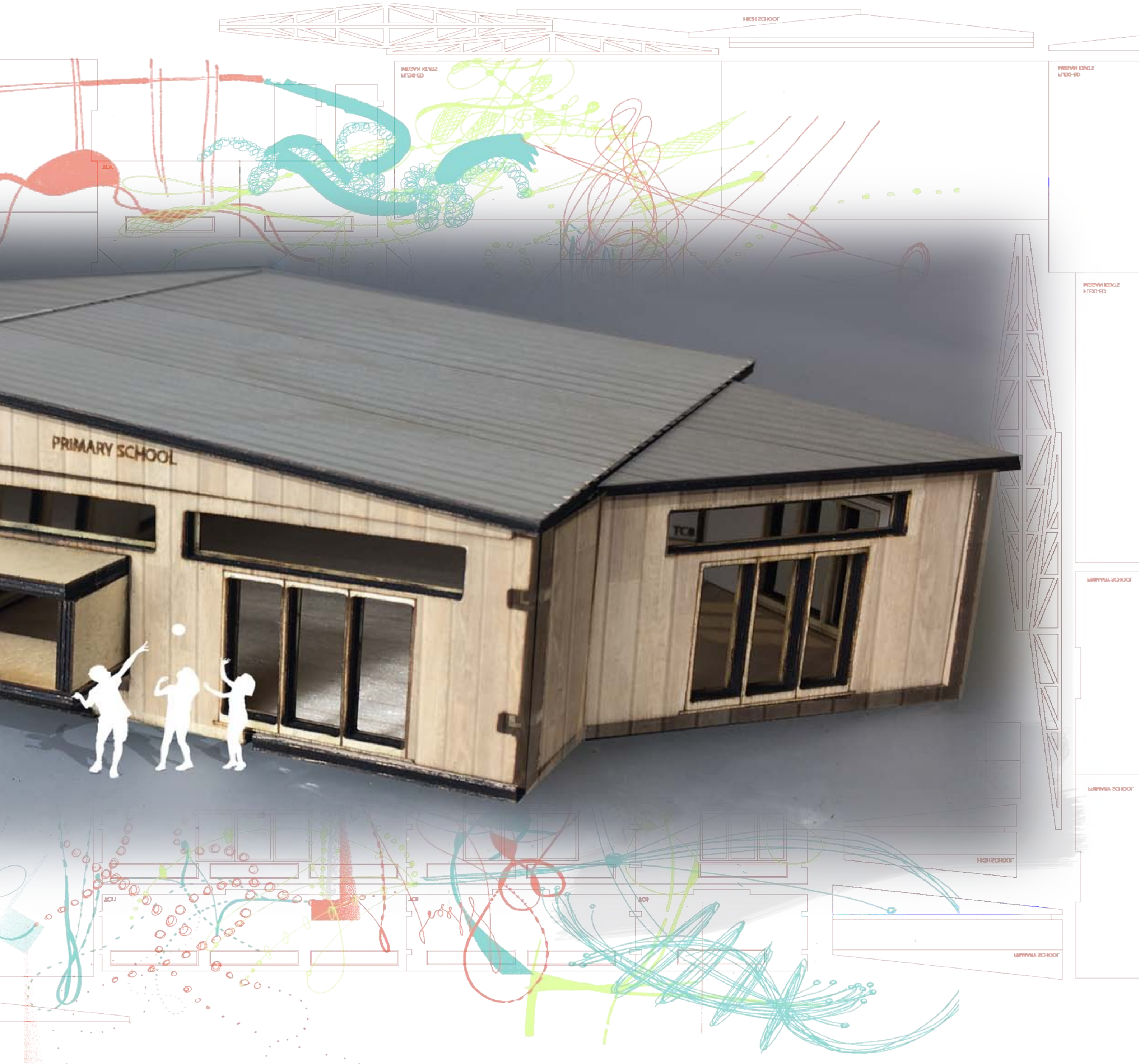


Fig 5.6.   Exterior view indicating occupation and materials


PRIMARY SCHOOL

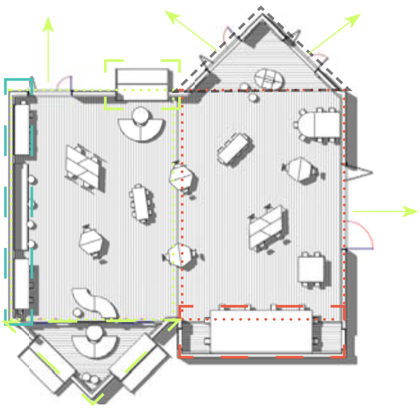
5.1 FLOOR PLAN CONFIGURATIONS >

Flexi-Ed provides a wide range of classroom configurations, catering to different sites, client specific briefs and budget. Figure 5.7 demonstrate just a fraction of the options that Flexi-Ed provides to the client, implementing individual school identity as each configuration has the possibility to be unique to the school.

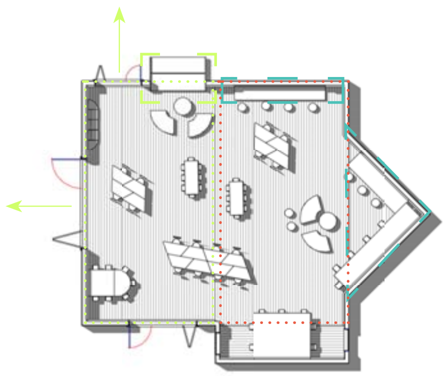
The floor plans shown in figure 5.7 demonstrate options for one to two teaching spaces. Flexi-Ed has the capacity to provide more learning areas in one classroom block upon consultation with a Flexi-Ed architect.

Primary School Teaching Space Entitlement:

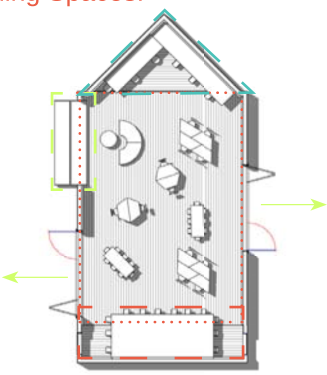
Orientation Driven:

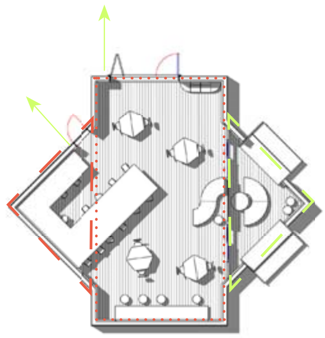


Secondary School Teaching Space Entitlement:

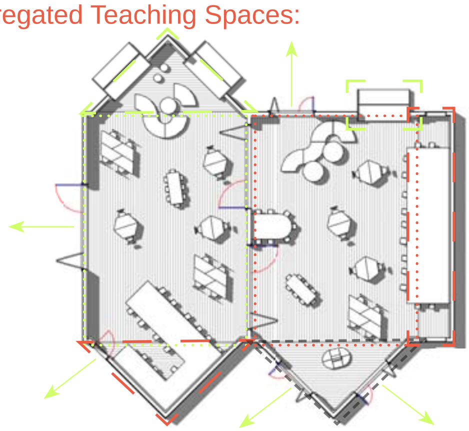


Single Teaching Spaces:





Segregated Teaching Spaces:



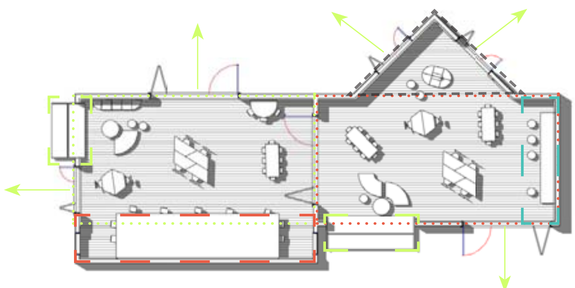


Fig 5.7. Examples of possible Flexi-Ed floor plan configurations

Proposed Floor Plan Configuration

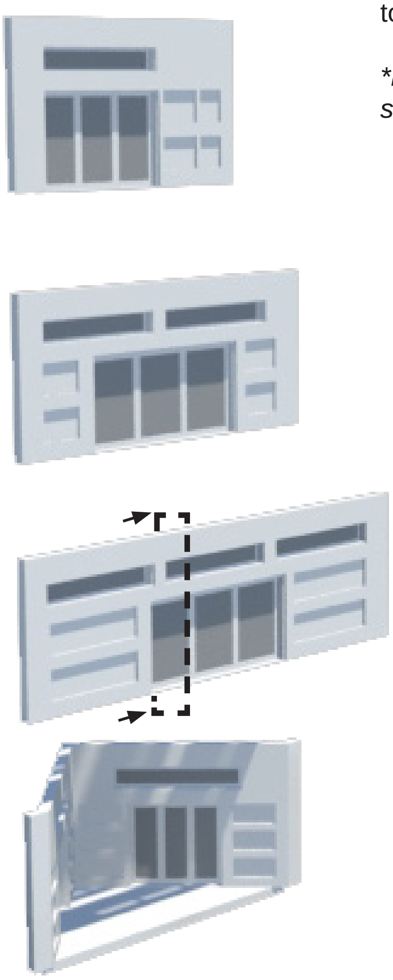
Teaching Spaces: 2
Level of Education: Primary

Fig 5.8. Axonometric view of proposed Flexi-Ed design (top)
Fig 5.9. Floor plan of proposed Flexi-Ed design (bottom)

5.3.1 Outdoor Learning Gateway

Each panel has been detailed to illustrate the application of the specifically designed learning settings. Prefabricated construction has been used as a tool to implement the learning setting within each panel.

**Details are shown as an indication only and are subject to review by a structural engineer.*



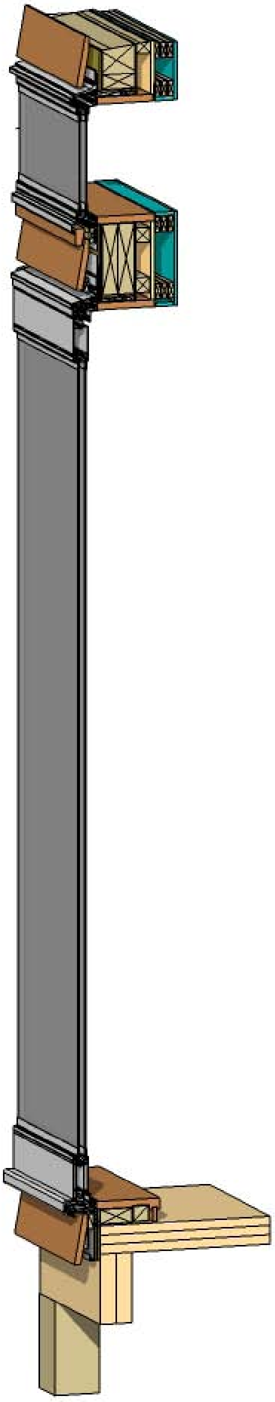


Fig 5.10. Outdoor Learning Gateway panel collection (left)
Fig 5.11. Outdoor Learning Gateway: 3D section (right)

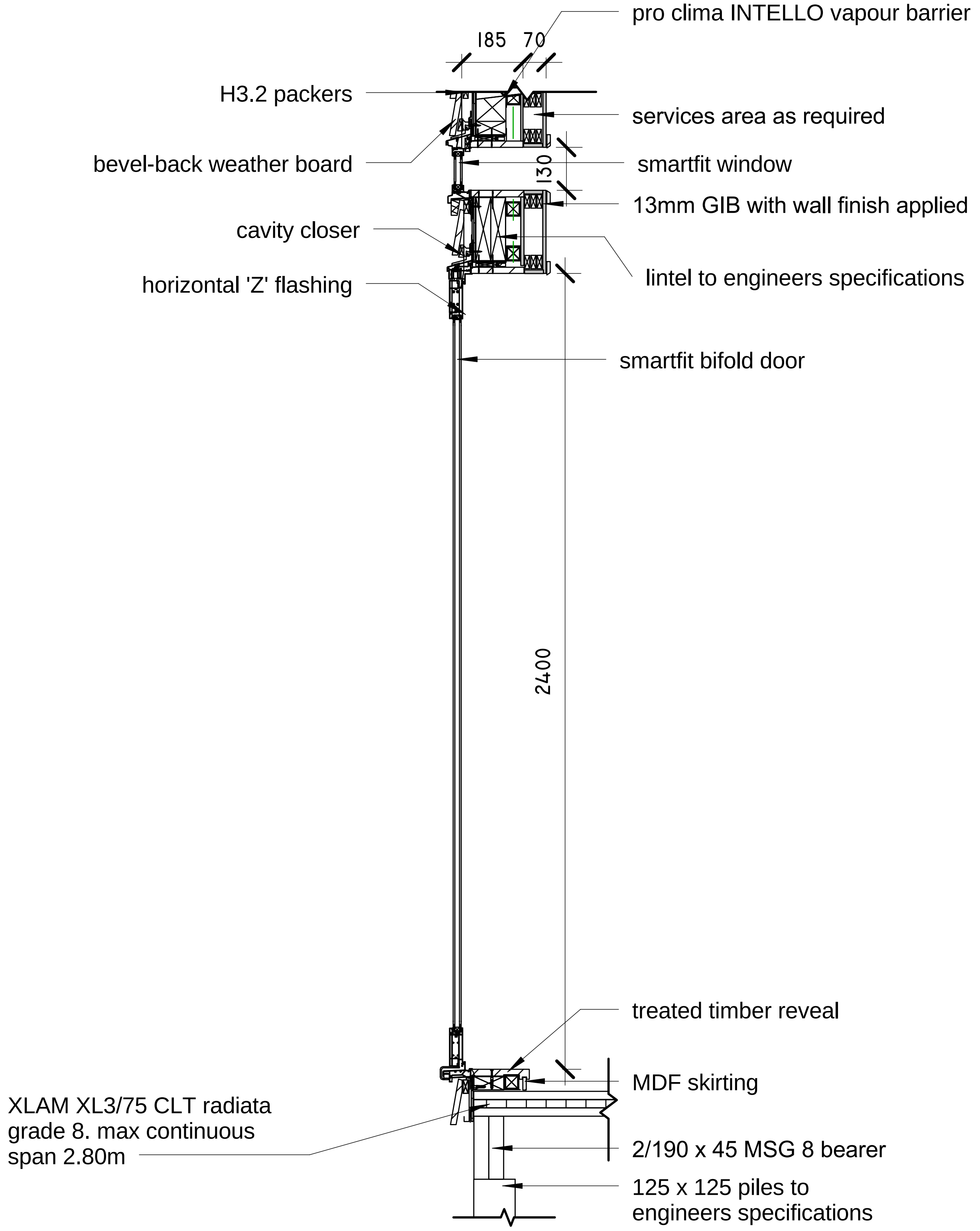


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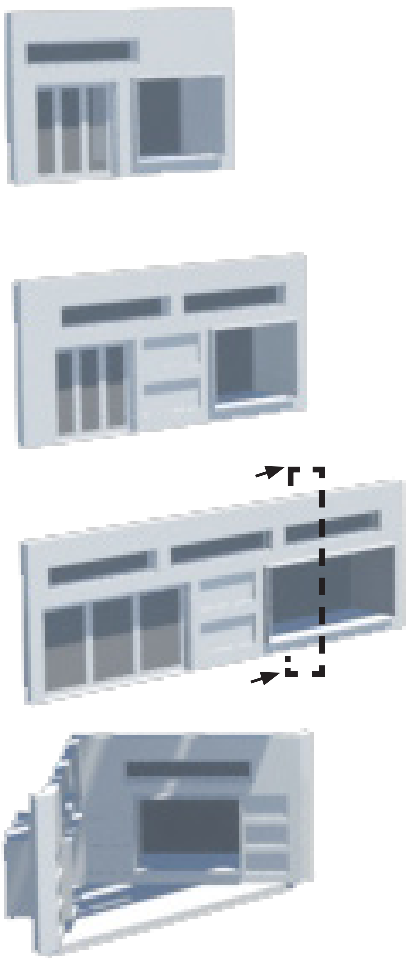
Fig 5.12. Outdoor Learning Gateway: Section detail

5.3.2 Breakout Nook



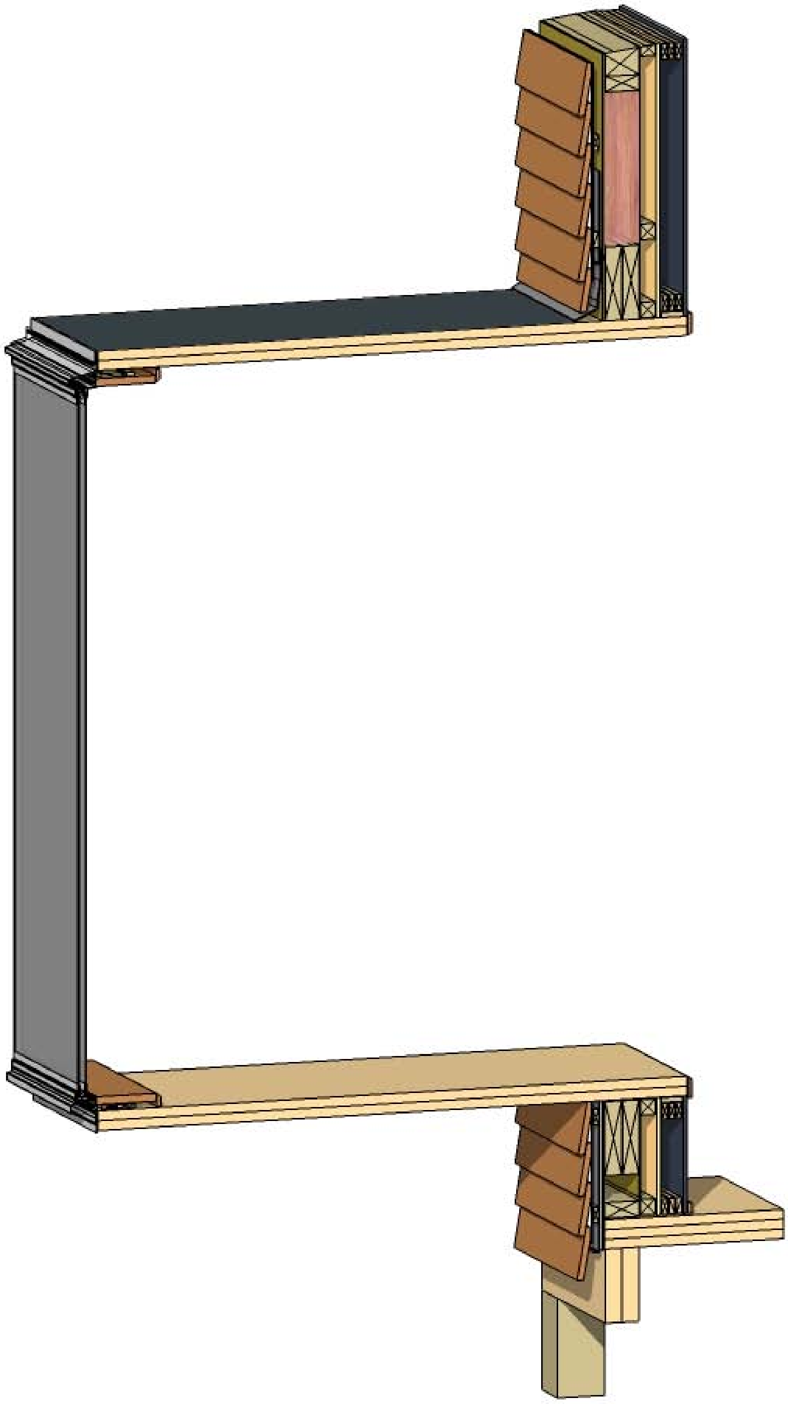


Fig 5.13. Breakout Nook panel collection (left)
Fig 5.14. Breakout Nook: 3D section (right)

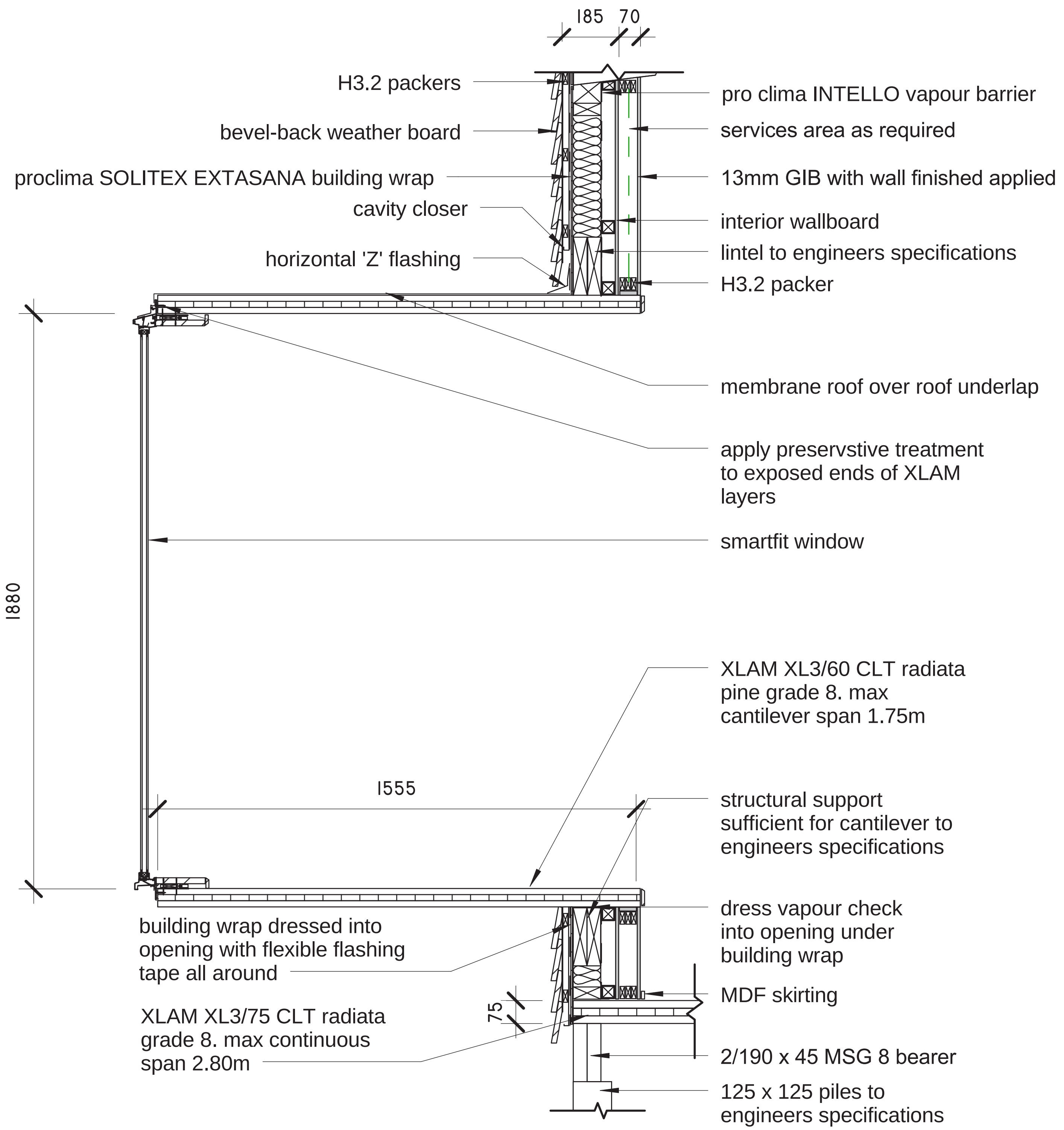


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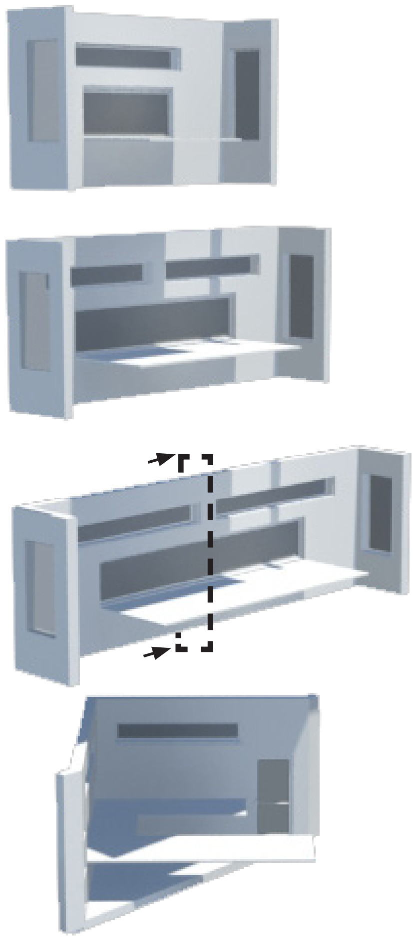
Fig 5.15. Breakout Nook: Section detail

5.3.3 Make Space



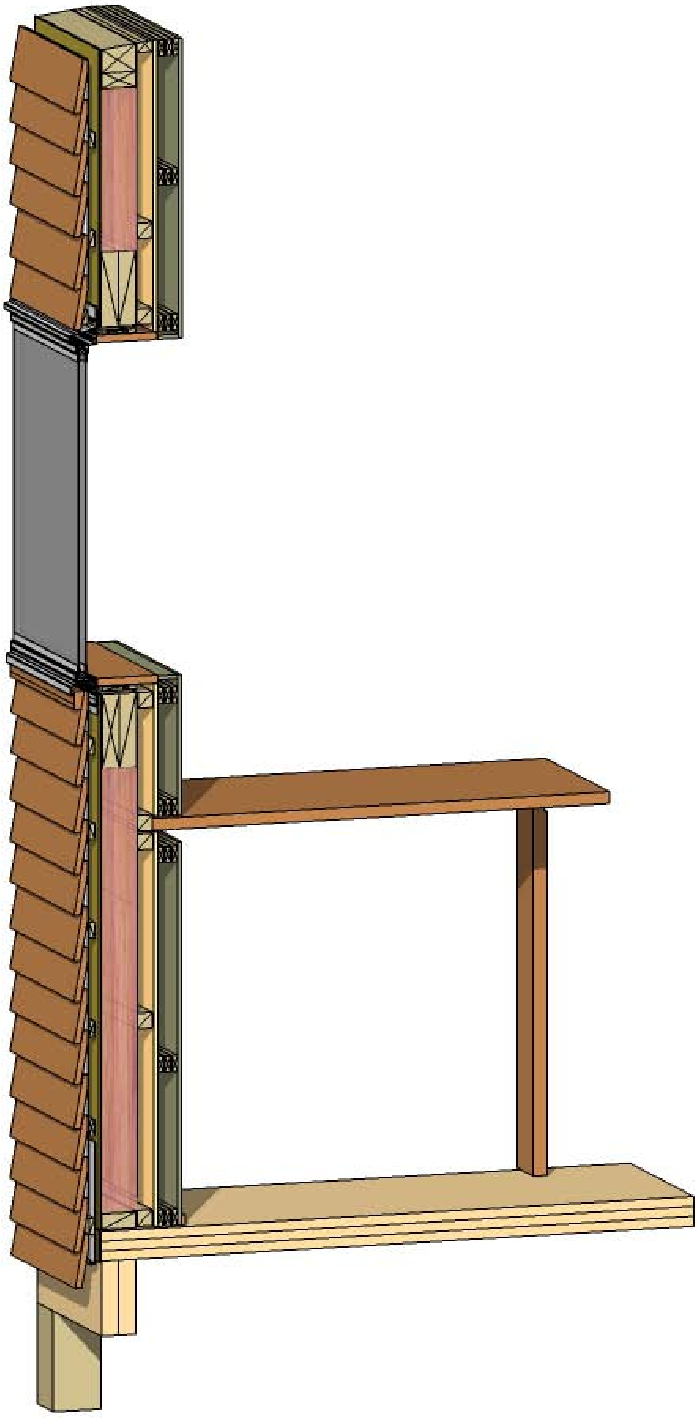


Fig 5.16. Make Space panel collection (left)
Fig 5.17. Make Space: 3D section (right)

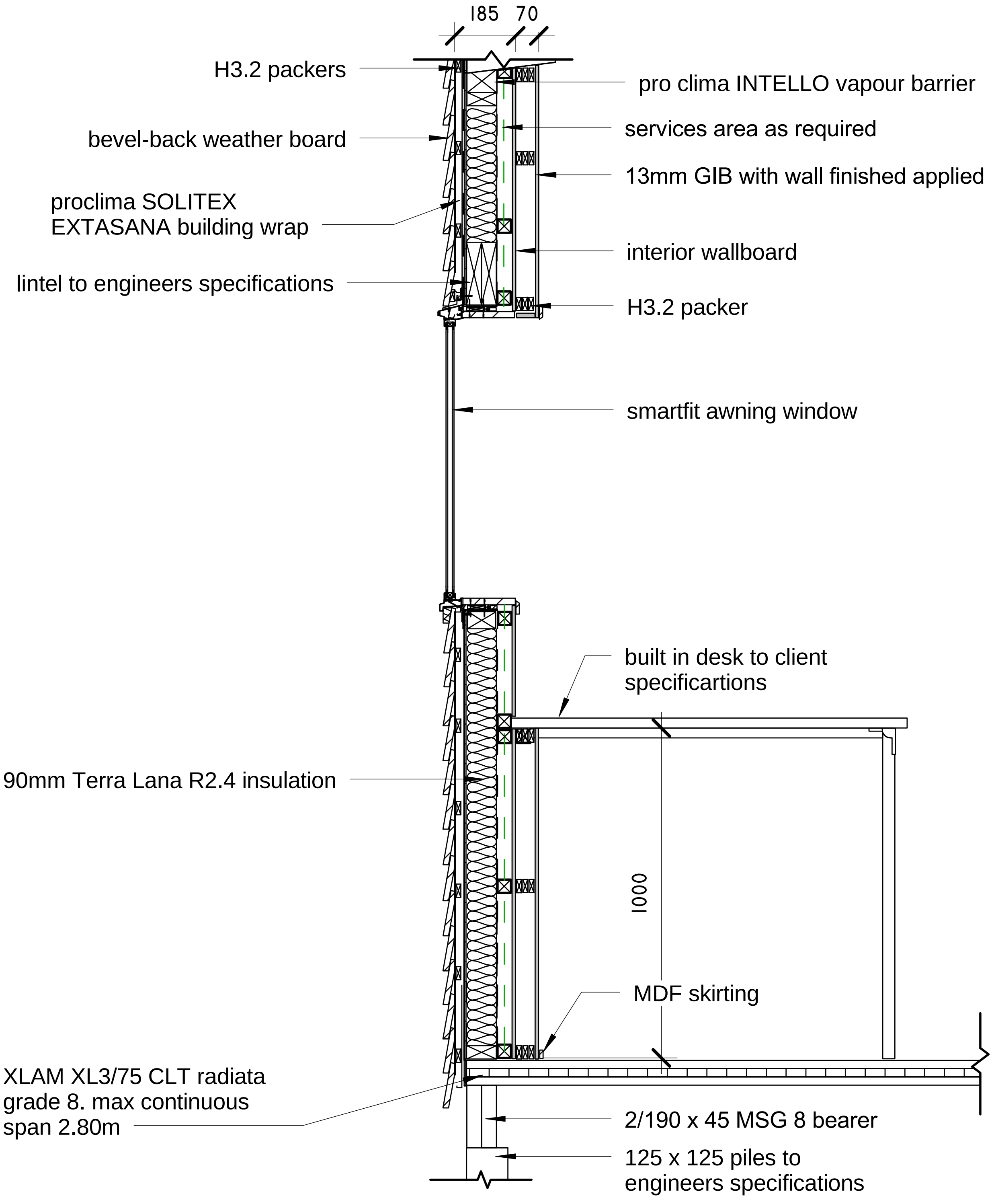


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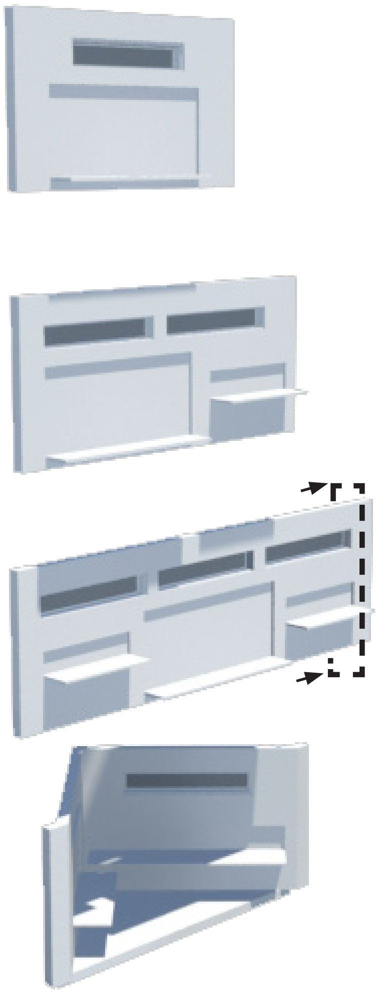
Fig 5.18. Make space: Section detail

5.3.4 Tech Centre



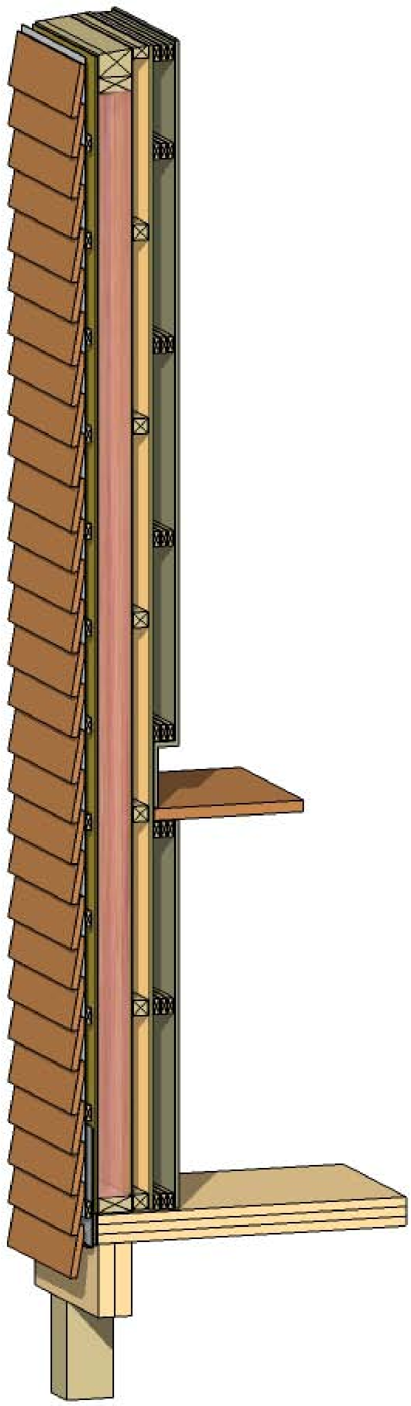


Fig 5.19. Tech Centre panel collection (left)
Fig 5.20. Tech Centre: 3D section (right)

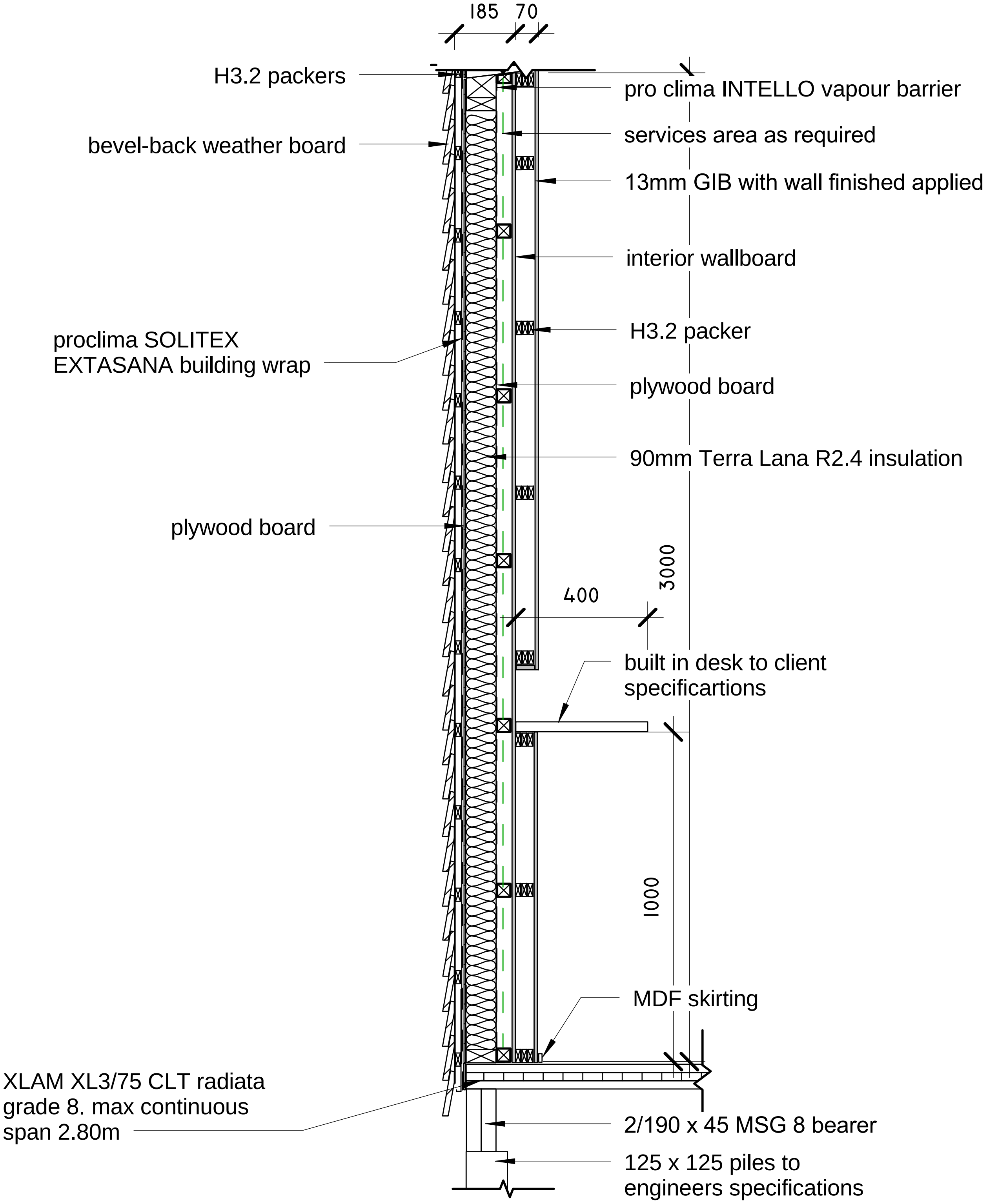


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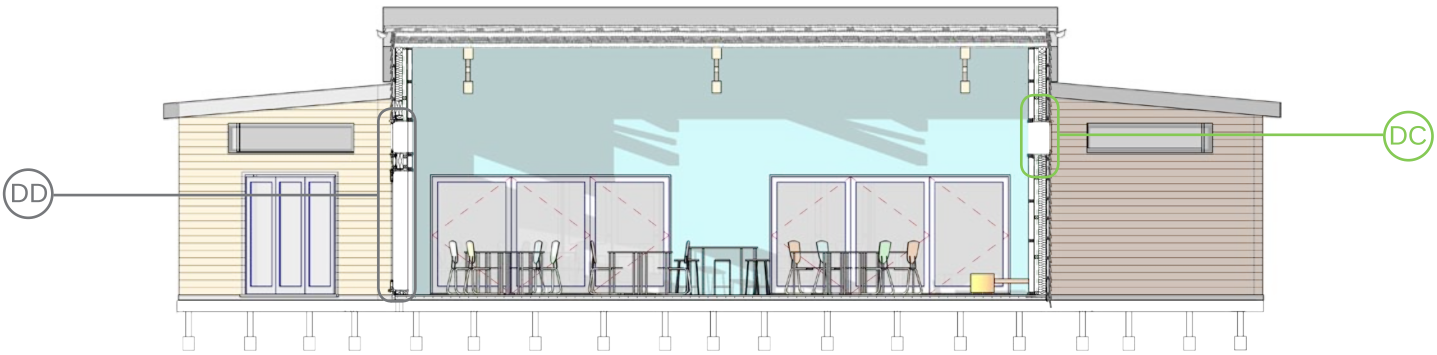
Fig 5.21. Tech Centre: Section detail

5.4.1 Floor Plan

The sections (see proposed design sections, figures 5.23 - 5.24) indicate the interior qualities achieved from the panel and roof module combination.

Fig 5.22. Proposed Flexi-Ed design: Floor plan

Section A:



Section B:

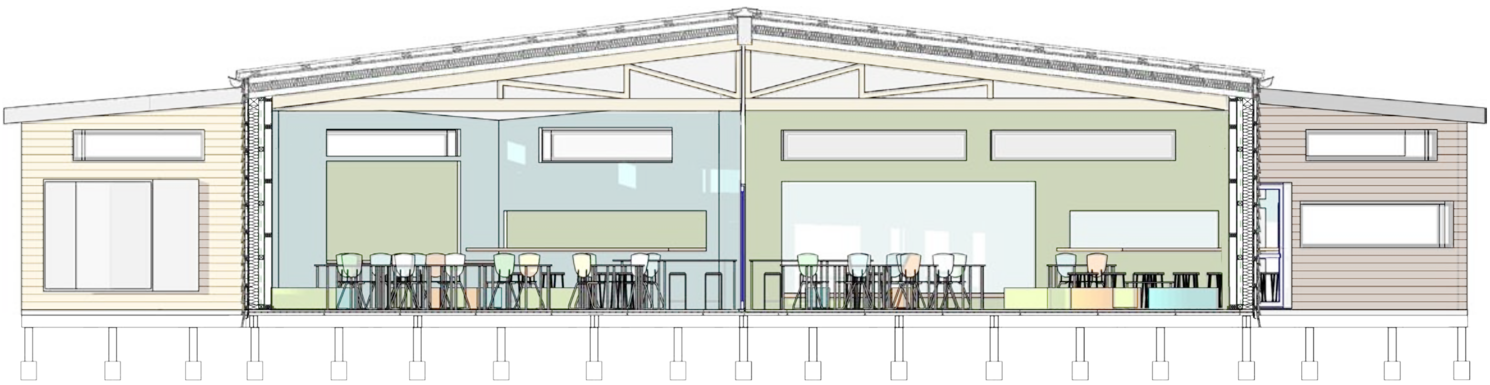


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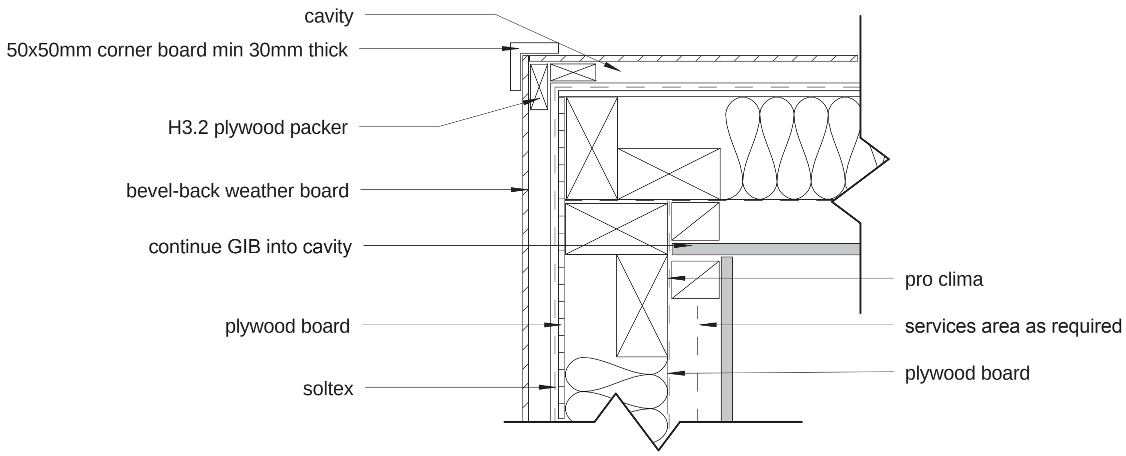
Fig 5.23. Section A (top)
Fig 5.24. Section B (bottom)

5.4.2 Panel Details

The on-site installation process (see figure 5.25) can be supported by the following panel details to indicate the connection between the individual panels made in the factory (see Detail DA, figure 5.26) and the connection made on-site between the modules (see Detail DB, figure 5.27).

Fig 5.25. On-site installation process

DA Panel to panel corner junction detail



DB Panel to Panel junction detail:

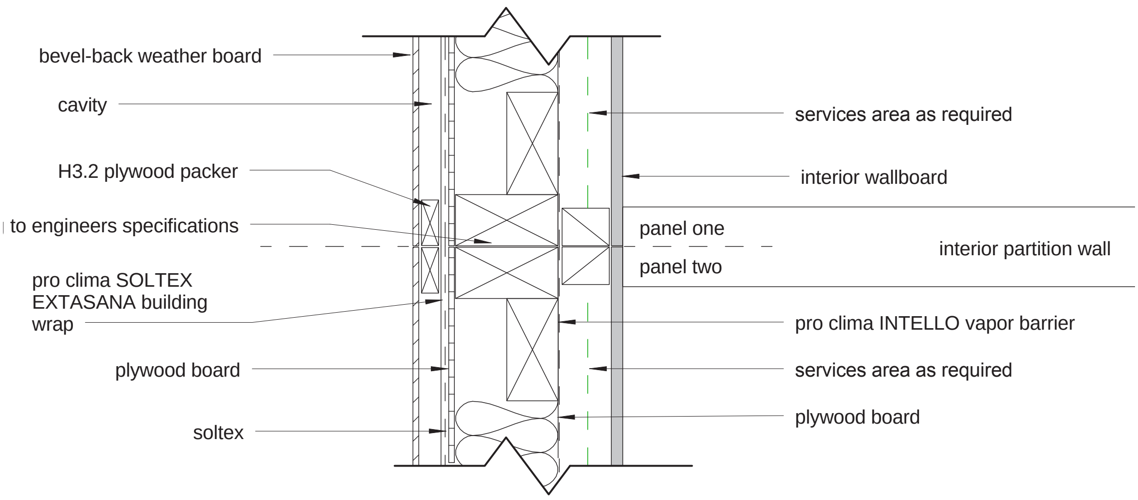


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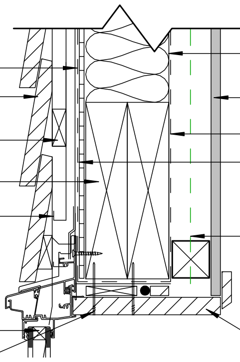
Fig 5.26. Detail DA: Panel to panel corner junction
Fig 5.27. Detail DB: Panel to panel junction detail

5.4.3 Window and Door Details

The window and door details indicate the construction that will house the selected smart fit window and door systems (see window and door detail, figures 5.28 - 5.29).

DC Smartfit awning window Detail:



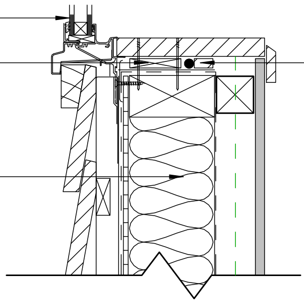
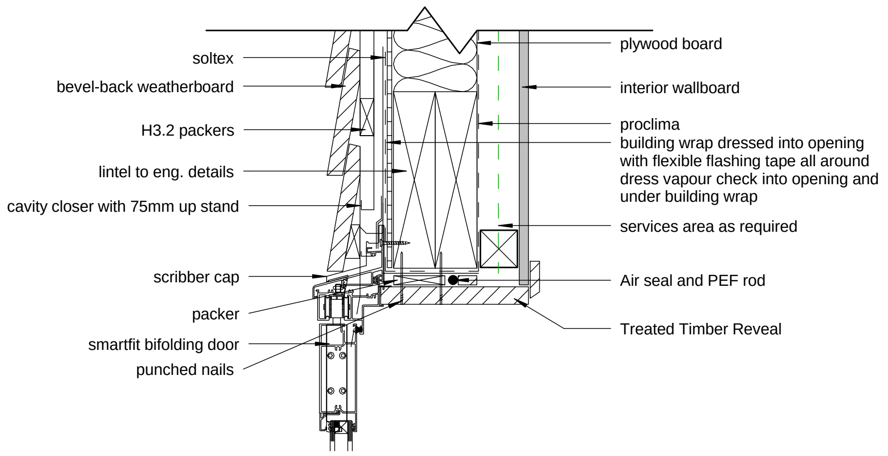


Fig 5.28. *Detail DC: Window Head and Sill detail*

DD Smartfit bifolding door detail:



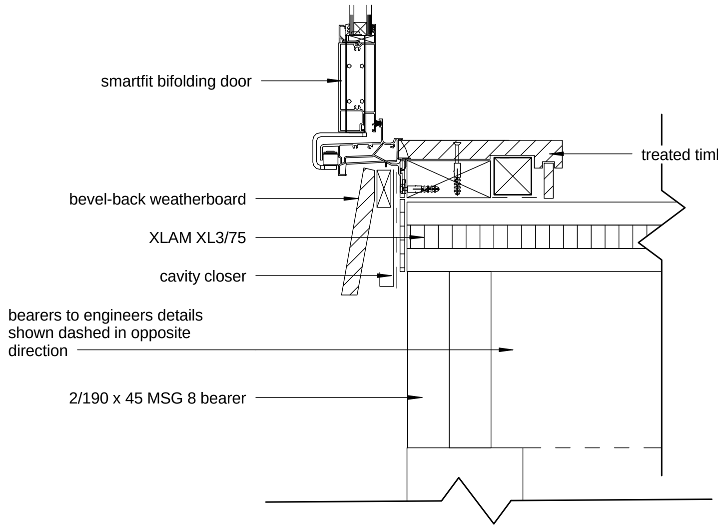


Fig 5.29. Detail DD: Door Head and Sill detail

5.4.4 Roof Module Construction
Monopitch Roof Detail

The two different roof options (see Roof section details, figures 5.30 - 5.31) are to be constructed as modules off-site and delivered as separate components. Once on-site the roof modules are to be connected to the wall and floor modules to create an weatherproof structure.

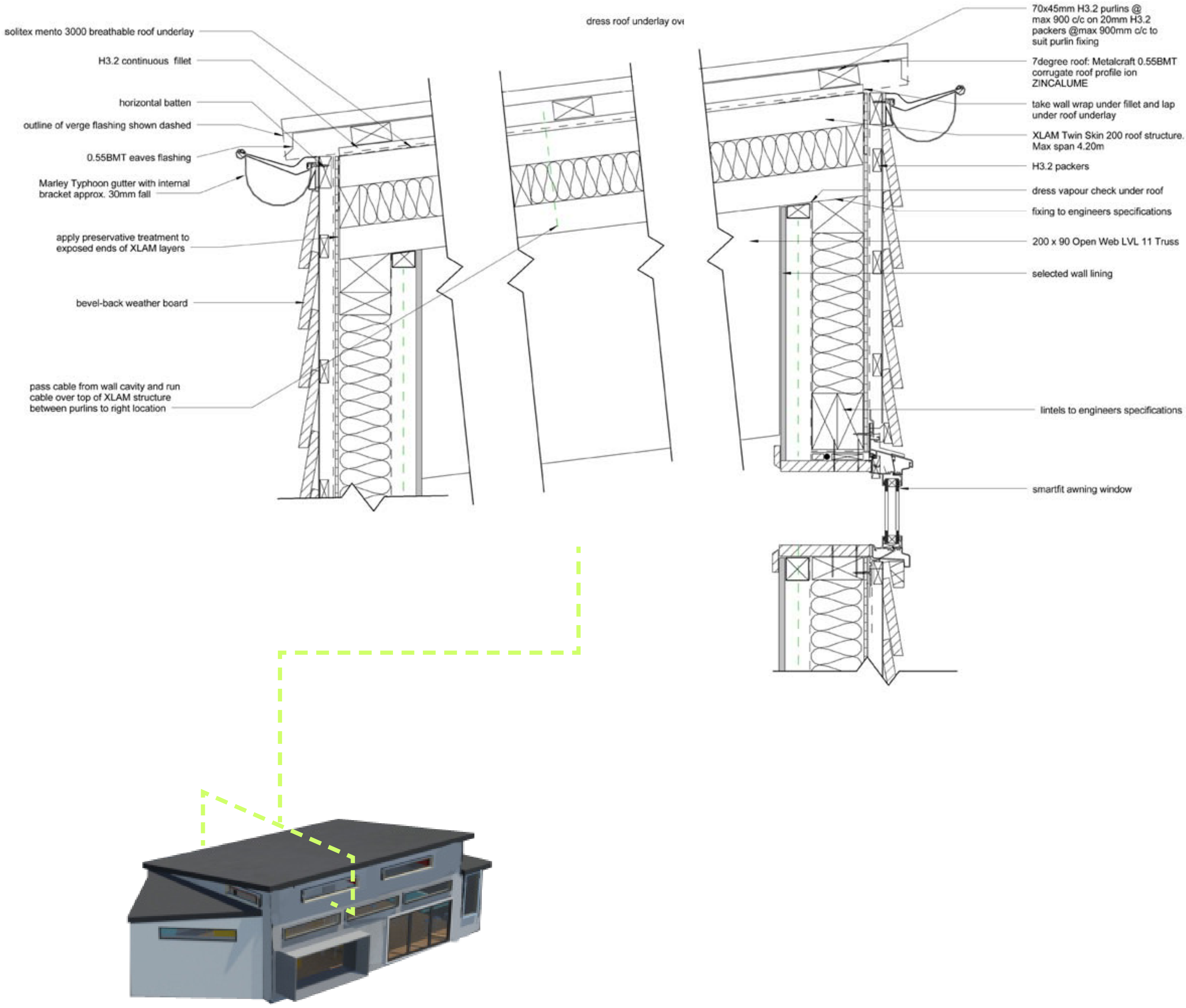
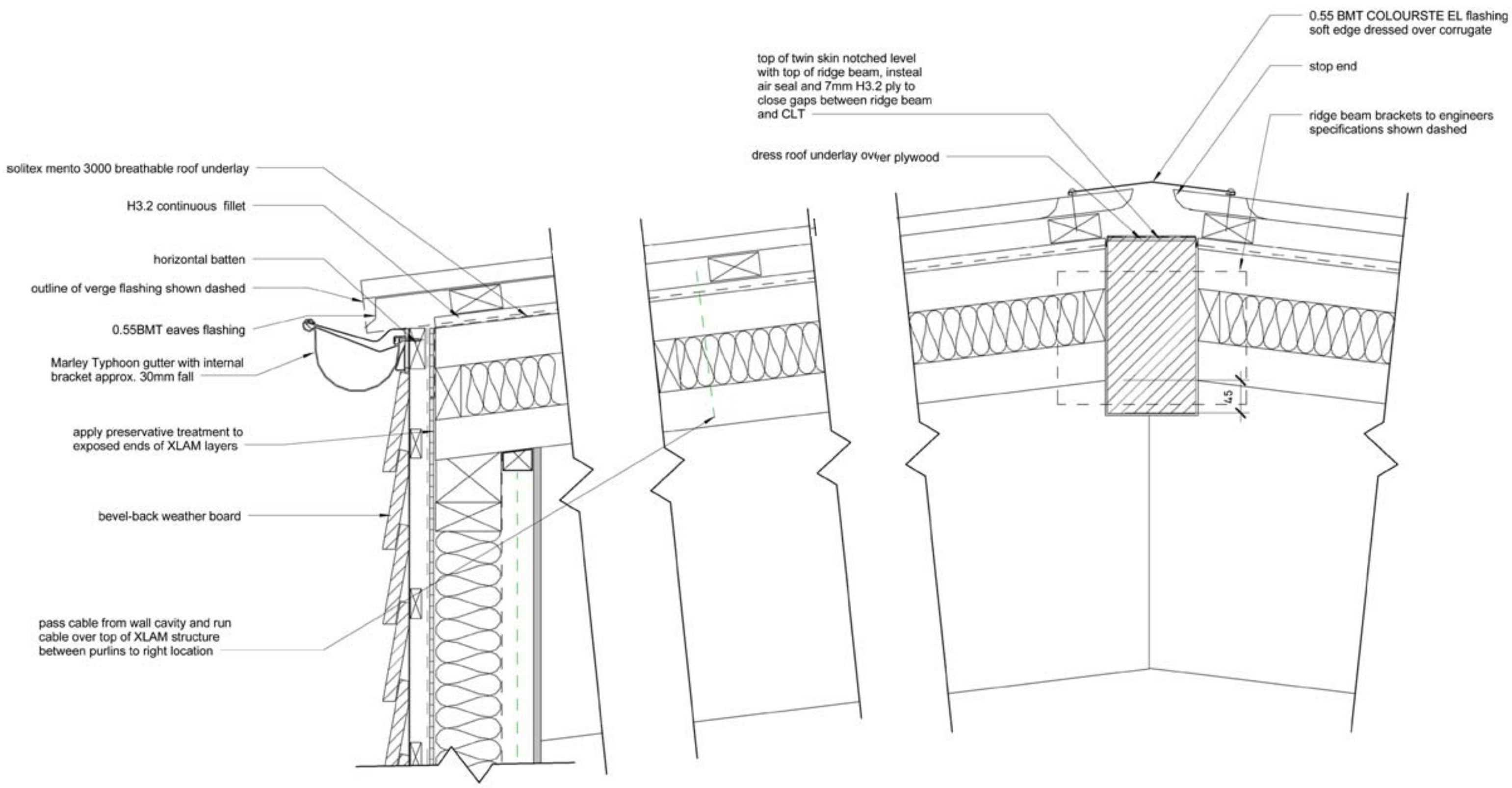


Fig 5.30. Monopitch roof section detail

Gable Roof Detail



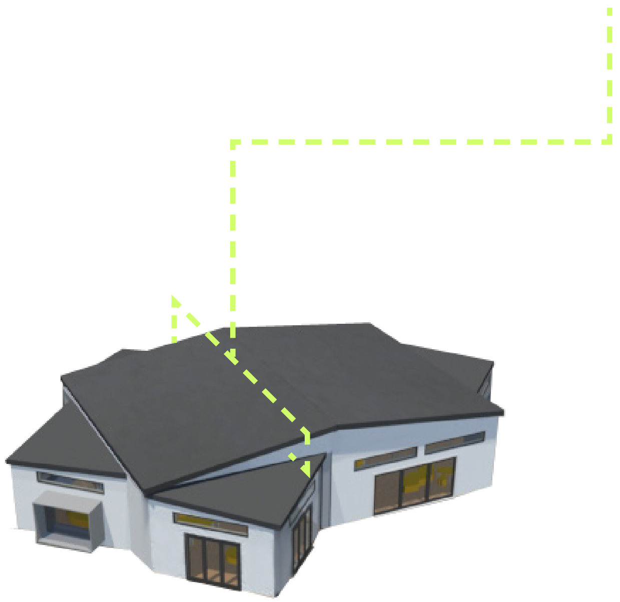


Fig 5.31. Gable roof section detail

5.5 CONSTRUCTION TIMELINE >

The construction timeline demonstrates the body of work that can be undertaken off-site due to the selected prefabricated construction technique.

By designing as a panel it increases the customisation for the client, whilst the delivery of the panel as a module reduces the time on-site in an attempt to minimise on-site disruption and hazards for a school community.

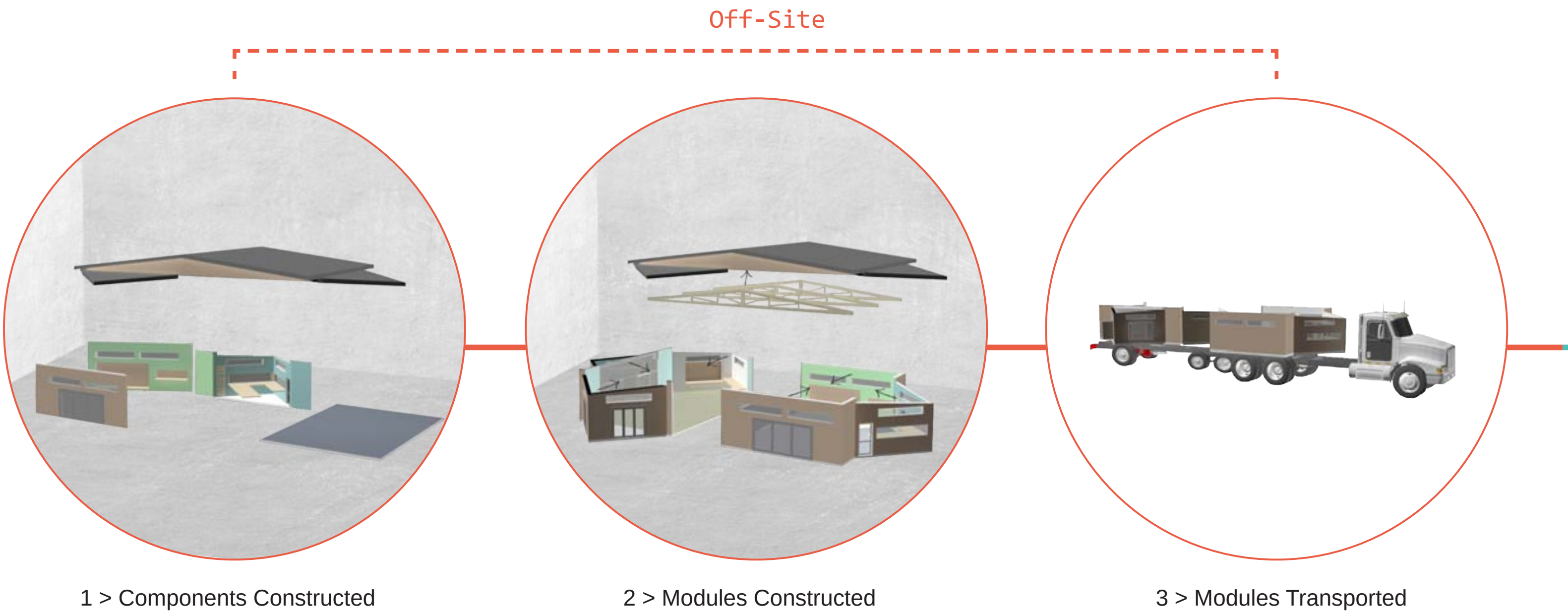
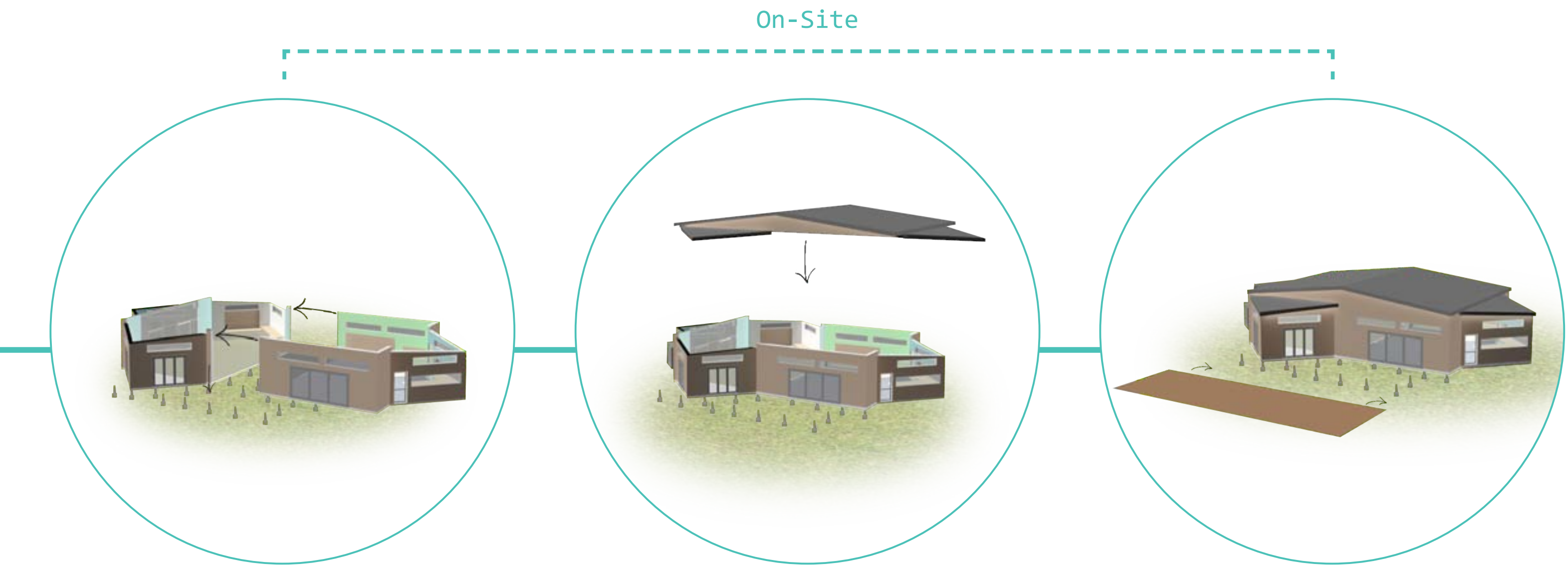


Fig 5.32. Flexi-Ed Construction process timeline



4 > Modules Installed and Connected

5 > Roof Modules Connected

6 > Additional Fixtures Installed

Fig 5.33. Axonometric plan. Demonstrating the relationship to site during a typical school day.

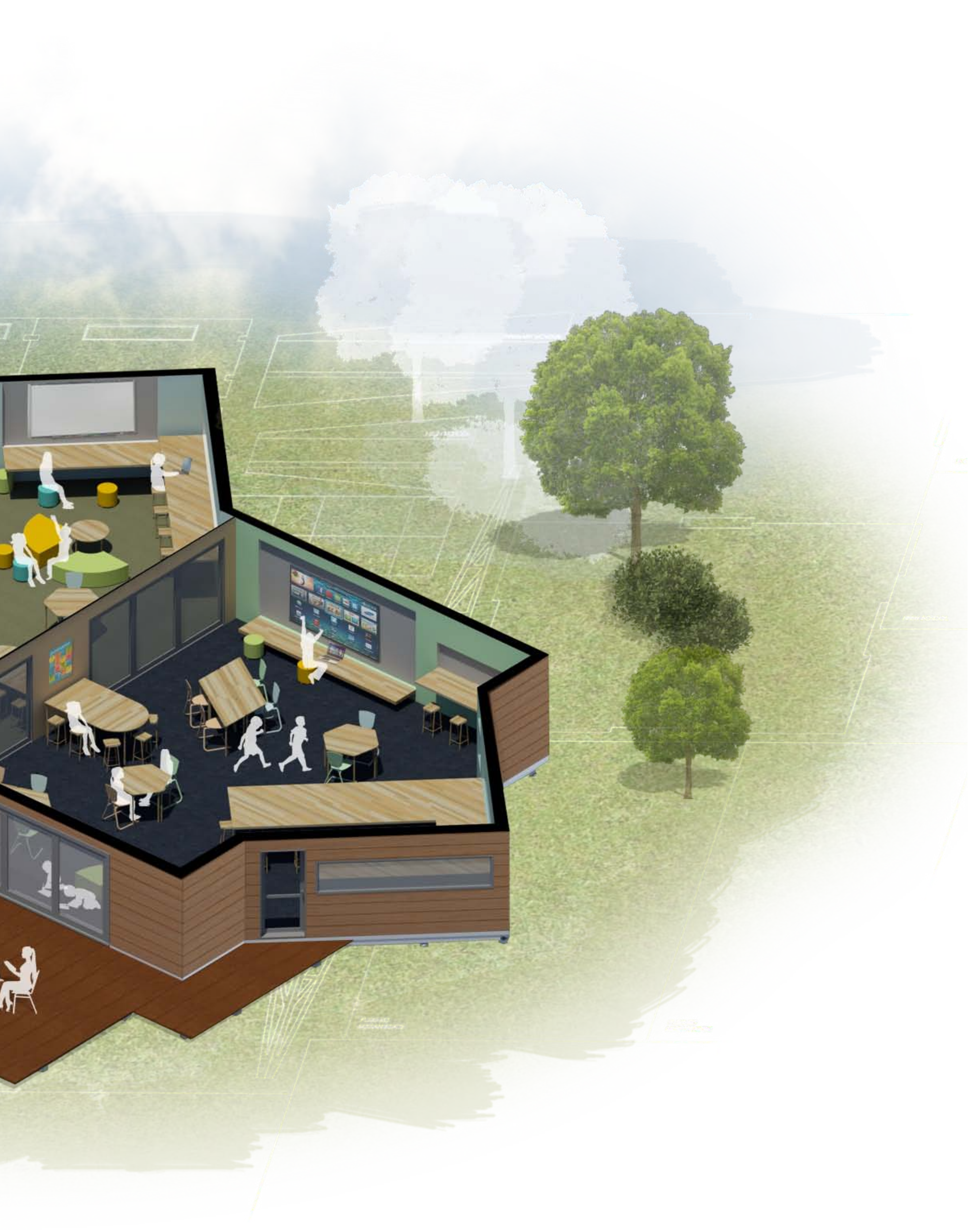


Fig 5.34. Interior view Learning hub 1. Displaying the different learning settings the panels provide during a typical school day.


123
456
789
10

Fig 5.35. Learning Hub 2 Interior view. Demonstrating the array of learning settings and interior customisation along with the relationship to surrounding site on a typical school day.

Fig 5.36. Section: Displaying the array of learning settings provided by the selected panels.

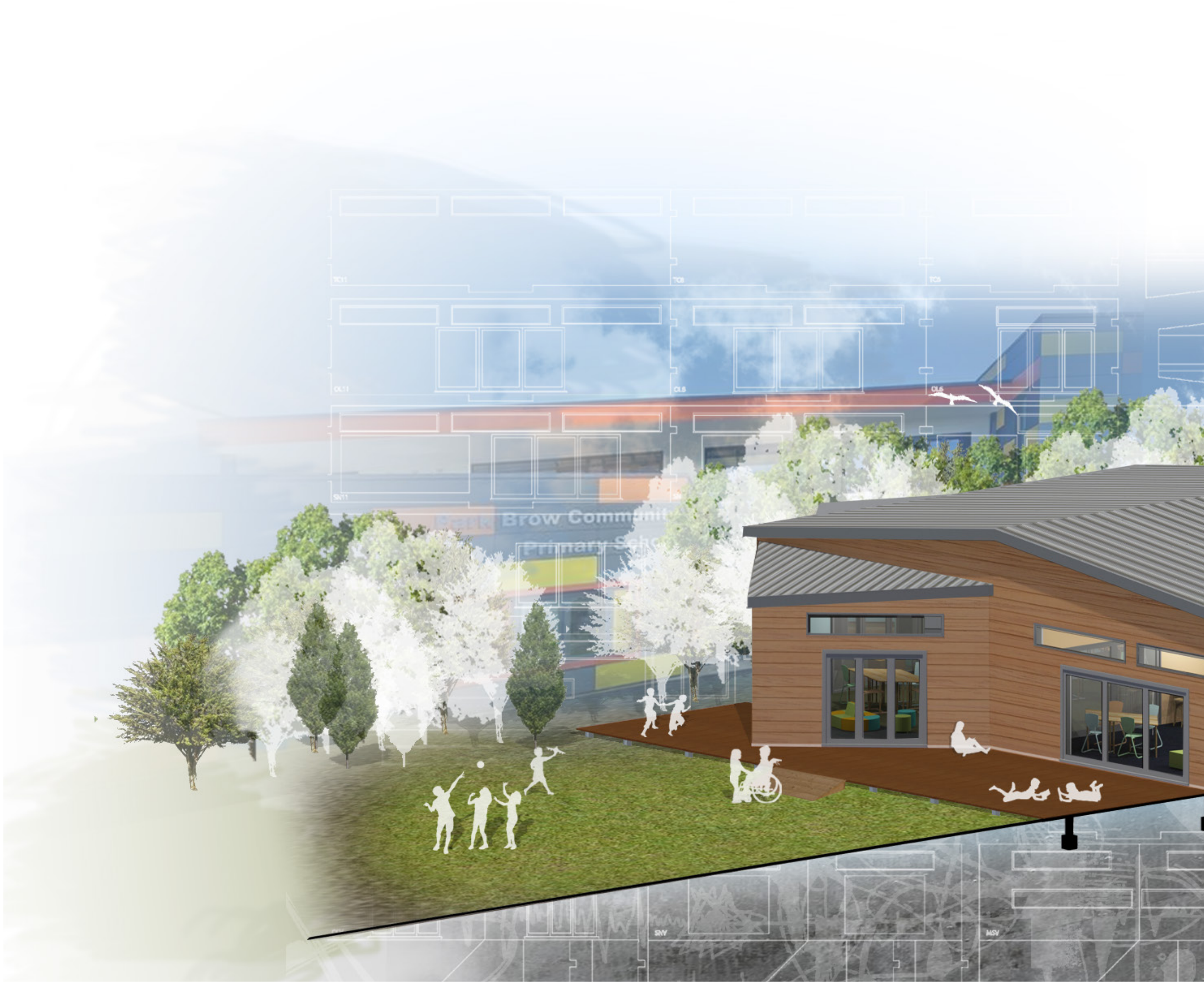
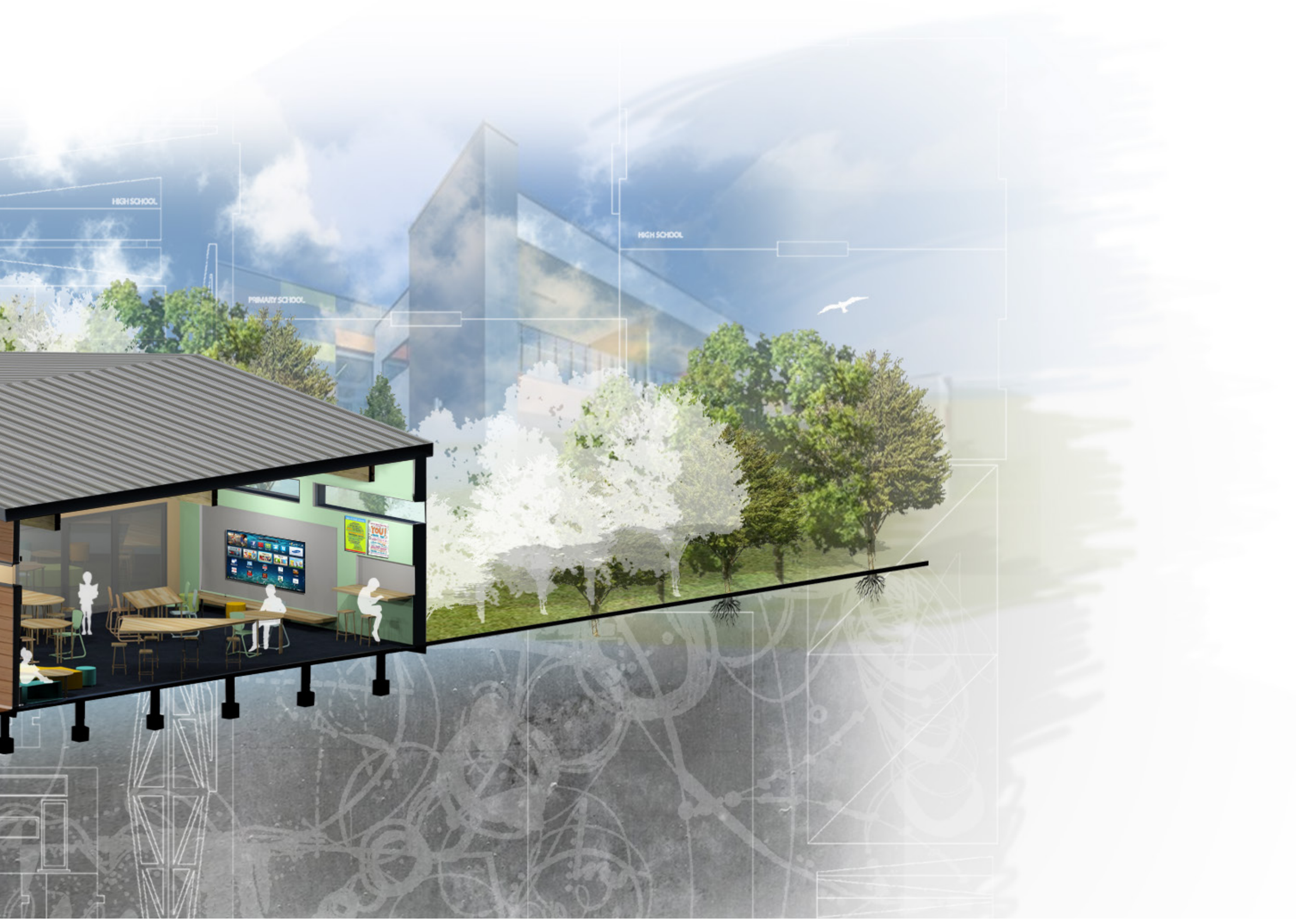


Fig 5.37. Site section: Displaying the relationship of interior, exterior and site on a typical school day.


HIGH SCHOOL
HIGH SCHOOL
PRIMARY SCHOOL

“Whatever good things we build, end up building us.”
- Jim Rohn

6.0 RESEARCH FINDINGS >

6.1 RESEARCH FINDINGS >

6.1.1 Findings

Flexi-Ed discovered that prefabrication has the capability to respond to both the site and occupants, all within a similar budget to the existing market competitor and default 'temporary classroom', the Portabuild modules, also known as the Portacom. Although both Flexi-Ed and the Portabuild modules are prefabricated, a comparison of the two demonstrates that Flexi-Ed consists of higher standard finishes and provides the opportunity for customisation. The panelised design approach of Flexi-Ed encourages lower life cycle costs, as each design will be site specific as well as enhance student learning facilities. Although Flexi-Ed has been designed as a temporary and relocatable classroom, the standard of finish has the capability to be used as a permanent facility, if the school requires.

Prefabrication has been utilized as a tool to heighten the standard of ILE through the initiation of panels that are specifically designed to cater to an array of learning settings. The design process encourages the client to configure the classroom on a panel by panel basis, stimulating an interior that is suited to the intended students. This design process ensures that Flexi-Ed has the capacity to support the evolving and adapting education practices, allowing schools to remain future focussed.

As part of the critical reflection, Flexi-Ed was presented to a group of Hagley Community College teachers in November 2016. These teachers have been previously engaged with Flexi-Ed as participants of the ILE user surveys during the research phase of this thesis.

The audience was made up of a mixture of teachers and the $19 million school rebuild team for the Hagley Community College rebuild project. On conclusion of the presentation surveys were anonymously completed, to gain a client review of Flexi-Ed.

Overall the responses highlighted Hagley's requirements for their rebuild project, which directly link to the benefits of prefabrication. With the unsettled school roll and the desire for a rapid construction, the audience could see the benefits of a prefab construction, and were particularly engaged with the customizable designed panels.

Areas of opportunity were including increased panel sizes and design options, prototyping and the possibility to broaden the scope of the project; whilst limitations focussed on the possibility that a change in government might result in a change of MoE requirements.

Overall the presentation to users and industry professionals clarified that Flexi-Ed can cater to what the education sector wants and needs; and in confirmation the Hagley Community College rebuild team have begun to purse queries into the use of prefabricated construction, in order to reap the benefits that are displayed in this thesis; and as a result made contact with the author to initiate a connection with the Welhaus team.

In November, Welhaus indicated their interest in displaying Flexi-Ed on the company website to demonstrate the bridge between residential and education projects that their Welhaus engineered welpanel can provide. Welhaus have seen a growth in the market of suppliers, businesses and architects who are seeking prefabricated products in both the residential and education sector. By including Flexi-Ed on their website, Welhaus believe it will increase both product marketability as well as illustrate the success of flexibility using elements of their prefabricated system as seen in Flexi-Ed.

"I would promote Flexi-Ed because it is quick, flexible, cost effective and pretty darn cool!"
- Hagley Community College Teacher, November 2016.

"As the Flexi-Ed system develops it would be cool to see more options and potential 'mini' panels for changing cohort"
- Hagley Community College Teacher, November 2016.

"The quick build time, with less on-site disruption can help us plan the build for less crucial times of the year"
- Hagley Community College Teacher, November 2016.

"More school ownership of the design is great, we can choose what combination and setting suits!"
- Hagley Community College Teacher, November 2016.

6.2 LIMITATIONS >

6.2.1 Scope of Work

The scope of project outlined at the beginning of Flexi-Ed determined not only the design outcome, but also the scale of research, site analysis and overall process. The scope states that Flexi-Ed intends to focus on the design and development of single storey, relocatable standalone classrooms for New Zealand schools. With the key area of focus based upon the construction system and the interior learning settings. Thus defining a scale that zooms in on the classroom as a singular component. As defined, this scope eliminated the possibility of designing a project that not only catered to the requirements of ILE at a classroom scale, but also the broader school site.

If the scope of project was more loosely written, Flexi-Ed could have examined at the possibility of designing a collective of panelised and modular components to provide for the design of a whole school. In addition, the Flexi-Ed system could have addressed the possibility of specialist teaching spaces, administration blocks and toilet modules to provide the market with a catalogue of Flexi-Ed systems.

6.2.2 Materiality

The selected construction material, timber, was chosen on the basis of it being lightweight and easy to transport. However if a different material were to have been selected the approach to Flexi-Ed and the relocatable aspect would have produced a significantly different outcome.

For example if concrete were to have been selected, in comparison, the approach to design, site installation and in particular transportation would have to be approached with a different strategy to ensure a successful outcome was still achieved.

6.2.3 Prefab Solution

The innovation in Flexi-Ed lies with the panelised system, providing a customisable approach which is reflected in the flexible architectural design, particularly the interior configuration. There is an opportunity for Flexi-Ed to potentially achieve a more efficient transportable system by only prefabricating the panels prior to transportation and site delivery.

The Flexi-Ed construction timeline outlines that the system is to be configured as a module prior to being dispatched for site delivery. This decision was made in an attempt to reduce time on-site, minimising disruption and hazards that schools are exposed to during a construction process.

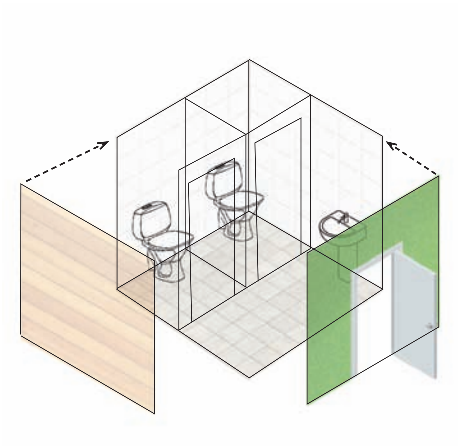
Along with the opportunities of modular delivery, there are constraints which could significantly hinder the marketability of Flexi-Ed, particularly site accessibility upon delivery. By eliminating the step of module prefabrication, it could achieve a system that has the potential to transport a larger number of panels in one trip, as well as increasing the number of accessible sites.

“Each new situation requires a new architecture.”
- Jean Nouvel

7.0 FUTURE DEVELOPMENTS >

7.1 FLEXI-ED SYSTEM DEVELOPMENT

7.1.1 Toilet Modules

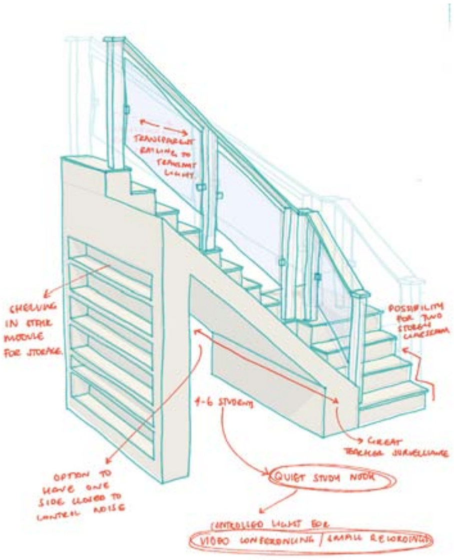


As part of the Flexi-Ed system it is important to cater to toilet requirements for school sites. This thesis has assumed that the analysed school sites provide sufficient toilet facilities for the number of teaching spaces being supplied and the school roll.

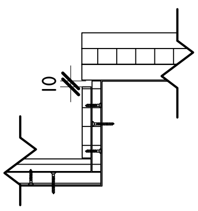
In order to address sites where the toilet requirements are not met, it is important for Flexi-Ed to design and include these facilities as part of the system collection.

While not yet designed, it is proposed that a toilet module will be available as an option for the client to select from when designing their classroom (see proposed toilet module, figure 7.1). The proposed toilet facilities are intended to be designed as modular components, acting as a 'wet room' with all wall linings and services pre-installed, along with all fittings and fixtures prior to site delivery.
These modules have the capability to either be implemented on a school site as standalone modules in close proximity to the classroom, or in place of a Flexi-Ed ILE panel to provide direct interior access from the main learning hub to toilets.

7.1.2 Accessibility



Stair tread to riser:



Stair to vertical panel:

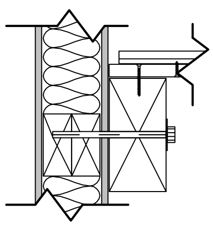


Fig 7.1. Toilet module concept (top)
Fig 7.2. Volumetric Stair concept (centre)
Fig 7.3. Stair tread to riser detail (bottom left)
Fig 7.4. Stair to panel detail (bottom right)

Accessibility is an area that requires further design intervention in the Flexi-Ed system and collection, in order to ensure that people of all abilities are able to access and enjoy the spaces.

Due to the specified pile foundation system, it is important to consider the accessibility from the classroom building itself to the surrounding exterior learning environment. Currently the external treatment consists of a decking system which is applied as a site specific element. By including a ramp as a feature inclusive of the decking, the classrooms become accessible by everyone.

This additional ramp component along with the decking system will be consulted with the Flexi-Ed architects on a case by case, site specific basis. Through individual consultation the external conditions have the opportunity to be representative of the classroom and surrounding school site that they are providing for, considering not only the topography but also the unique school narratives and their landscapes.

Another area of accessibility which has the opportunity for future development in the Flexi-Ed system collection is the storey height.

The existing Flexi-Ed system has the structural capabilities to provide for up to two-storey classroom blocks, however the design requires further refinement to include different panel lengths and floor cassette sizes to allow for internal access between the different levels. The proposed method to access the second-storey is via a prefabricated volumetric staircase that can be inserted into the teaching modules on-site, doubling as a quiet breakout nook and classroom storage (see sketched volumetric stair, figure 7.2).

As the development of a multi-storey Flexi-Ed system progresses, accessible access to all occupants, including those with disabilities, must be considered to provide multiple levels of learning that can be enjoyed by all.

7.1.3 Acoustic Analysis

The Flexi-Ed system design process has taken into consideration the acoustic qualities from the beginning stages. However the system requires further acoustic analysis to see if any further development is required to improve acoustics within the interior classroom space. Specific panel testing and their affect on the interior would be of benefit to calculate whether minor alterations could be made to the panels to provide a more suitable form for the interior acoustic qualities.

7.1.4 Make Space Panel

The developed prefabricated panels currently house a services cavity to provide a location for electrical and data to be installed prior to site delivery.

One panel in particular, the “make space”, could be further developed to provide a wet area for the learning setting and wider learning hub. By detailing the installation of plumbing (see make space panel section plumbing installation example, figure 7.5) to provide for sink facilities the panel has the capabilities to cater to this desire for a ‘wet’ area, maintaining a high level of classroom cleanliness, encouraging students to tidy up after themselves

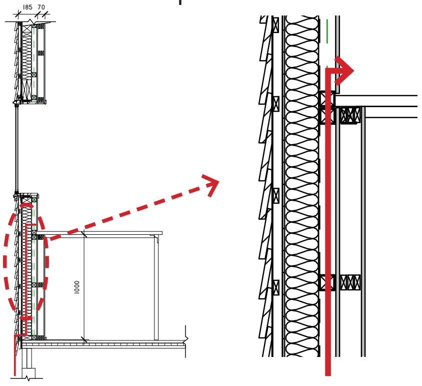


Fig 7.5. Make Space panel: Plumbing installation

7.1.5 Scope of Work

Classrooms to Schools

As this thesis demonstrates a successful approach to transportable classroom design; the opportunity of broadening the scope of work could be a possibility for future development. By widening the focus from classrooms to an array of school facilities, Flexi-Ed has the chance to design and develop transportable schools.

This could be done by taking the Flexi-Ed classroom system and using this as a base design to push, pull and evolve to provide a catalogue of panelised systems; each with a programme specific application ranging from administration to specialist teaching spaces and storage.

International Market

One key area of opportunity for Flexi-Ed is to increase the market share. By extending off the shores of New Zealand; Flexi-Ed has the chance to engage with different countries in need of transportable classrooms.

With the mass customisation design approach of Flexi-Ed it allows clients from different cultures and backgrounds to imprint what is important to them on the final design as well as catering to the different climates across the globe with only minor product alterations.

If Flexi-Ed extended the scope of work and addressed the international market, the out sourcing for components provides the opportunity for Flexi-Ed to decrease in cost; providing the same high standard product for a fraction of the price. However freight cost would have to be taken into consideration if the system was to expand internationally to address whether this is a feasible option for schools globally.

Aligning with the international market approach, the user-friendly Flexi-Ed website requires development to appeal to a wider spectrum of people globally. By introducing a Virtual Reality component to the website, clients would have the ability to virtually inhabit their designs prior to the construction phase, minimising the risk of client dissatisfaction for those offshore.

“All real education is the architecture of the soul.”
- William Bennett

8.0 CONCLUSION >

8.0 CONCLUSION >

8.1 Thesis Conclusion

Flexi-Ed has demonstrated an insight into the opportunities that prefabrication can provide for the education industry within New Zealand. These opportunities can be seen through the success of the system in gaining multiple areas of flexibility within one prefabricated system. Providing a construction typology that has demonstrated that adaptability can be achieved, catering to the evolving, growing and ever changing cities of New Zealand.

Prefabrication has allowed Flexi-Ed to provide a degree of flexibility that caters to not only the fluctuation in enrolment numbers, which traditional construction techniques are unable to do, but also reflect this adaptable nature into the almost endless options of interior configurations.

Ultimately providing a system that addresses the three areas of flexibility required by the education industry for a successful transportable classroom. First in the sense of being easy to assemble and disassemble, catering the unpredictable school roll; second through the joints of the structure, coping with seismic conditions and activity; and thirdly by offering flexible interior learning environments, aligning with the ILE movement as well as existing space entitlement requirements. Flexi-Ed has proven in this thesis that these three principles are indeed achievable.

Now is the time to initiate the change in transportable classrooms by utilizing Flexi-Ed as the tool to surpass the traditional school of thought; encouraging the students of our future to take pride and responsibility in their learning. As Maria Montessori once said "…education is not what the teacher gives; education is a natural process spontaneously carried out by the human individual, and is acquired not by listening to words but by experiences upon the environment".

9.0 BIBLIOGRAPHY >

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9.1.2 Figure List

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5.0 THE BUILD >

10.0 APPENDIX >

TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI
VICTORIA
UNIVERSITY OF WELLINGTON

Flexi-Ed.

INFORMATION SHEET FOR PARTICIPANTS

Thank you for your interest in this project. Please read this information before deciding whether or not to take part. If you decide to participate, thank you. If you decide not to take part, thank you for considering my request.

Who am I?

My name is Megan Keats and I am a Masters student in Architecture at Victoria University of Wellington. This research project is work towards my thesis.

What is the aim of the project?

The main objective of my research is to design a prefabricated system that can be assembled and disassembled on a school site with relative ease. This system will have the ability to cater for the fluctuation in Canterbury school rolls. Once constructed this system will provide an innovative learning environment for students and teachers to occupy.

This research has been approved by the Victoria University of Wellington Human Ethics Committee reference 0000022764.

How can you help?

If you agree to take part I will interview you in a public place, such as a café or on-site. I will ask you questions about prefabrication. The interview will take 20-30minutes. I will either record the interview or take notes and write it up later. You can stop the interview at any time, without giving a reason. You can withdraw from the study up to four weeks after the interview. If you withdraw, the information you provided will be destroyed or returned to you.

What will happen to the information you give?

This research is confidential. I will not name you in any reports, and I will not include any information that would identify you. Only my supervisors and I will read the notes or transcript of the interview. The interview transcripts, summaries and any recordings will be kept securely and destroyed 3 years after the research ends.

What will the project produce?

The information from my research will be used in my Masters Thesis Report. You will not be identified in my report. I may also use the results of my research for conference presentations, and academic reports. I will take care not to identify you in any presentation or report.

If you accept this invitation, what are your rights as a research participant?

You do not have to accept this invitation if you don't want to. If you do decide to participate, you have the right to:

- choose not to answer any question;
- ask for the recorder to be turned off at any time during the interview;
- withdraw from the study up until four weeks after your interview;
- ask any questions about the study at any time;
- receive a copy of your interview recording (if it is recorded);
- read over and comment on a written summary of your interview;
- agree on another name for me to use rather than your real name;

- be able to read any reports of this research by emailing the researcher to request a copy.

If you have any questions or problems, who can you contact?

If you have any questions, either now or in the future, please feel free to contact either:

Student:

Megan Keats

keatsmega@vuw.ac.nz

Supervisor:

Joanna Merwood-Salisbury

Head of Architecture School

Victoria University of Wellington

Joanna.Merwood-Salisbury@vuw.ac.nz

Human Ethics Committee information

If you have any concerns about the ethical conduct of the research you may contact the Victoria University HEC Convener: Associate Professor Susan Corbett. Email susan.corbett@vuw.ac.nz or telephone +64-4-463 5480.

SCHOOL OF ARCHITECTURE Te Kura Waihanga
FACULTY OF ARCHITECTURE & DESIGN Te Wāhanga Waihanga-Hoahoa
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Phone +64-4-463 6200 Fax +64-4-463 6204 Email architecture@vuw.ac.nz Web www.victoria.ac.nz/architecture

Site Visit Information Letter:
Flexi-Ed.

To whom it may concern,

My name is Megan Keats and I am a Master of Architecture student at the School of Architecture, Victoria University of Wellington. The main objective of my research is to design a prefabricated system that can be assembled and disassembled on a school site with relative ease. This system will have the ability to cater for the fluctuation in Canterbury school rolls. Once constructed this system will provide an innovative learning environment for students and teachers to occupy.

This research has been approved by the Victoria University of Wellington Human Ethics Committee reference 0000022764.

In order to understand how innovative learning environments it would be of benefit for my research to observe a class in action for approximately 30-60minutes. Taking notes of how the space is occupied and diagramming the spatial qualities and movements.

Another key area for my research is to receive feedback for the users of the space, including teachers and a small number of students through a survey. The main objective of the survey is to collect information and feedback on the existing learning area that you are working in along with your view on innovative learning environments, and should only take 5-10 minutes.

The questions are set up to understand your current learning area and the style that you work in and how you can envisage how it may work better. The expectation is that the surveys are returned to the researcher within two weeks.

Should any participants feel the need to withdraw at any stage from the project, they may do so with no reason provided, via email before September 1st 2016. The responses collected will inform the design phase of my project, enhancing the design outcome for the innovative learning environments as well as being put into a written report. Each participant will be anonymous and all information collected will be confidential. After this research is completed all data collected will be destroyed.

A summary of the data collected will be provided at your request after the research project is completed in November/December 2016. The final thesis will be deposited in the Victoria University Library.

If you have any questions or would like to receive further information about the project, please contact me.

Thank you for your time,
Megan Keats
keatsmega@vuw.ac.nz

TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI
VICTORIA
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SCHOOL OF ARCHITECTURE Te Kura Waihanga
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Consent form for Survey and Classroom Observation:
Flexi – Ed.

Please read through the following and sign at the end to agree to take part in my research.

- I have been provided with adequate information in regards to the nature and objectives of this research project.
- I have been given the opportunity to seek further clarification or explanations.
- I understand that I may withdraw from this study at any time, without providing reason
- I understand that if I withdraw any information that I have provided will be destroyed
- I understand that any information that I have provided will be kept confidential to the research and her supervisor. The results published will not include my name and no opinions will be attributed to me in any way that will identify me.
- I understand that the information that I have provided for this research will be destroyed after the research has been published
- I understand that the information I have provided will only be used for this research project and any further use will require my written consent

According to the information provided, I agree to participate in this survey: Yes / No

I would like to receive a summary of the results of this research when completed: Yes / No

Signature of participant: ________________________________

Name of participant: ________________________________

Date: ______________

Contact details: ________________________________

Thank you for choosing to participate in this survey, I value your honest opinion and feedback. The survey will take approximately 5-10 minutes and will be completely anonymous. Should any participants feel the need to withdraw at any stage from the project, they may do so with no reason provided by September 1st, via email.

The expectation is that the surveys are returned to the researcher within two weeks via the email address provided.

Thank you,

Megan Keats
keatsmega@vuw.ac.nz

TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI
VICTORIA
UNIVERSITY OF WELLINGTON

Flexi – Ed.

CONSENT TO INTERVIEW

This consent form will be held for 3 years.

Researcher: Megan Keats, Architecture School, Victoria University of Wellington.

- I have read the Information Sheet and the project has been explained to me. My questions have been answered to my satisfaction. I understand that I can ask further questions at any time.
- I agree to take part in a (video/audio) recorded interview.

I understand that:

- I may withdraw from this study up to four weeks after the interview, and any information that I have provided will be returned to me or destroyed.
- The information I have provided will be destroyed three years after the research is finished.
- Any information I provide will be kept confidential to the researcher and the supervisor. I understand that the results will be used for a Masters report and a summary of the results may be used in academic reports and/or presented at conferences.
- My name will not be used in reports, nor will any information that would identify me.
- I would like a copy of the transcript of my interview: Yes ☐ No ☐
- I would like a summary of my interview: Yes ☐ No ☐
- I would like to receive a copy of the final report and have added my email address below. Yes ☐ No ☐

Signature of participant: ________________________________

Name of participant: ________________________________

Date: ______________

Contact details: ________________________________

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Survey Information Letter:
Flexi – Ed.

To whom it may concern,

My name is Megan Keats and I am a Master of Architecture student at the School of Architecture, Victoria University of Wellington. The main objective of my research is to design a prefabricated system that can be assembled and disassembled on a school site with relative ease. This system will have the ability cater for the fluctuation in Canterbury school rolls. Once constructed this system will provide an innovative learning environment for students and teachers to occupy.

This research has been approved by the Victoria University of Wellington Human Ethics Committee reference 0000022764.

A key area for my research is to receive feedback for the users of the space, including teachers and a small number of students through a survey. The main objective of the survey is to collect information and feedback on the existing learning area that you are working in along with your view on innovative learning environments, and should only take 5-10 minutes.

The questions are set up to understand your current learning area and the style that you work in and how you can envisage how it may work better. The survey contains questions regarding the teaching space currently used and the positive and negative outcomes due to architectural design and furniture layout. The expectation is that the surveys are returned to the researcher within two weeks via the email address provided at the bottom of this letter.

Should any participants feel the need to withdraw at any stage from the project, they may do so with no reason provided by September 1st, via email. The responses collected will inform the design phase of my project, enhancing the design outcome for the innovative learning environments as well as being put into a written report. Each participant and all information collected will be confidential. After this research is completed all data collected will be destroyed.

A summary of the data collected will be provided at your request after the research project is completed in November/December 2016. The final thesis will be deposited in the Victoria University Library.

If you have any questions or would like to receive further information about the project, please contact me.

Thank you for your time,

Megan Keats
keatsmega@vuw.ac.nz

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Teacher Survey:
Flexi – Ed.

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Please tick your answers

1. When was the last renovation of the learning space you teach in undertaken?
- Less than 5 years ago
- Less than 20 years ago
- More than 20 years ago
- No renovation undertaken since initial build

2. How many students do you teach on a regular basis in your learning area?
- Less than 20 students
- 20 – 30 students
- More than 30 students

3. What year level are taught on a daily basis in your learning area?
Year Level/s:

4. How many full time equivalents (FTE) teach in your learning area on a daily basis?
- Just you
- You + 1 FTE
- You + 2 FTEs
- You + 3 FTEs

Other:

5. How frequently do you/your school check the Ministry of Education guidelines for classroom design standards?
- Often
- Occasionally
- Never
- You are unaware of Ministry guidelines

6. What style of learning space are you teaching in?
- Single-cell Classroom
- Open – plan environment

Other:

7. How satisfied with the style of learning space you are teaching in?
- Extremely dissatisfied
- Dissatisfied
- Neutral
- Satisfied
- Extremely Satisfied

8. How frequent do you make changes to furniture layout in your learning area?
- Daily
- Weekly
- More than once term
- Once a term
- Once a year
- Never

9. Circle one of the two options below to indicate what is more important to you for a successful learning area?
- Desks arranged in rows / Desks arranged in groups
- Collaborative learning / Individual tasks
- Open plan learning areas / Single cell classroom
- Written work / Electronic Work

10. What are the most successful aspects of your learning area? (e.g classroom size, acoustic, thermal etc.)

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11. What changes would you make to your learning area to increase student motivation and achievement? (e.g classroom size, acoustic, thermal etc.)

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12. Why would/wouldn’t you promote innovative learning environments?

Draw a diagram of how you best envisage your learning environment layout:

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Student Survey:
Flexi – Ed.

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Please tick your answers

What style of learning space are you learning in?
- Single-cell Classroom
- Open – plan environment

Other:

Rank in order what style of learning you prefer:
- Large group work
- Small group work
- Individual work
- One on one with teacher

Circle one of the two options below to indicate what is more important to you for a successful learning area?
- Desks arranged in rows / Desks arranged in groups
- Collaborative learning / Individual tasks
- Open plan learning areas / Single cell classroom
- Written work / Electronic Work

What do you like best about your learning area?

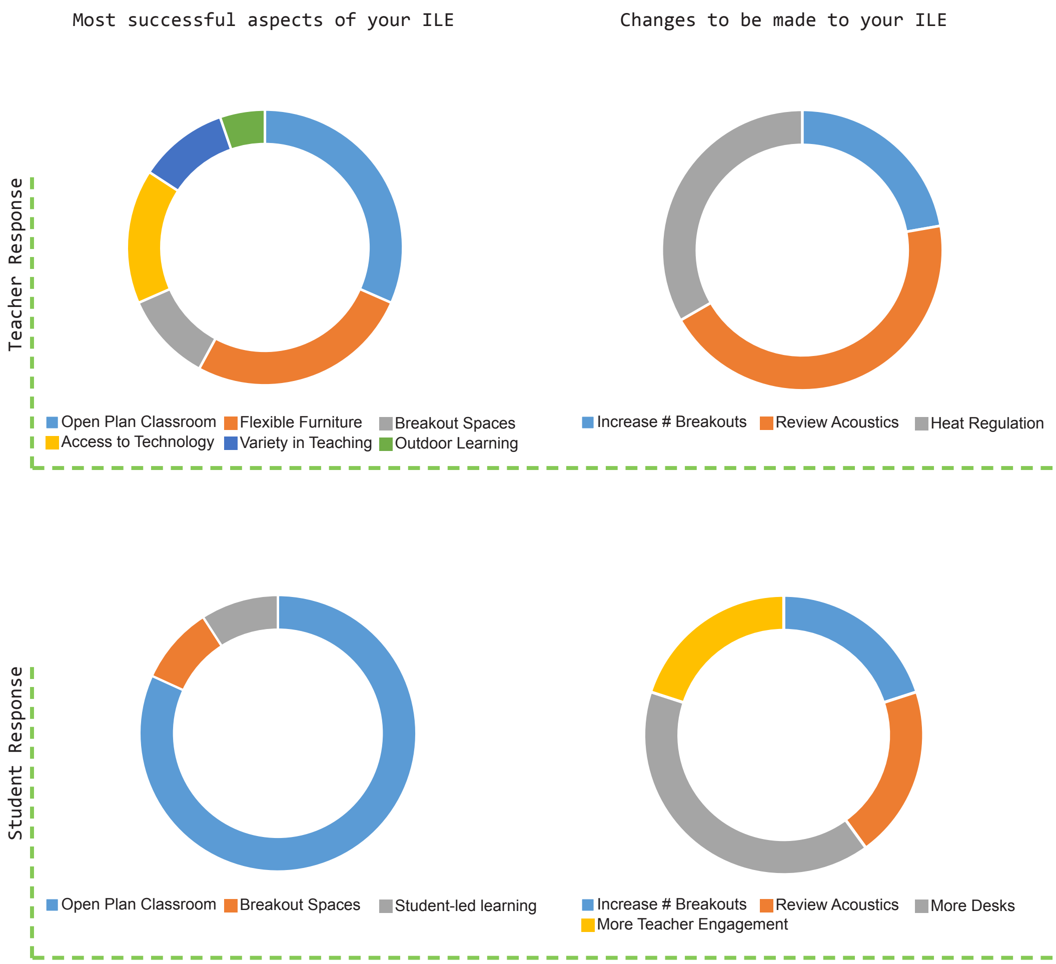
What changes would you make to your learning area to help you be more motivated and gain higher grades?

Why would/wouldn't you promote innovative learning environments (Open-plan classroom)?

Draw a diagram of how you best envisage your learning environment layout:

Teacher and Student Survey Results:

All participants in the survey attend schools, which utilize Innovative Learning Environments. The following demonstrates a summary of the results received from the school surveys.



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Presentation Review:
Flexi – Ed.

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1. Rate the following statements on a scale of 1 – 10.

   1----2----3----4----5----6----7----8----9----10
   Requires Review Successful

   [ ] Student-led learning opportunities
   [ ] Learning Settings provided
   [ ] Teacher support Flexi-Ed provides
   [ ] Overall design (prefabricated system)
   [ ] Interior Flexibility
   [ ] Environment consideration
   [ ] Selected options for interior finishes
   [ ] Website user interface

2. What limitations do you see in the system design as a potential client of Flexi-Ed? (E.g. cost/design options/flexibility/learning settings)

   ____
   ____
   ____
   ____

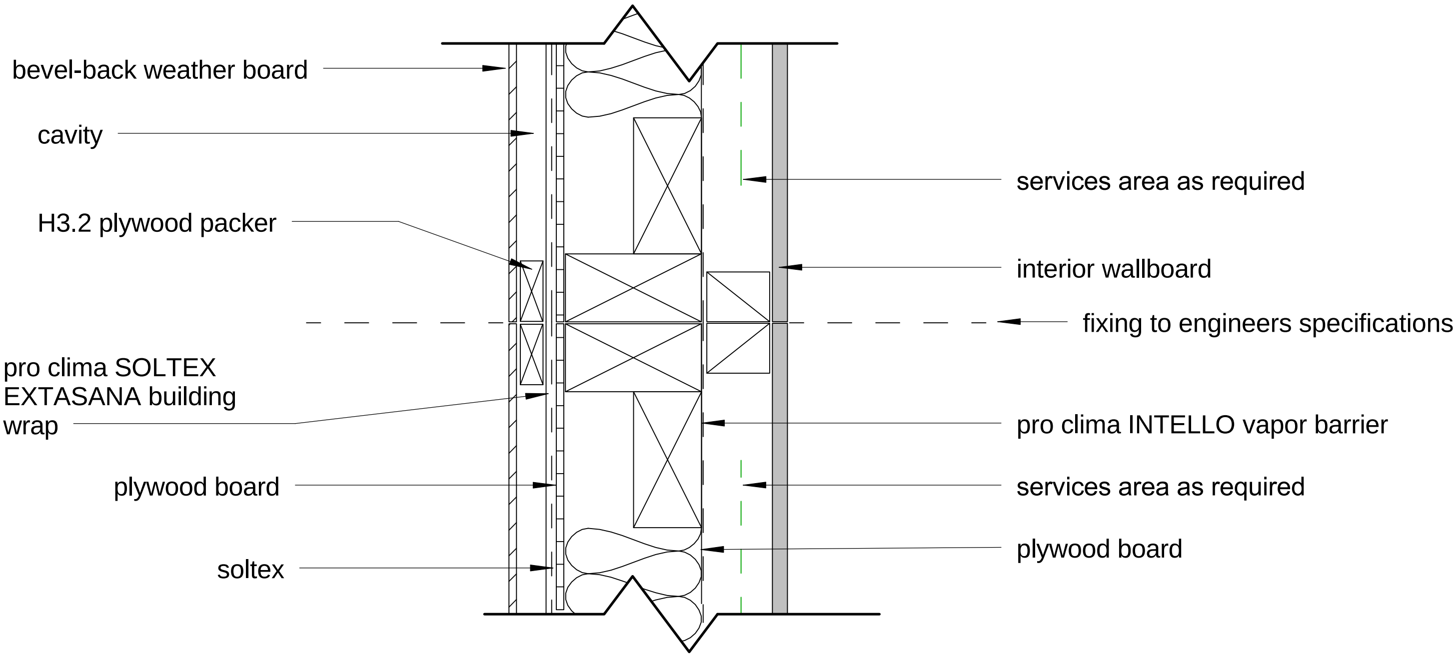
3. What opportunities do you see in the system design as a potential client of Flexi-Ed? (E.g. cost/design options/flexibility/learning settings)

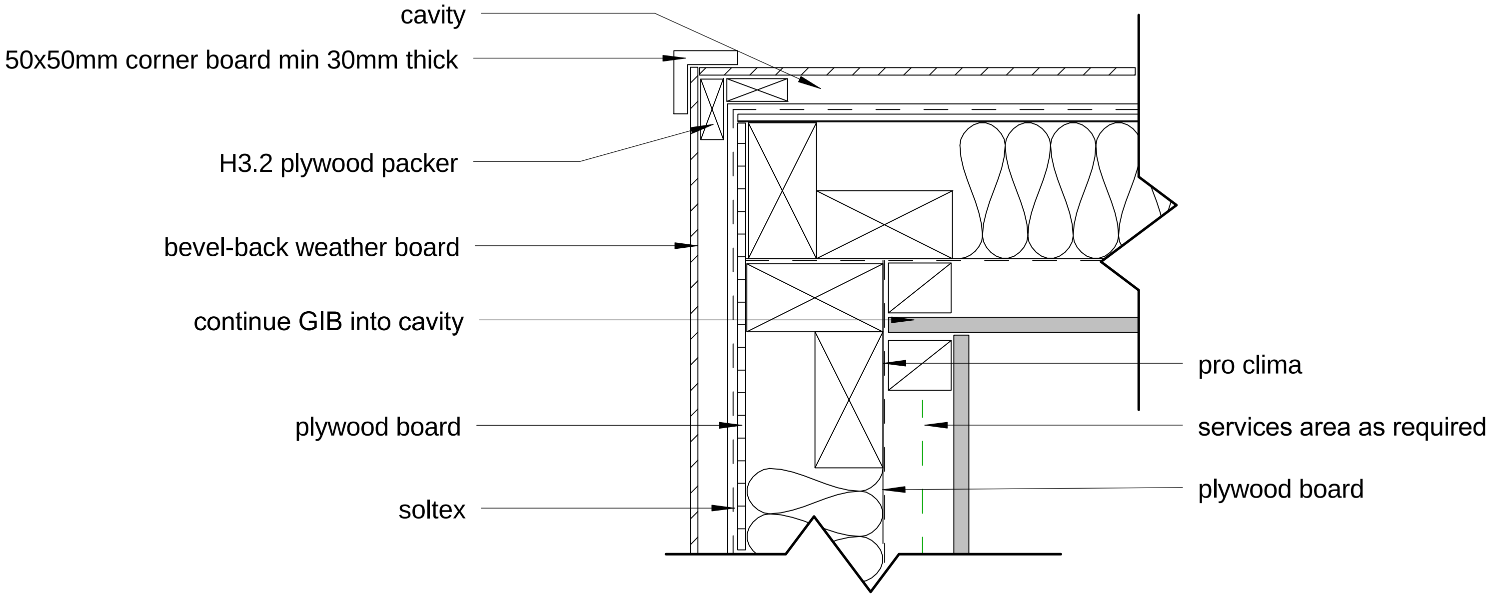
   ____
   ____
   ____
   ____

4. As the Flexi-Ed system develops what future considerations would you suggest?

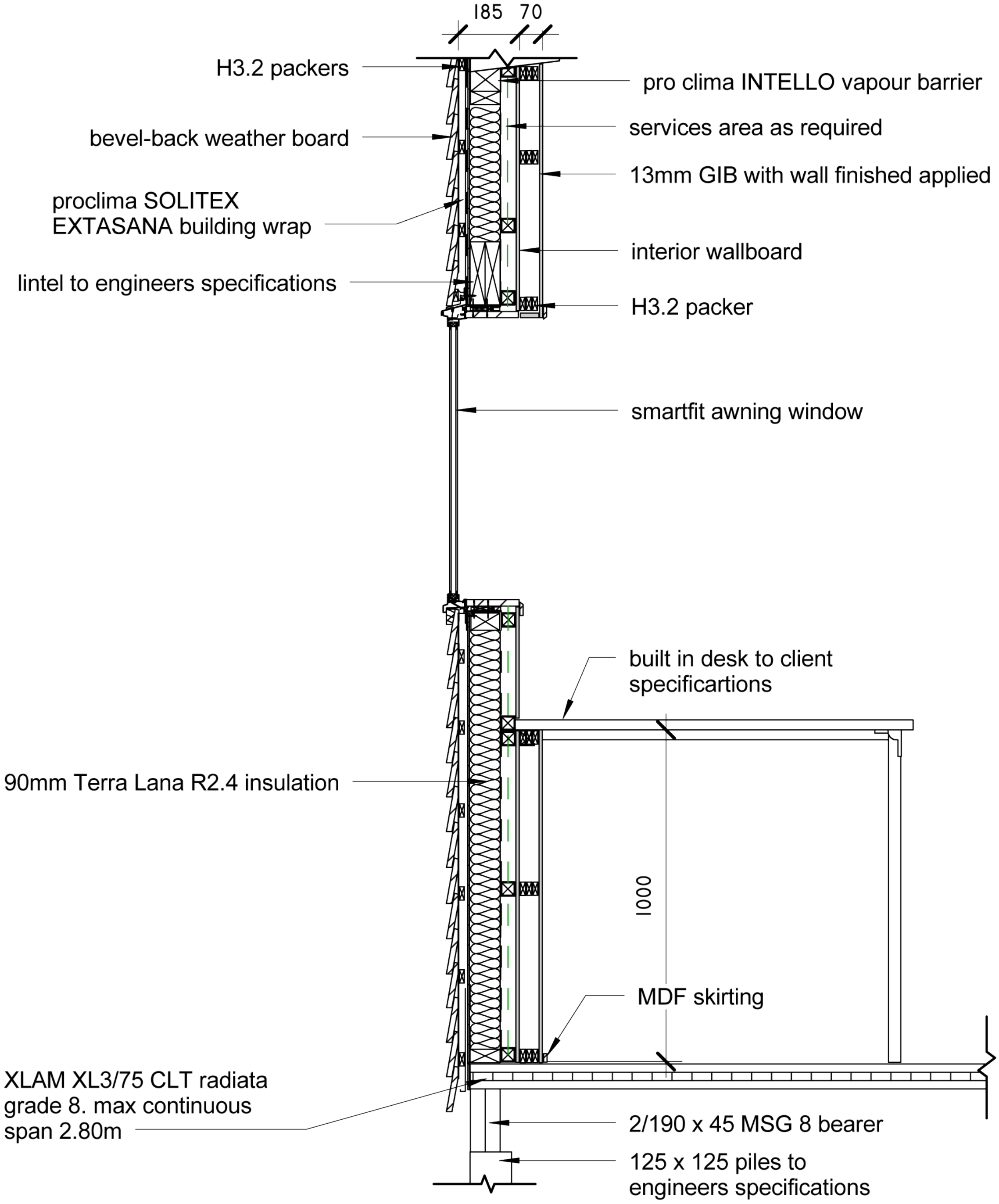
   ____
   ____
   ____
   ____

5. Please Circle one of the following and complete the sentence:
   I would / wouldn't promote Flexi-Ed because ______________________________
   ____
   ____



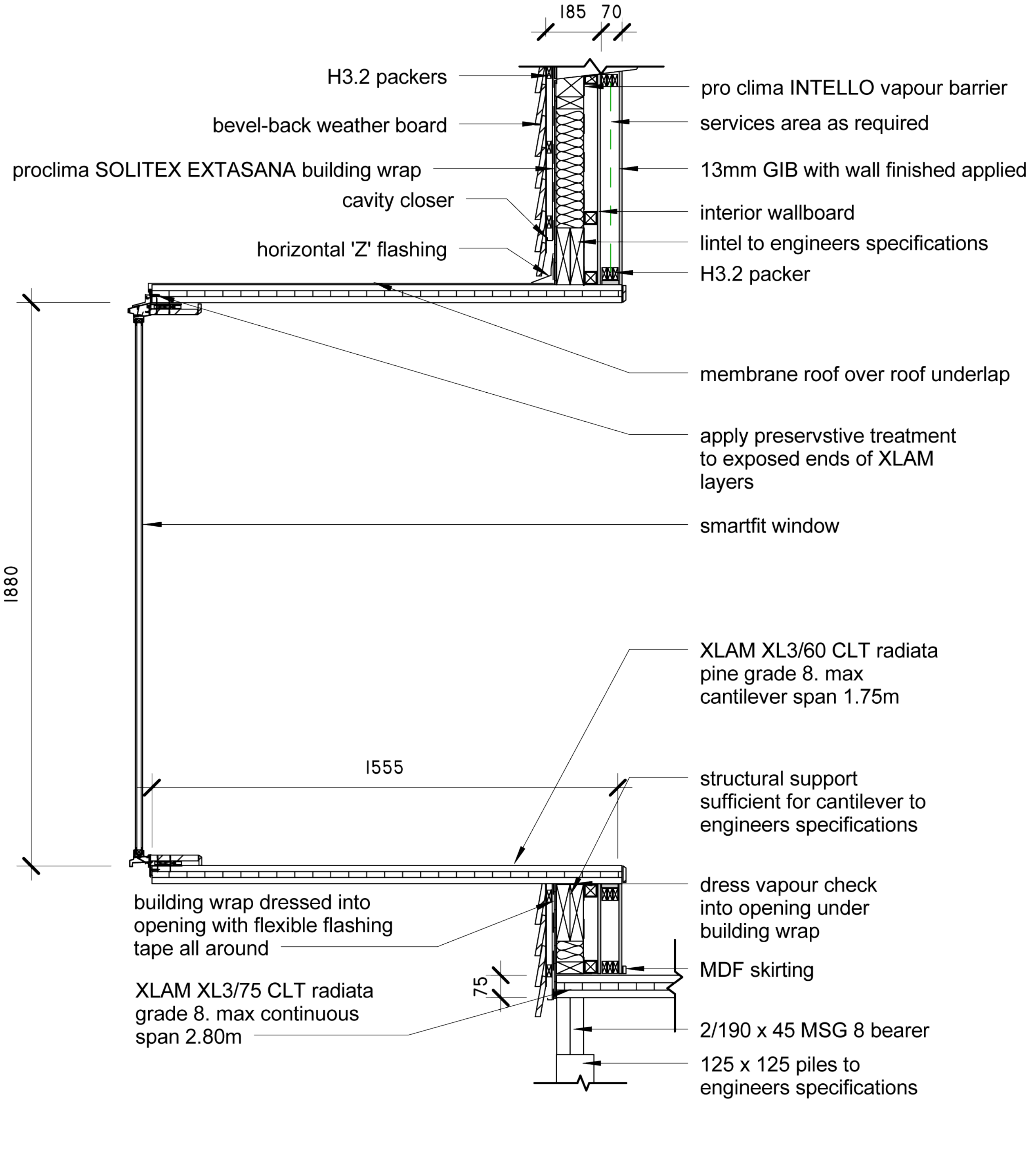


Flexi-Ed	Date: 11/09/16	Panel Connection Details (@ A4) Scale: 1 : 5



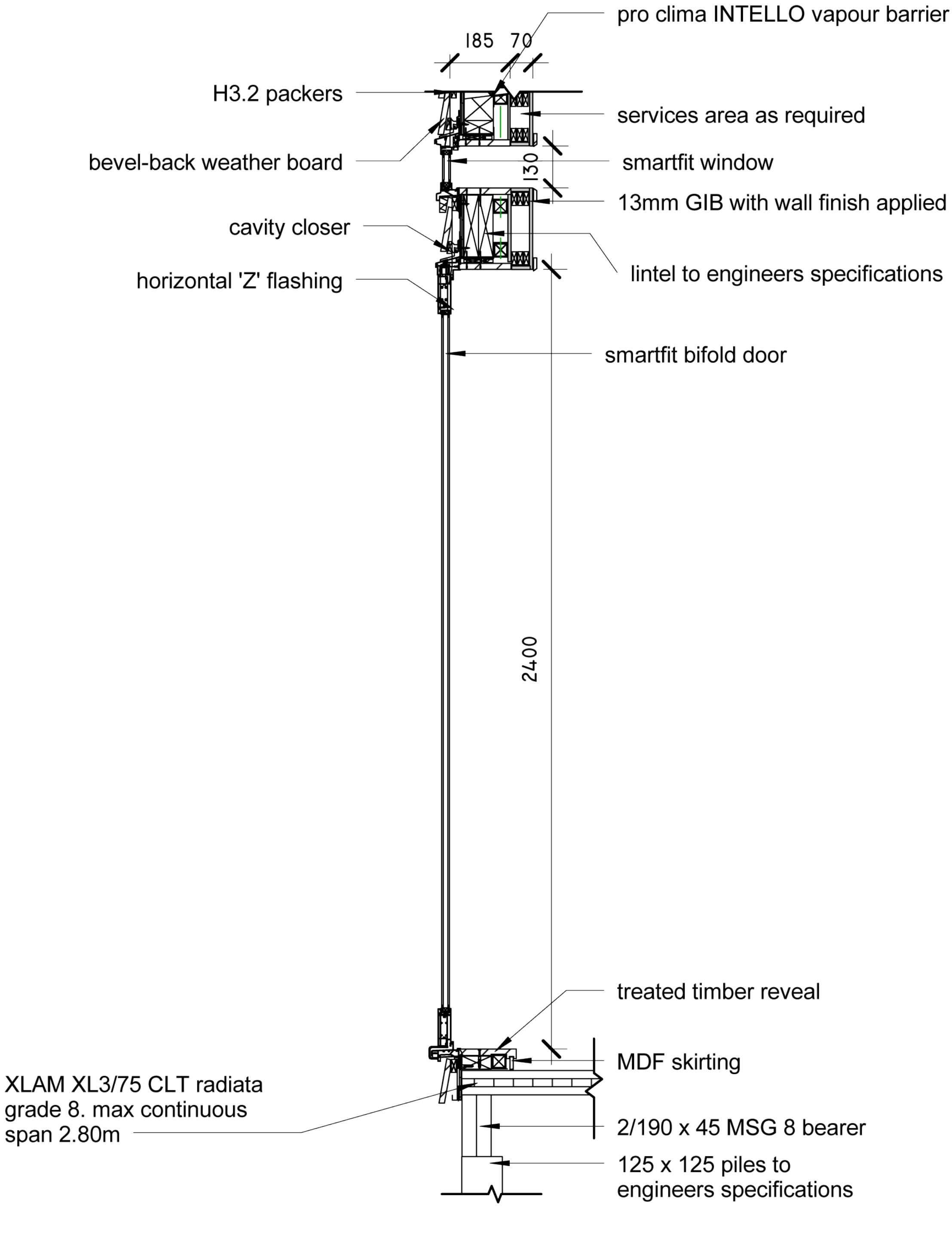
Make Space

Flexi-Ed Date: 11/09/16	Panel Section Details (@ A4) Scale: 1 : 20



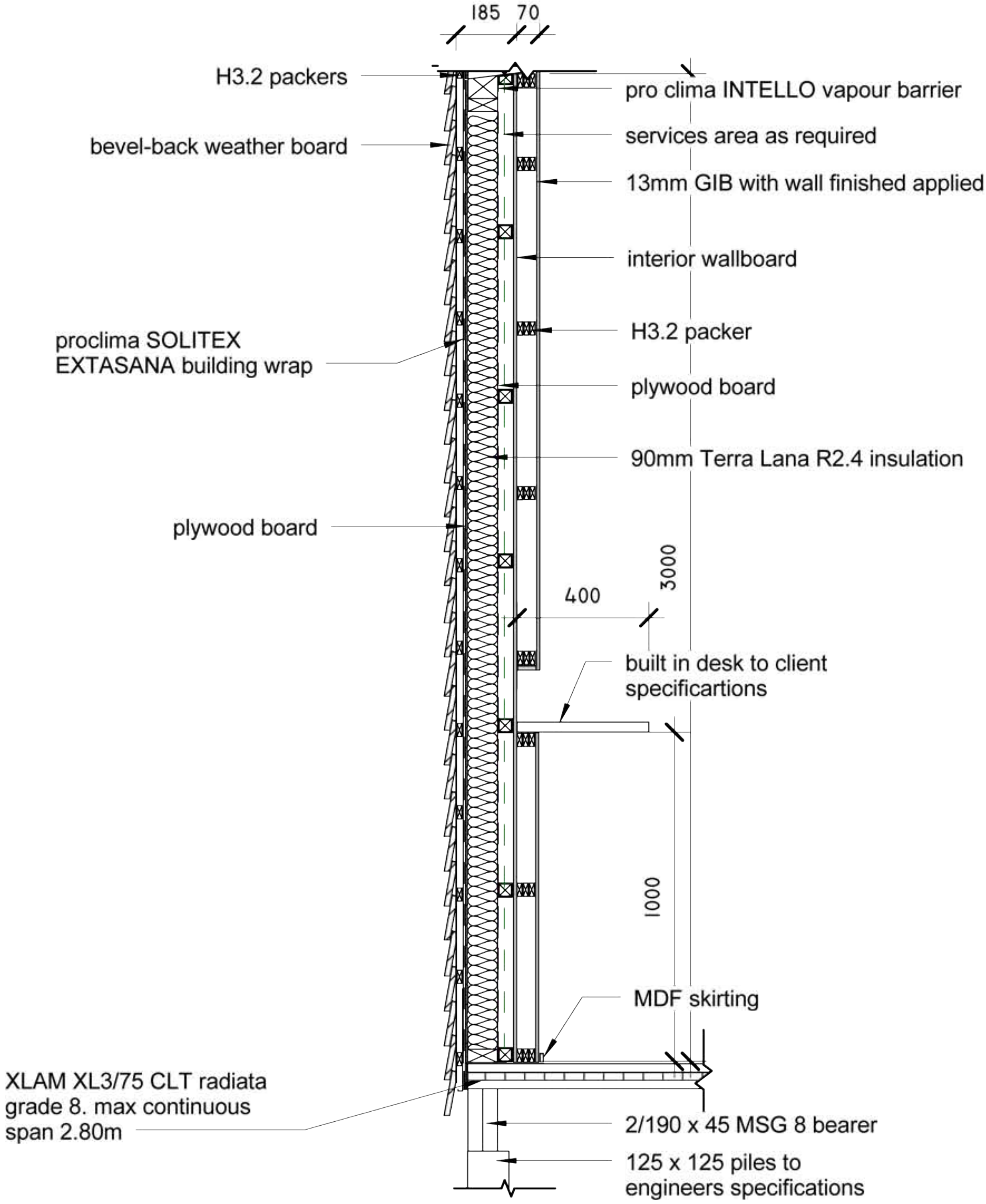
Breakout Nook

Flexi-Ed	Date: 11/09/16	Panel Section Details (@ A4) Scale: 1 : 20



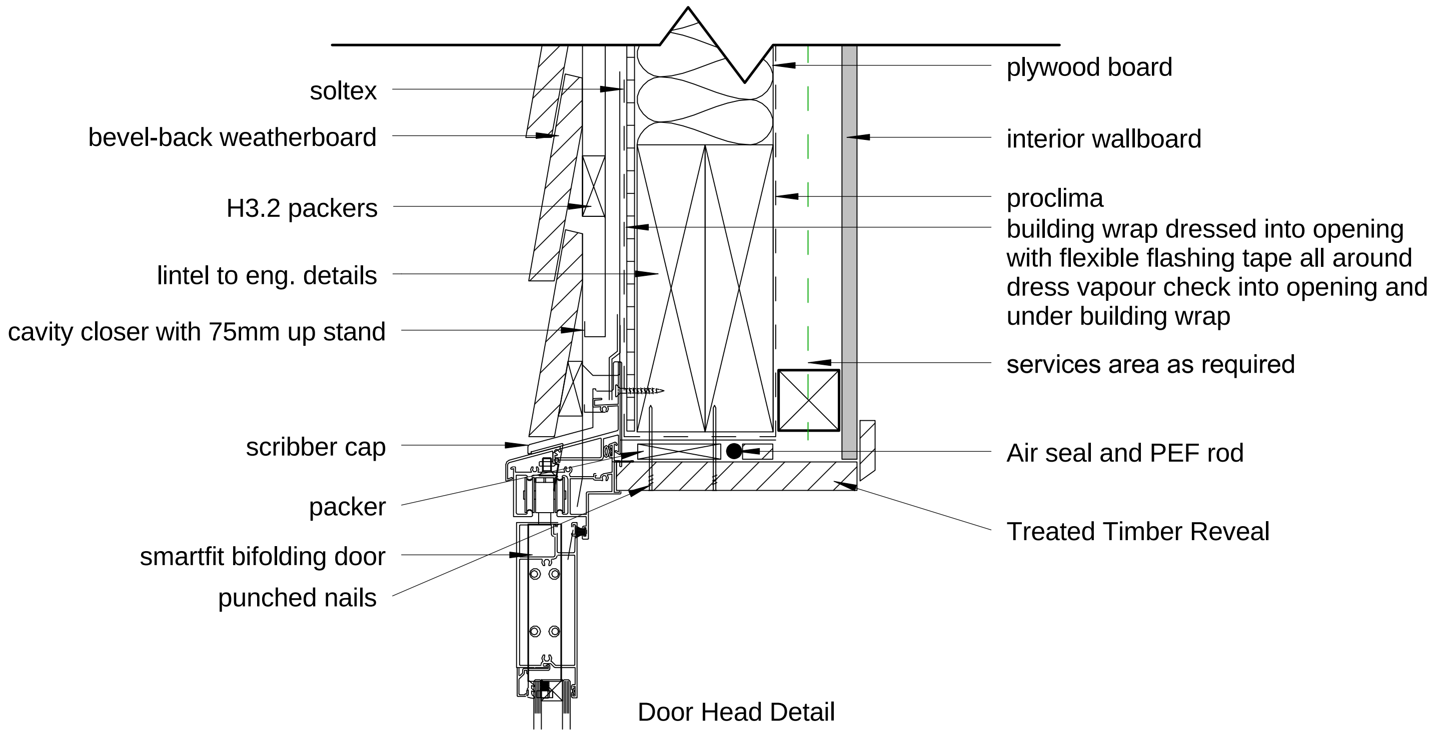
Outdoor Learning Gateway

Flexi-Ed Date: 11/09/16	Panel Section Details (@ A4) Scale: 1 : 20

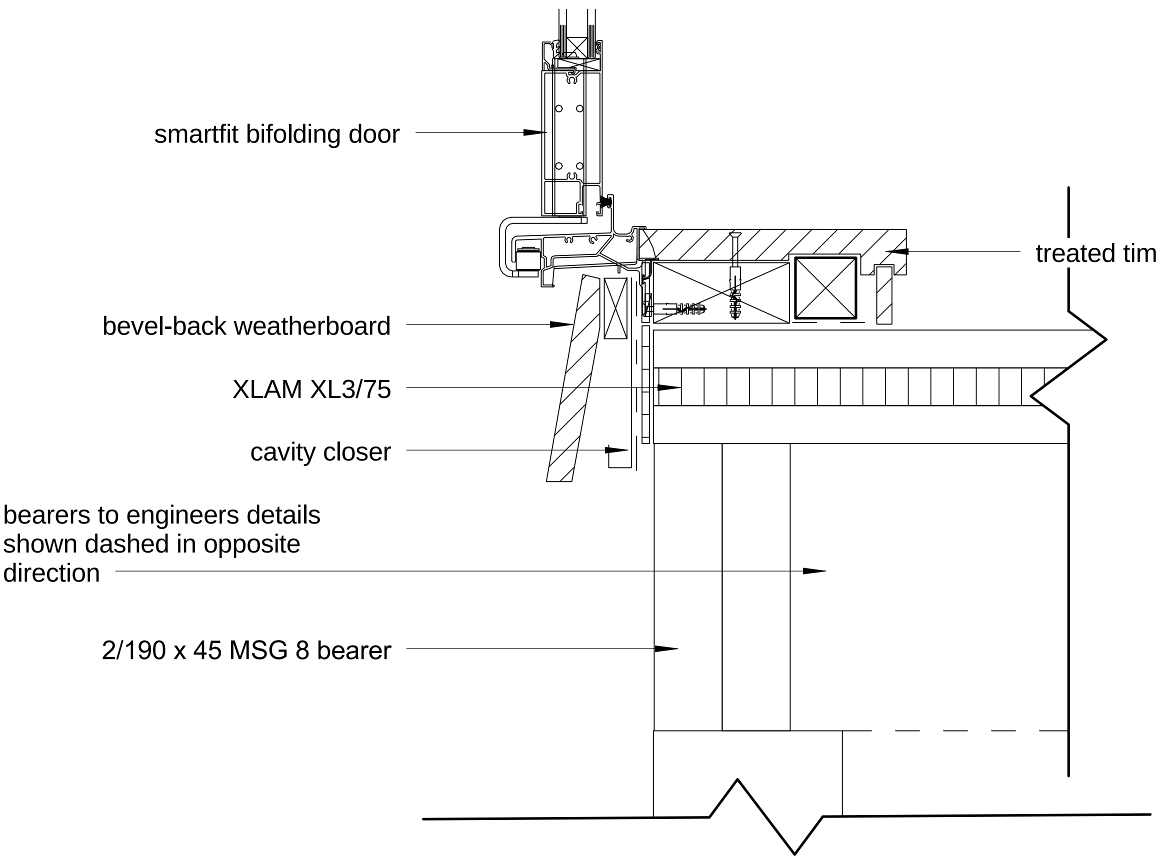


Tech Centre

Flexi-Ed	Date: 11/09/16	**Panel Section Details** (@ A4) Scale: 1 : 20

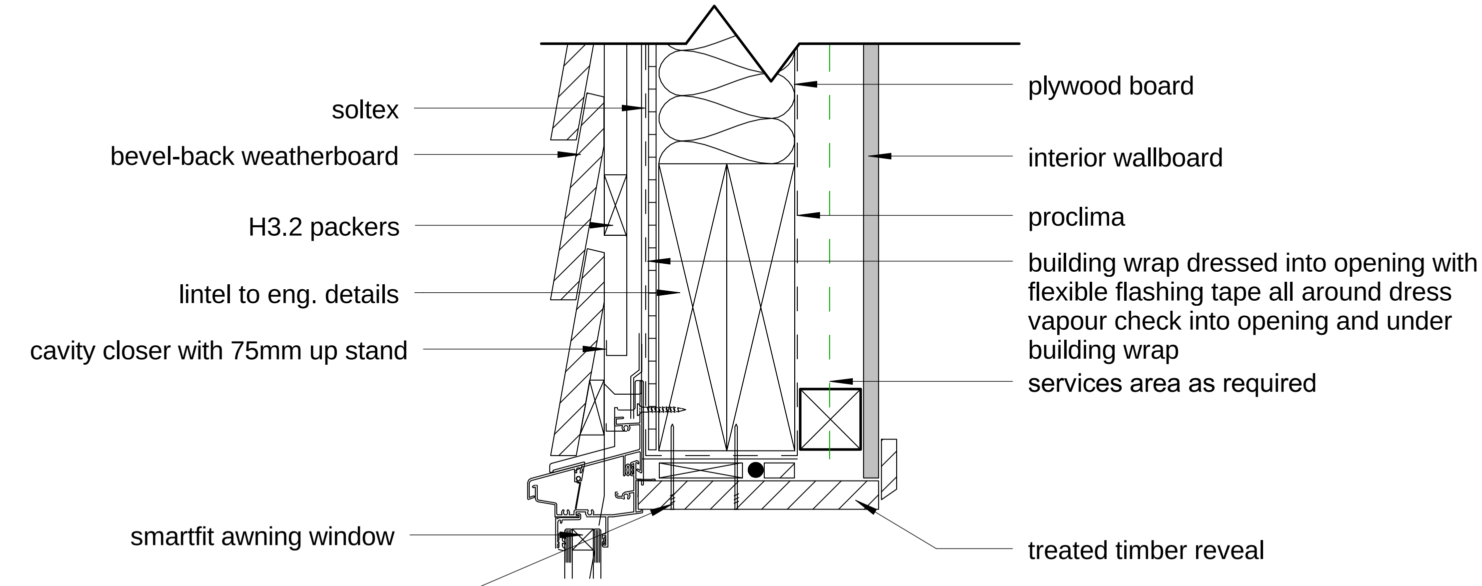


Door Head Detail

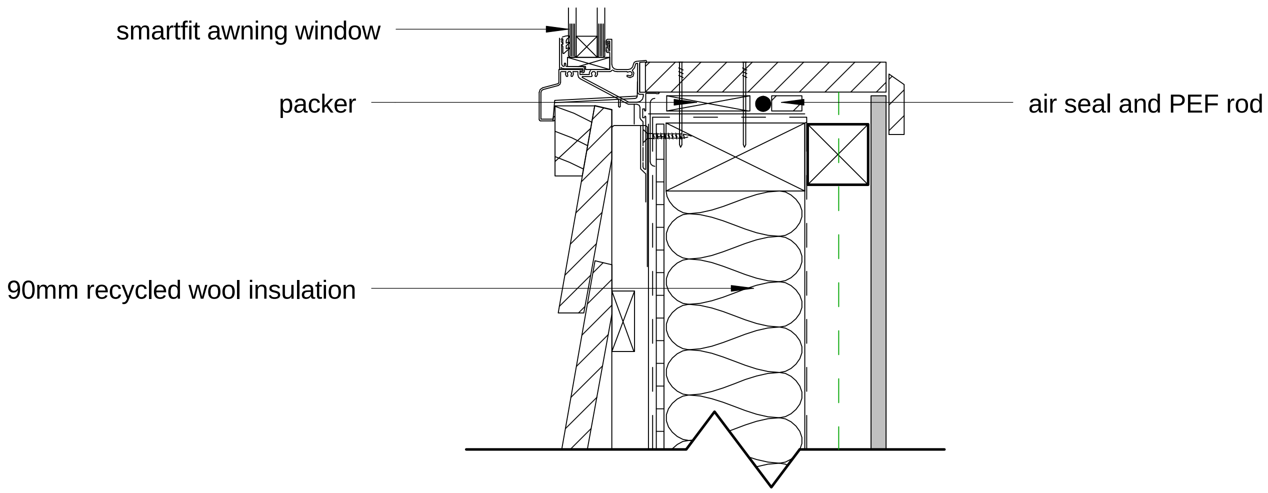


Door Sill Detail

Flexi-Ed Date: 11/09/16	Door Head & Sill Detail (@ A4) Scale: 1 : 5

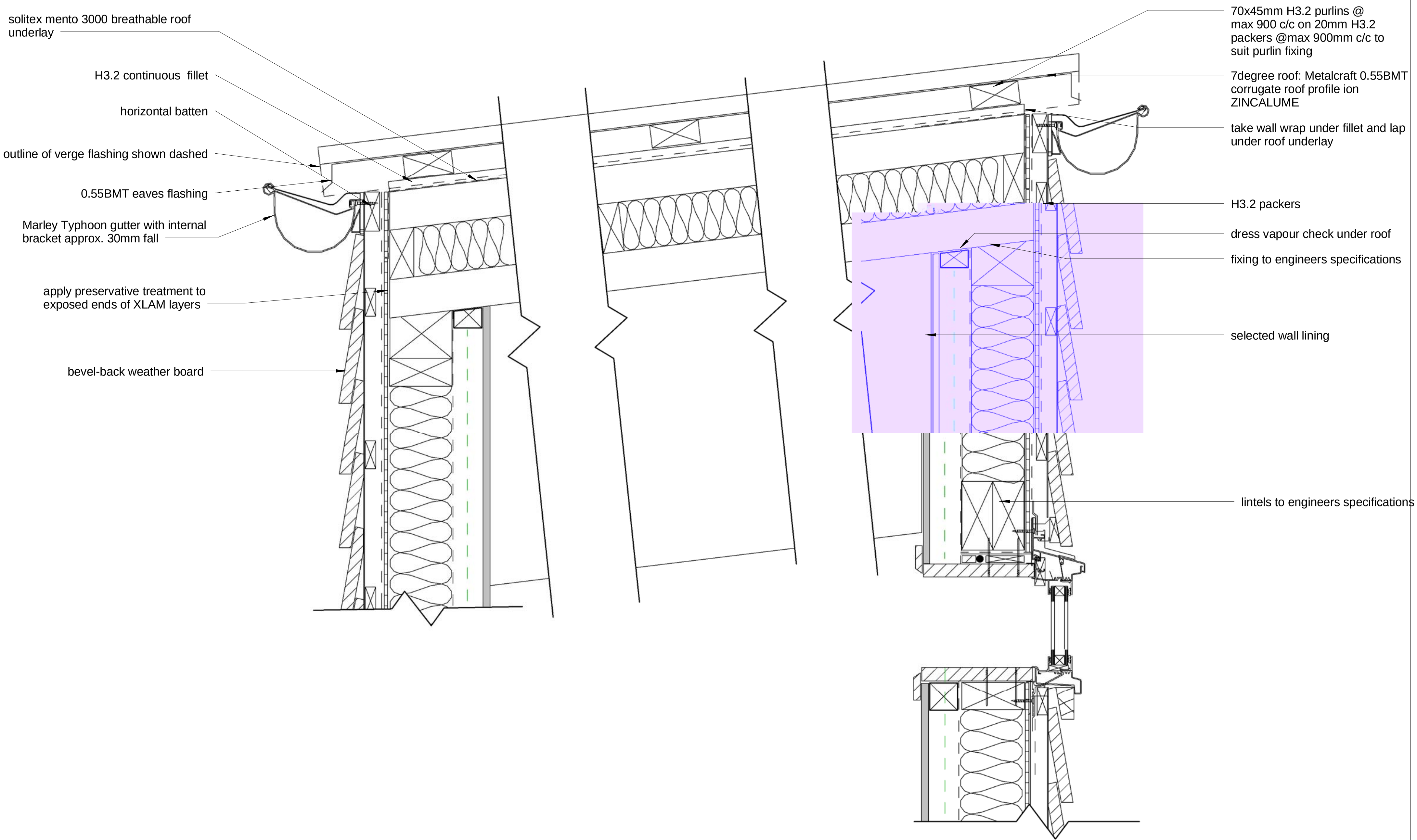


Window Head Detail



Wnidow Sill Detail

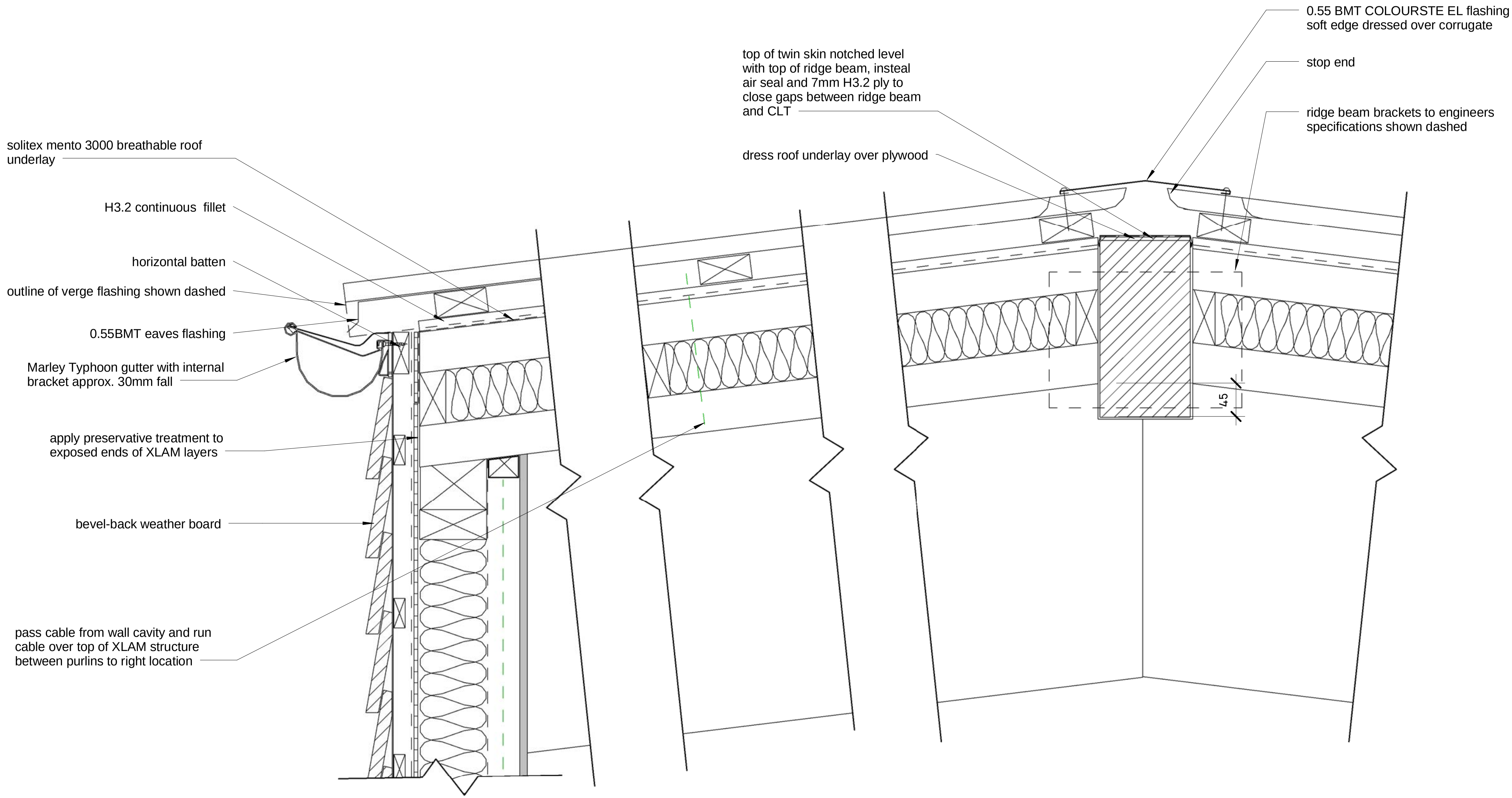
Flexi-Ed	Date: 11/09/16	Window Head & Sill Detail (@ A4) Scale: 1 : 5



Flexi-Ed

Monopitch Roof Section

Drawn Scale:
(@ A3) 1 : 5



Flexi-Ed

Gable Roof Detail

Drawn Scale:
(@ A3) 1 : 5

Thesis Mind Map:
A visual documentation tool which was added to weekly, displaying the progression of the Author's mind throughout the process of this thesis.