

# EDUCATION IN MOTION

Employing modular classrooms to create vibrant, collaborative, and flexible  
learning environments in the Seattle School District

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**Abstract**

Education In Motion

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The Seattle Public School District (SPS) has been experiencing an increase of 1000 students per year for the past five years. In the Seattle Public School District a common solution to alleviate the issues capacity overruns and budgetary constraints is to install modular classrooms. These spaces are effective in delivering almost immediate, economical learning space. However, where this building typology falls short is in its indoor environmental quality, durability, and spatial relationships.

This doesn't need to be the case. With a greater emphasis placed on the design of modular classrooms as educational space, a re-tooling of the

fabrication process, the use of digital fabrication technologies, and the advent of the new structural technology of engineered heavy timber, modular classrooms are uniquely positioned to bridge the gap between cheap temporary modular classroom space and expensive highly customized permanent classroom space.

Altering the design, fabrication, and assembly processes for modular classrooms gives this typology the capability to create vibrant, collaborative, semi-permanent educational space to schools while also allowing a level of future flexibility to school districts.

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## CHAPTER I - INTRODUCTION

*Public education is one of the central tasks of a democratic society, and the buildings that house this important task not only shape the way we teach, but provide icons and symbols for the values we hold common as a society. (Baker 3)*

Classrooms are enablers of democracy. They are constructed volumes where knowledge can be reliably disseminated from teacher to student. In American society, we expect this transference of knowledge to be powerful, effective, and collaborative. Historically, these societal expectations have been significant determinates in the design of America's educational spaces. These ideals have generated an architectural vocabulary of presence, hierarchy, collaboration, and permanence. U.S. schools. (Figure 1.1)

If you juxtapose the traditional classroom model with the modular classroom, the contrast is quite significant. While both are technically educational space, the genesis of each is derived from distinctly different

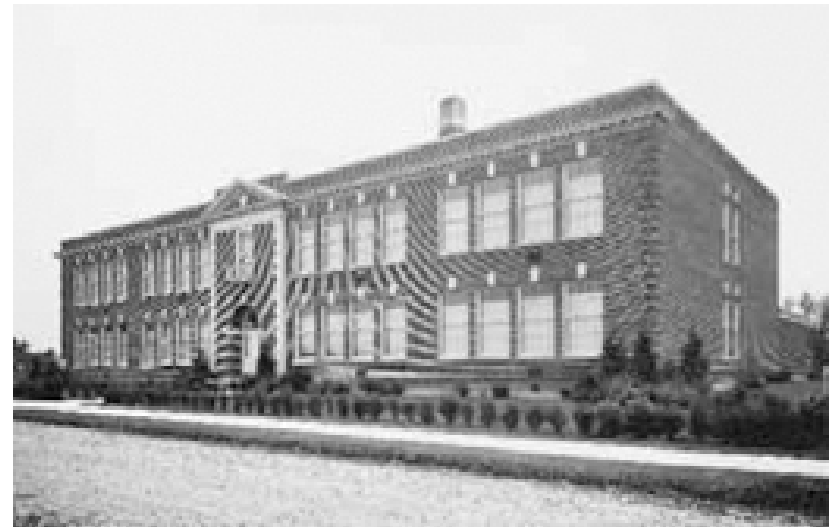


Figure 1.1 - Laurelhurst Elementary circa 1930



Figure 1.2 - Norwood Elementary quiet classroom



Figure 1.3 - Norwood Elementary science classroom

thought processes. The primary intent, in the design of permanent classroom space, has been to formalize civic space that engenders a distribution of knowledge and social interaction, propelling civilization forward. Recognizing its essential role in the democratization process, elected officials often support space being optimally designed and constructed so that the current understanding and ideals of American society can be communicated to the next generation. This approach to the design of educational space is proactive. Because, as a society, we have invested in the thoughtful design and construction of permanent classroom space we have become highly proficient at delivering effective, vibrant, and collaborative educational space. (Figure 1.2-1.3)

However, the mentality that leads to the use of modular classrooms is the opposite, it is reactionary. A more pragmatic American society views them, and subsequently allows them to be designed, as temporary utilitarian buildings. They are effective at providing shelter for students in an immediate and economical way, but little effort is placed on designing these spaces to be beneficial learning environments that are

integrated into their larger site context. Currently, modular classrooms have anti-hero status, they get public school districts and educators out of financial and enrollment binds, but they are exceptionally flawed.

## MODULAR CLASSROOMS | THE ANTI-HERO

School districts are often battling capacity and budget constraints. A common solution to alleviate both of these issues is to install modular classrooms. These spaces are very effective in delivering almost immediate, economical learning space. However, where this building typology falls short is in its indoor environmental quality, durability, and spatial relationships. As educational space, modular classrooms do not convey presence, hierarchy, collaboration, and permanence, and thus fail to reinforce the common values Americans hold as a society. The design and fabrication of modular classroom operate around the assumption that they are temporary fixes to a problem. Insufficient environmental systems are installed, which contributes significantly to indoor environmental quality issues such as excess moisture, high CO<sub>2</sub>



Figure 1.4 - typical interior of modular classroom



Figure 1.5 - Laurelhurst Elementary modular classroom & permanent classroom interface

levels, and poor daylighting. Materials are selected which have with a quicker rate of deterioration because of the assumption that these buildings are temporary. The reality is usually the opposite, these spaces are used well beyond their intended life span which further compounds the initial design and fabrication deficits. For these reasons, among others, modular classrooms are viewed as an inappropriate typology for educational space. (Figure 1.4) (Drury)

This negative perception of modular classrooms is further compounded by the way these spaces are sited. The site analysis and positioning of modular classrooms is primarily an exercise in logistics, ignoring variables which can lead to optimal learning experiences for the students. Architects are brought into the process of modular classroom delivery exclusively for their knowledge of the permitting process and cost-effective utility hook-up locations. This flawed process of site integration results in these classroom having little to no relationship to each other or the existing school and site. (Figure 1.5-1.6)

## MODULAR CLASSROOMS | THE HERO

This doesn't need to be the case. With a greater emphasis placed on the design of modular classrooms as educational space, a re-tooling of the fabrication process, the use of digital fabrication technologies, and the advent of the new structural technology of engineered heavy timber, modular classrooms are uniquely positioned to bridge the gap between cheap temporary modular classroom space and expensive highly customized permanent classroom space.

Altering the design, fabrication, and assembly processes for modular classrooms gives this typology the capability to create vibrant, collaborative, semi-permanent educational space to schools while also allowing a level of future flexibility to school districts. (Figure 1.7)



Figure 1.6 - Laurelhurst Elementary modular classroom entry



Figure 1.7 - new northeast approach to Laurelhurst Elementary

## CHAPTER II - CURRENT DESIGN AND FABRICATION PROCESSES OF MODULAR CLASSROOMS + DISTRICT ANALYSIS

It is the position of these thesis that the majority of the problems associated with modular classrooms result from improper design, fabrication, and integration processes. This chapter provides an depth outline of the shortcomings of modular classrooms. Understanding these issues will act as a benchmark to measure design, fabrication, and integration process adjustments against existing models. Currently, modular classrooms have several technical, spatial, and perceptual deficiencies due to the way they are designed and manufactured. The issues regarding indoor environmental quality (IEQ) and durability are many and well documented. In addition to the IEQ and durability problems, modular classrooms are spatially disconnected from each other and the permanent classrooms/schools they are sited adjacent to. All these shortcomings have lead to a overwhelming negative public view of modular classrooms.

## PLANNED OBSOLESCENCE | TECHNICAL PROBLEMS:

### DURABILITY

With the way modular classrooms are currently designed and constructed, they have an intended useful lifespan of up to 10 years if properly maintained. (U.S Department of Energy 38) There is a perceived value in the mobility of these classrooms. The assumption is that they can provide temporary facilities for students until the enrollment spikes decrease, but the reality is these classrooms are rarely ever moved or returned. In Seattle (51%), Lake Washington (53%), and Puyallup (57%) of the modular classrooms in these school districts' are over 20 years old and still in use. (Drury).

While modular school buildings are built to meet the current building code, the durability of the materials used to construct these structures is often lower than traditional classrooms. (Figure 2.1) This design consideration is a significant contributor to the favorable economics



Figure 2.1 - siding rot on modular classroom, Bellingham, WA

of modular classrooms. The decision to use less durable materials is made with the assumption that the classroom will only be in operation for a few years. The problem is these spaces are often used well beyond their intended lifespan. While upfront capital cost needed to make modular classrooms operational is low compared to traditional methods of delivering permanent classroom space, the operational cost to maintain modular classrooms is significantly higher especially when they are used beyond their planned lifetime. (U.S Department of Energy 38) One of the problems is that modules are exclusively powered by electricity, and are usually charged residential utility rates, which can be 25-30 percent higher than utility rates for the rest of the school (Drury). In addition, modular classrooms require significantly more energy to maintain comfortable indoor temperatures. Manufacturers of these spaces insulate and fenestrate to energy performance code minimums. Because of the lower insulation levels modular classrooms require increased energy level to maintain comfortable temperatures. Adding to this dilemma, the standard HVAC system are electric heat

strips, which is an inefficient way to regulate temperature. It is a high grade of energy to perform the low grade function of heating and cooling a space. Permanent classroom design and construction in the northwest are overwhelmingly moving to the use of heat pumps and radiant heating. These systems consume half the energy as does electric heating. (Electric Resistance Heating) As these modular classrooms age, especially beyond their intended use, these durability issues are significantly compounded. The combination of higher electricity rates, inefficient HVAC systems, minimum energy performance levels, and insufficient maintenance result in operating costs per unit being as much as twice that of a conventional classroom space. (U.S Department of Energy 38)

## INDOOR ENVIRONMENTAL QUALITY

Compared to permanent classrooms, modular classrooms have measurably higher levels of CO<sub>2</sub>, VOCs, mold, and other contaminants that contribute to poor indoor environmental quality. Typical outdoor CO<sub>2</sub> concentrations are approximately 380 ppm, outdoor levels of 500 ppm in urban areas are not uncommon. A study performed by the Department of Energy found that moderately high indoor concentrations of carbon dioxide (CO<sub>2</sub>) can significantly impair decision-making performance. Nine decision-making categories were measured at 600 ppm, 1000 ppm, and 2500 ppm CO<sub>2</sub> thresholds. Significant reductions in performance were registered at the 1000 ppm CO<sub>2</sub> threshold for 6 of the 9 categories. Seven of the 9 categories saw even greater declines in performance when the 2500 ppm CO<sub>2</sub> threshold was reached. Basic Activity, Initiative, Information Utilization, Breath of Approach, and Basic Strategy were the decision-making categories that registered the greatest decrease in performance based on CO<sub>2</sub>

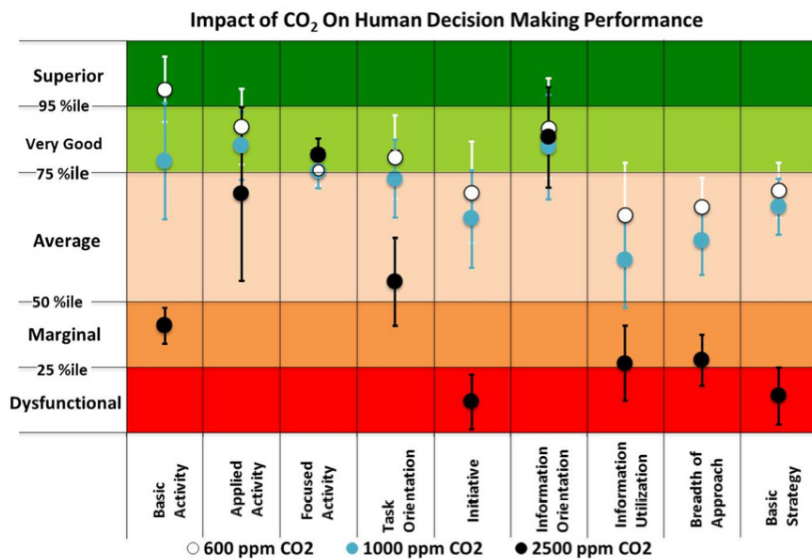


Figure 2.2 - impact of CO<sub>2</sub> on human decision making performance

levels. (Satish 1675) A study of several hundred portable classrooms throughout California found modular classrooms had CO<sub>2</sub> levels above 1000 ppm 40 percent of the time and above 2000 ppm 10 percent of the time while occupied. (Jenkins 12) Another study looking at the correlation between high CO<sub>2</sub> levels and student absence found when indoor classroom space CO<sub>2</sub> levels were 1000 ppm above normal outdoor concentration levels corresponded to a 1 percent decrease in annual attendance. The study also found that yearly attendance was 2 percent higher in traditional classrooms compared to modular classrooms. (Shendell 335)

Several important conclusions can be drawn from these findings. First, indoor CO<sub>2</sub> levels, which have generally been considered acceptable, can in fact have serious negative impacts on learning. Second, modular classrooms have measurably higher levels of CO<sub>2</sub> concentrations than traditional permanent classrooms, and the levels regularly fall in the range where learning comprehension can be negatively affected. In

addition to the academic loss associated with higher CO<sub>2</sub> levels there is an economic loss as well. With modular classrooms having a 2 percent lower annual attendance rate than traditional classrooms (Satish 1675) and since funding rates are often attached to student attendance the school loses out on funds due to the lower attendance rates in modular classrooms.

## IDENTITY CRISIS | PERCEPTUAL PROBLEMS:

### EXTERIOR ARCHITECTURE

The lack of enthusiasm around the exterior architecture of modular classroom is typically a secondary complaint, but is still one that should be addressed. Within the past year Laurelhurst Elementary was looking to replace the 4 modular classrooms, which have been on site since the 1960s, with new modules. The new classrooms being considered were the SAGE classrooms. These modular classrooms have addressed the indoor environmental quality and durability issues that



Figure 2.3 - interior of SAGE classroom at Corvallis Waldorf School



Figure 2.4 - exterior of SAGE classroom at Corvallis Waldorf School

typical modular classrooms struggle with. With these improvements, the SAGE classrooms were going to cost more than a prototypical modular classroom, but still significantly less than permanent classroom design and construction. The school would be able fund the cost of a typical modular classroom, but if parents could raise the funds for the remainder, the new SAGE classrooms would be installed.

The parents at Laurelhurst Elementary recognized that the SAGE classrooms had comparable IEQ and durability standards to a traditionally built classroom, but the decision not to fund the SAGE classrooms was eventually settled on because they did not want to invest additional money to install modular classrooms that still looked like “portables”. (Talbot 2016)

## **SITE PLACEMENT**

Permitting and utility hook-ups consume a significant portion of the budget allocated to modular classrooms. If an architect is brought into the process at all, it is strictly to streamline the permitting process and utility hook-up coordination. (Talbot 2016) An architect typically is not asked to perform any kind of meaningful site analysis in order to optimally locate the modular classrooms in relationship to the existing school or each other. This approach to site analysis tends to lead to spatially disjointed relationships between multiple modular classrooms and an awkward connection to the existing school.

## **MODULAR CLASSROOM INTEGRATION**

If multiple modular classrooms need to be placed on a school campus they are frequently clustered together. In an effort to conserve limited exterior space, the space allotted in-between each unit is roughly the dimension sufficient for egress in and out of the classroom. The resulting

dimension ranges between 8-10 feet, basically just wide enough to fit in two 4 foot wide exit ramps. This narrow spacing between each classroom creates an awkward entry/exit experience for the students and educators. The tight spacing between each module also reduces the effective daylighting capability of any vertical glazing on the modular classrooms.

The myopic emphasis on the entry/exit circulation creates a missed opportunity in how the modular classrooms relate to each other and the existing school. The narrow spacing between the modules removes opportunities for the school to program shared break out, co-teaching, or flex space in-between the modular classrooms. Also, the modular classroom “additions” are an island unto themselves having no spatial or programmatic relationship to the existing permanent school facilities.

(Figure 2.5)

## SEATTLE PUBLIC SCHOOLS OVERVIEW

The greater Seattle area is experiencing rapid population growth. In conjunction with this growth, the Seattle Public School District (SPS) has been experiencing an increase of 1000 students per year for the past five years. This influx of students is not being equally distributed across the district. Neighborhoods such as West Seattle, Columbia City, Wallingford, Eastlake, Montlake, and Beacon Hill have experienced a surge of new students, while neighborhoods such as Magnolia, Queen Anne, Capitol Hill, Fremont, and Phinney Ridge have seen enrollment plateau or even decrease.

During the 2015 academic year Seattle School District operated 2768 classrooms, of those classrooms 221 were modular classrooms. This number jumped to 252 in 2016, which is equal to 9 percent of the classroom population in the district (Figure 2.7-2.8). (Todd 2016)



Figure 2.5 - Laurelhurst Elementary modular classroom site layout

Currently SPS does not impose age limitation or adequate ventilation requirements for existing and new modular classrooms. 51 percent of the portable classrooms in operation in the Seattle school district have been in operation more than 20 years. (Drury) It is evident that a significant portion of the modular classroom building stock in SPS has aged beyond effective use and needs replacement. The dilemma for SPS is whether to purchase new modular classrooms or engage in the long process of permanent classrooms space

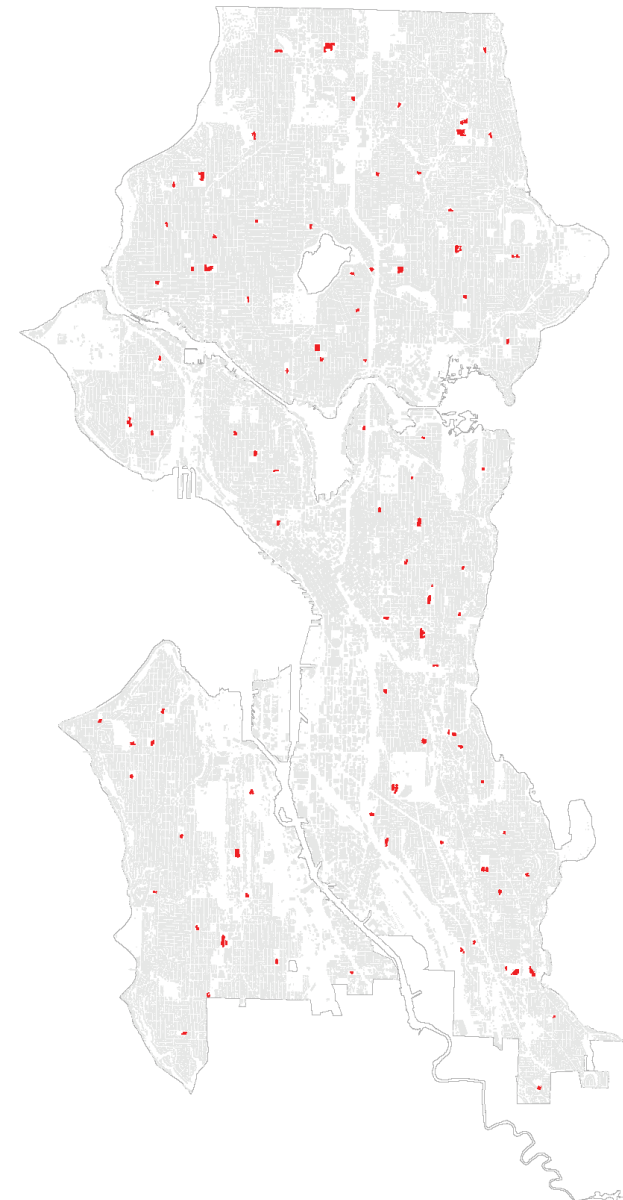


Figure 2.6 - Seattle School District figure ground (red = schools)

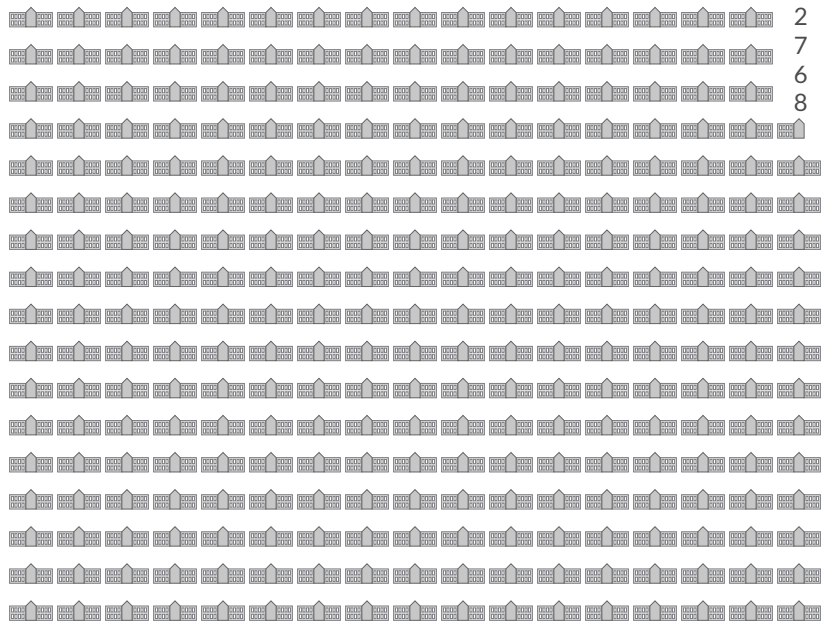


Figure 2.7 - number of classrooms in SSD (2768 classrooms)

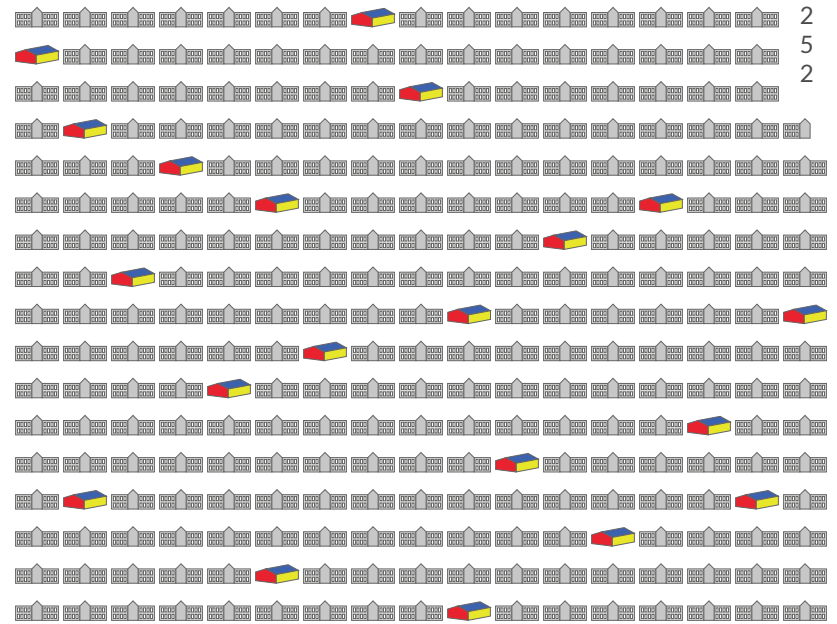


Figure 2.8 - number of modular classrooms in district (252 classrooms)

### CHAPTER III - NEW APPROACH TO DESIGN, FABRICATION, AND INTEGRATION PROCESSES OF MODULAR CLASSROOMS

While researching this thesis a few conclusions became increasingly evident. First, the typology of modular classrooms is not fatally flawed for educational use. The way we conceive, construct, and [dis]connect these spaces is what is problematic.

Second, while we have become exceptionally proficient and producing vibrant and collaborative permanent classrooms and educational space, these spaces can be problematic when anticipating the future needs of the SPS. School choice programs continue to expand, and the general mobility of families continues to rise. If all new educational building stock in the SPS were to be traditional permanent classrooms the district would be restricted in their ability to respond to these mobility variables over the long term.

Lastly, it became clear that modular classrooms were uniquely suited to address the needs of both immediacy and economy while also being poised to address educators desire for collaboration and the districts need for flexibility.

How can this be accomplished? If the problem with modular classrooms primarily lies with their design, delivery, and integration processes (as this thesis proposes) then it would make sense that if we improve these processes, or inputs, then the output should also improve.

This thesis will focus on re-defining the process of design/fabrication, the process of construction assemblies, and the process of module/site integration. The process of design and fabrication is the first to be re-tooled. Currently manufacturing companies involved in the design of storage space such as equipment storage, liquid storage, and jobsite trailers are the ones designing and constructing modular classrooms.

With the way American society views modular classrooms, as a



Figure 3.1 - exterior co-teaching/flex space

temporary volume of space to house students, it makes sense that we would look to these companies to design them.

The first move in re-structuring the design/fabrication process is to move the responsibility for design of modular classrooms from those well versed in designing storage space to those proficient in designing educational space. This change alone will alleviate many of the issues that are currently associated with modular classrooms, particularly those associated with IEQ, durability, and spatial connections.

The second change in re-structuring the design/fabrication process is more of a shift of the construction process. Pre-fabrication construction technologies are currently employed to fabricate modular classrooms. This fabrication method has several distinct advantages to traditional site built construction. It reduces material waste, increases accuracy and speed of delivery and can be economical if employed properly. This process simply needs to be adjusted to account for the use of regional

materials to strengthen local economies, to employ emerging structural and fabrication technologies, and to use the pre-fabrication process to address the needs for future flexibility. (Smith 184)

Figure 3.2 is an overview diagram that breaks down the design and fabrication process into 4 major steps: structural fabrication (mill it), flat-pack unit assembly and dry-fitting (make it), shipment (move it), and finally site assembly (mount it).

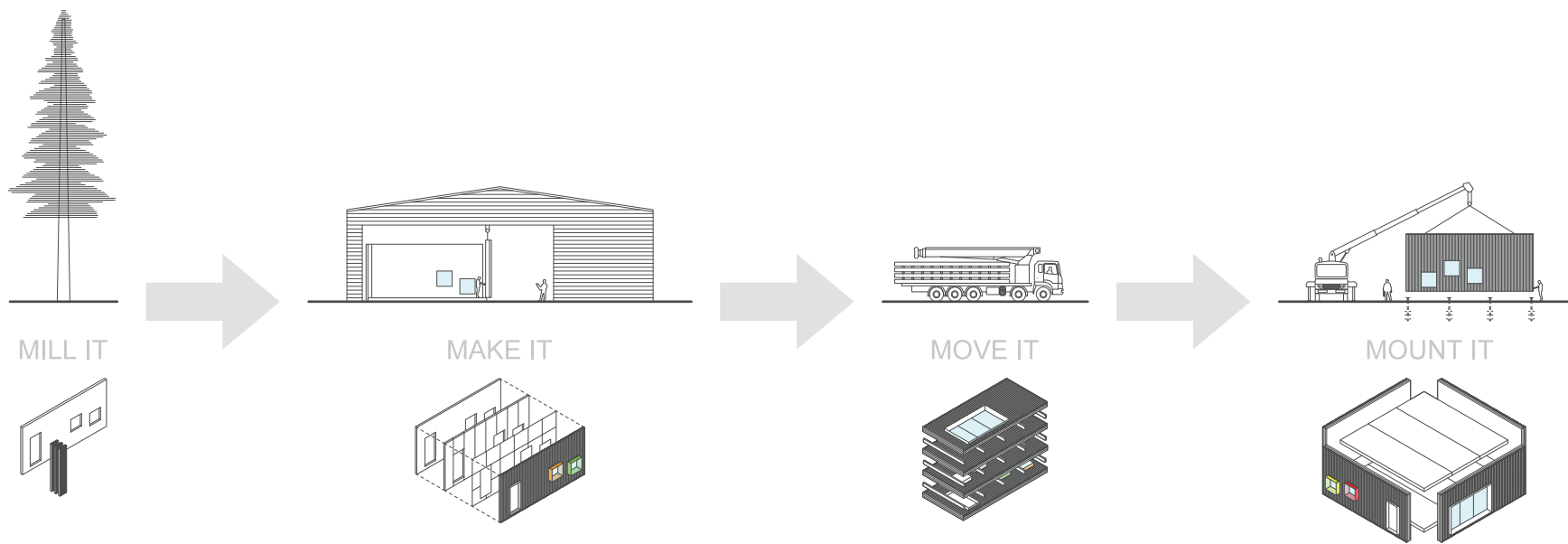
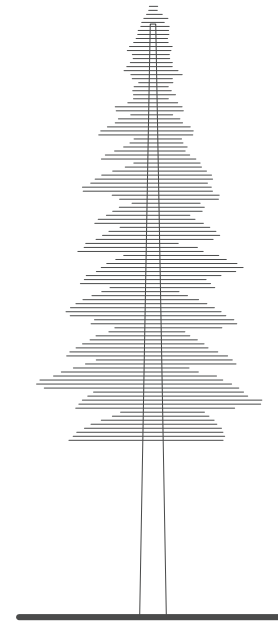


Figure 3.2 - design/fabrication process overview diagram

## MILL IT

The structural fabrication phase is where the raw material is converted into building material. Raw timber is milled, pressed and cut to appropriate width and length dimensions along with customized fenestration openings.

Cross laminated timber (CLT) used in conjunction with glue laminated beams (Glulam) is the structural system employed for the classroom modules. The environmental merits of using CLT/Glulam are many and well documented. CLT has great carbon sequestration capabilities and wood requires a low carbon output to get from raw material to building material compared to steel which traditionally is used for the base of a modular classroom (FPInnovations 22). Using engineered heavy timber also has economic benefits in the Northwest US, where wood is an abundant resource tied to much of the region's economy.



MILL IT

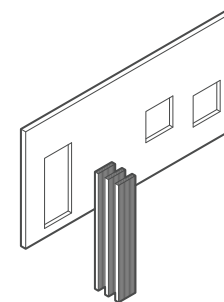


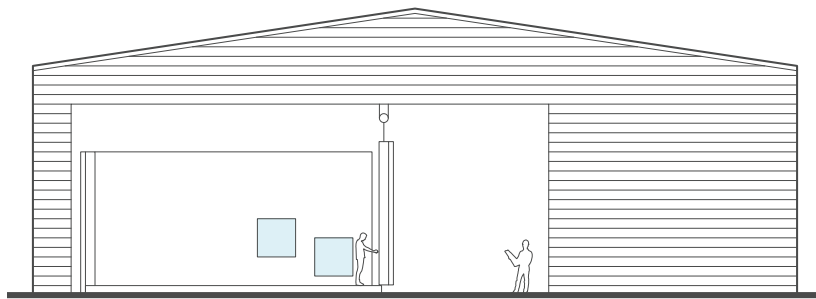
Figure 3.3 - structural CLT/GluLAM fabrication

In addition to its environmental and economic merits, using a robust structural system such as CLT/glulam for modular classroom construction ensures durability of structure, and provides flexibility in assembly, disassembly, and re-assembly.

## MAKE IT

The unit assembly phase is where the pre-fabricated structural components are brought together with other building material into pre-finished floor, wall, and roof flat-pack assemblies. Once each flat-pack assembly is complete all floor, wall, and roof assemblies are dry fit to ensure proper alignment before they are disassembled and shipped to the site for installation.

Throughout the entire design and fabrication process digital fabrication tools are used. The use of these tools assists in the reduction of project schedules, material waste, and user error while simultaneously increasing the level of customization on each project without increasing a project's budget due to labor costs or change orders.



## MAKE IT

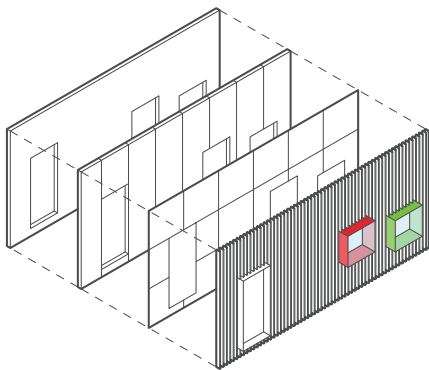
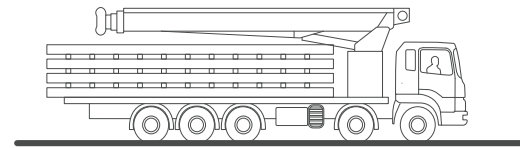


Figure 3.4 - flat pack unit pre-fabrication

## MOVE IT

Once the floor, wall, and roof flat-pack assemblies have been dry-fit together and everything is aligning properly they are broken down and shipped in their constituent parts. While using a pre-fabricated flat-pack system requires a higher level of coordination to ensure proper configuration than a pre-fabricated module unit system, because of the way it is shipped it provides an additional 2.5 feet of height to each classroom module over a pre-built module unit type of pre-fabrication.



## MOUNT IT

The final phase in the refined design and construction process is the site delivery and installation. Once all the pre-fabricated flat-pack assemblies are on site they are fastened to each other and to the foundation system. The corners of each wall assembly are left unfinished so the proper building wrap or waterproofing membrane can be applied on site, once properly sealed the corners are finished. All the roof flashing and water-

## MOVE IT

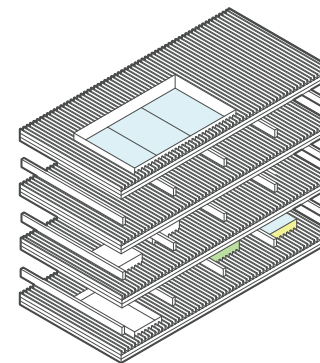
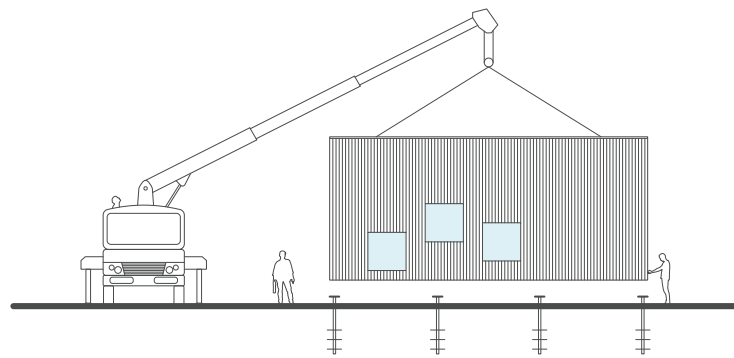


Figure 3.5 - flat pack shipping diagram

proofing is performed on site as well.

## CONSTRUCTION ASSEMBLY

Figures 3.7-3.8 detail the construction assembly process for a typical classroom module. The structural CLT panel is left exposed on the interior of the wall while an exterior insulation and rainscreen assembly system is applied to the material. Helical piles are used instead of spot or continuous footings. Helical piles allow for minimal site intervention and are quick to install. They also can be removed and reused if needed in the future.



MOUNT IT

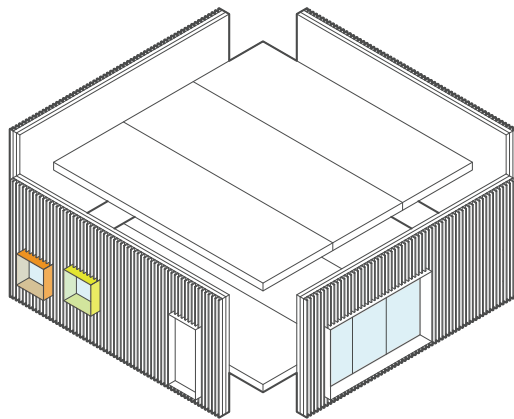


Figure 3.6 - module site installation

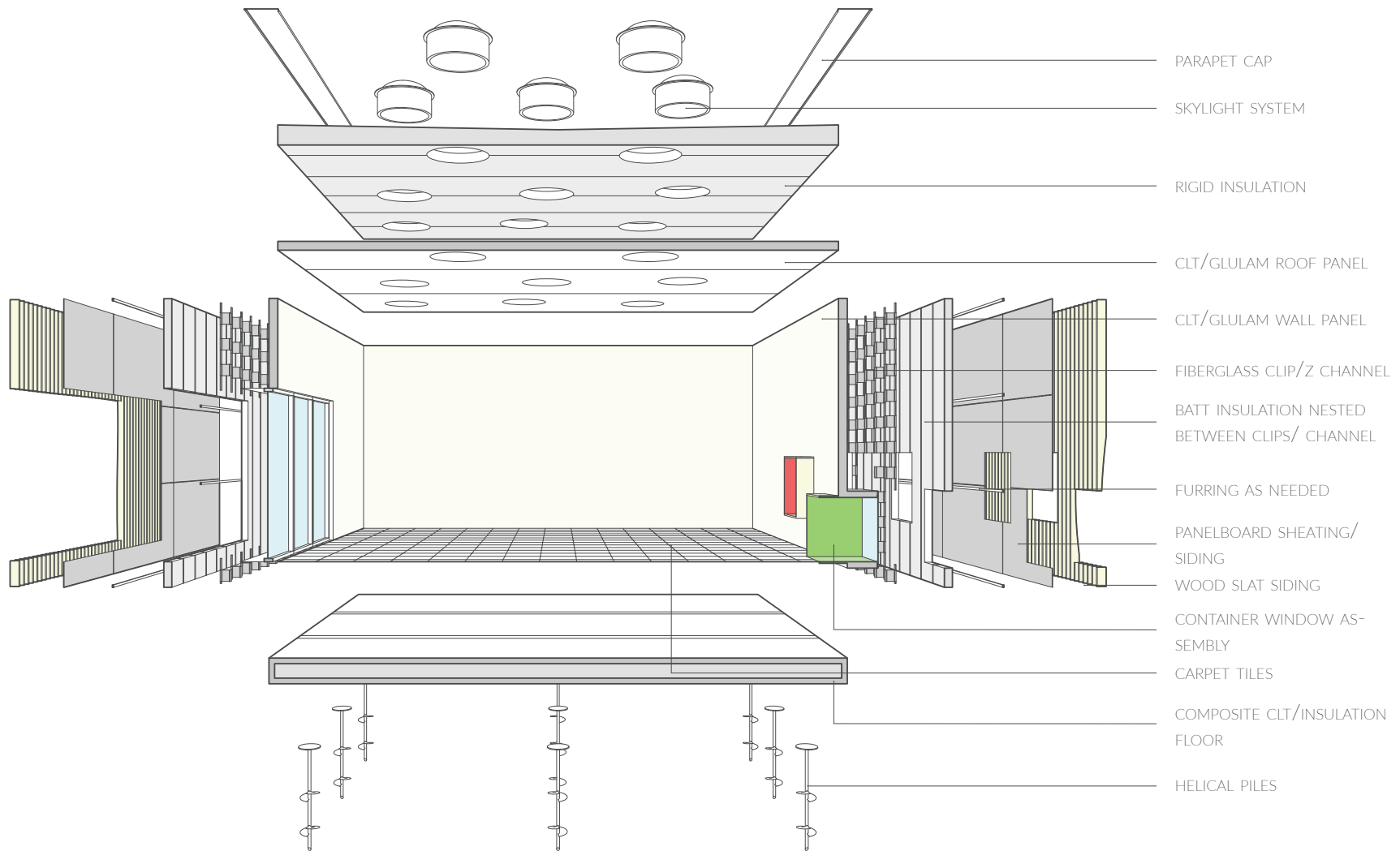


Figure 3.7 - exploded axon of typical classroom module assembly

NOTCHED BALLOON FRAMED  
ROOF/WALL CONNECTION

CUSTOMIZED SCALLOPED  
WOOD SLAT FACADE

CONTAINER WINDOW  
ASSEMBLY DETAIL

COMPOSITE CLT/INSULATION  
FLOOR PANEL

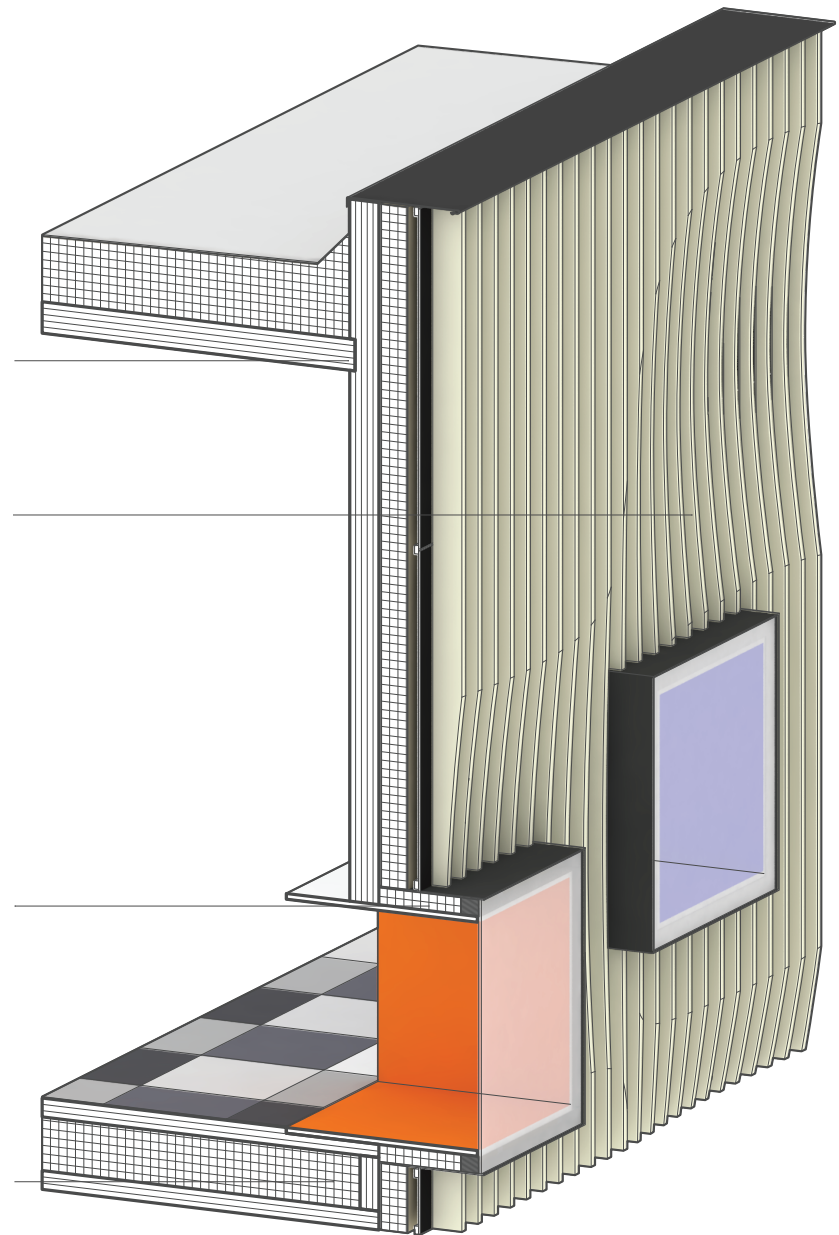


Figure 3.8 - typical classroom floor/wall/roof section

## INTEGRATION PROCESS (MODULES)

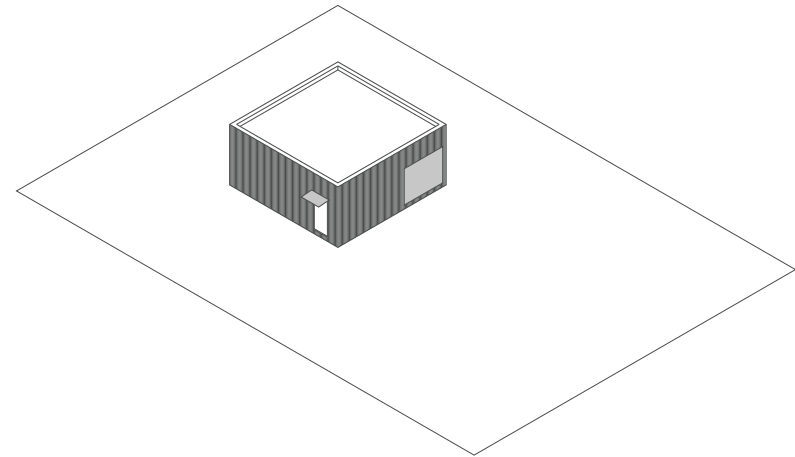
With the design/fabrication, and construction assembly processes established the next issue is the integration process. To enhance integration between the modules themselves and the existing site context a kit-of-parts or a series of modules at various scales were developed. Used in conjunction with each other, this should result in a higher level of engagement and connection.

## CLASSROOM

The first module in the kit-of-parts is the classroom (Figure 3.9). This module measure 30' x 30' and 14.5' in height. The length of the classroom has the capability to increase to 60' in length by 10' panel increments if a larger or double classroom is needed. The classroom module unit dimensions are a balance between several constraints, namely: optimal classroom viewing angles and ratios, shipping constraints, and structural capabilities.

## KIT OF PARTS

CLASSROOM



CLASSROOM  
CONTAINER WINDOW

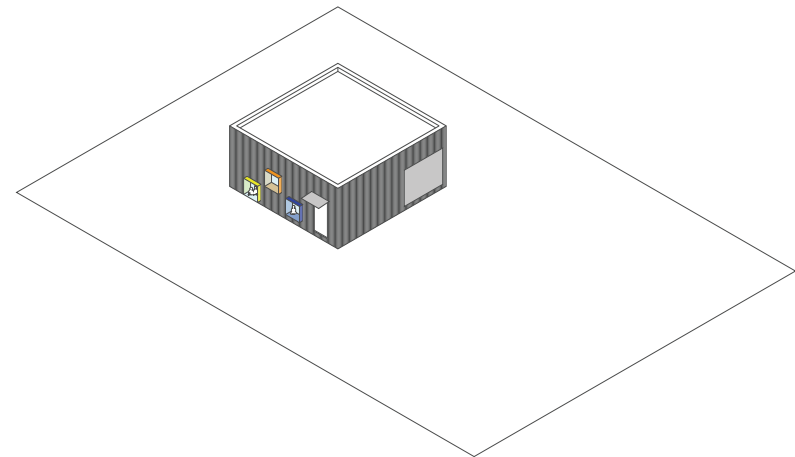
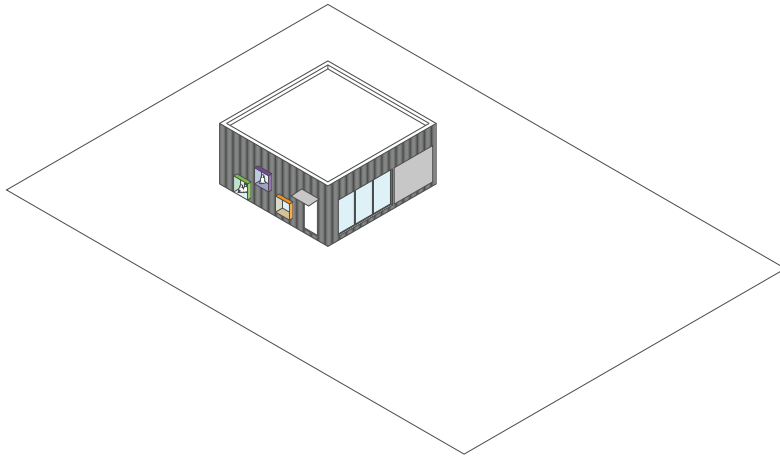


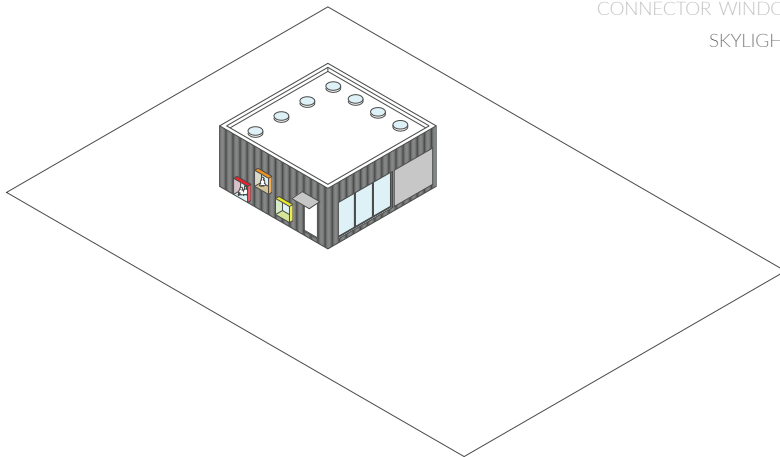
Figure 3.9 - classroom & container window modules

## KIT OF PARTS

CLASSROOM  
CONTAINER WINDOW  
CONNECTOR WINDOW



CLASSROOM  
CONTAINER WINDOW  
CONNECTOR WINDOW  
SKYLIGHTS



## CONTAINER WINDOW

The inside void space created by this module measures as a 3' cube (Figure 3.9). These modules are scaled and positioned specifically with the students in mind. The color is intended to provide visual stimulation for the students and a bit of architectural playfulness. The container window module provides views to the outside for students while also allowing a more intimate study, investigation, or reading space to each classroom module.

## CONNECTOR WINDOW

The purpose of this window module is to assist in the connection of multiple classrooms (Figure 3.10). It is comprised of a retractable window-wall system.

Figure 3.10 - connector window & skylight modules

## SKYLIGHTS

The goal of the skylight module is to meaningfully daylight the space (Figure 3.10). Extensive use of skylights allows the daylighting and glare control strategies to be de-coupled. While exact placement will vary on each classroom module, it will follow the general rule of 6-8% of the floor area will also be translucent skylight glazing to adequately daylight the space for critical visual tasks. (Meek 2016)

Using skylights as the daylight source has multiple benefits, especially in Seattle. First, during overcast sky conditions the brightest point in the sky is the zenith, so it makes sense to have the primary daylighting source. Second, intentionally restricting the vertical glazing in each classroom frees up wall surface area. Vertical surfaces are coveted, particularly among primary school educators, as pinup space.

## KIT OF PARTS

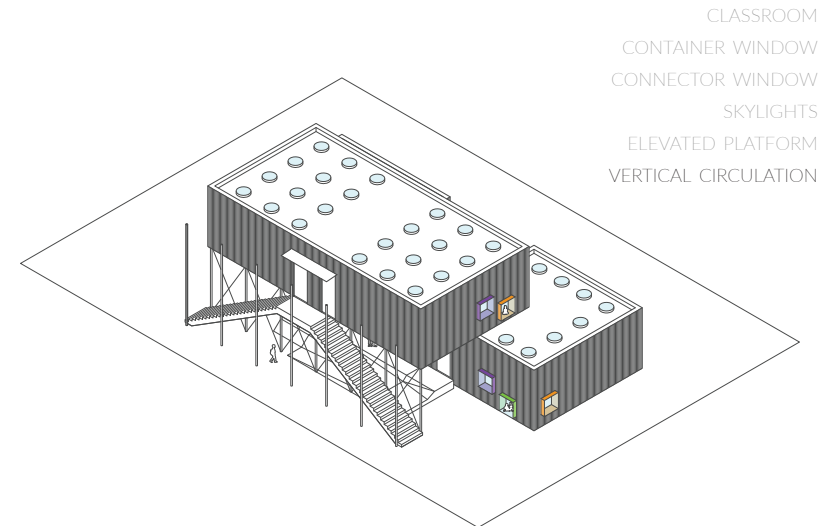
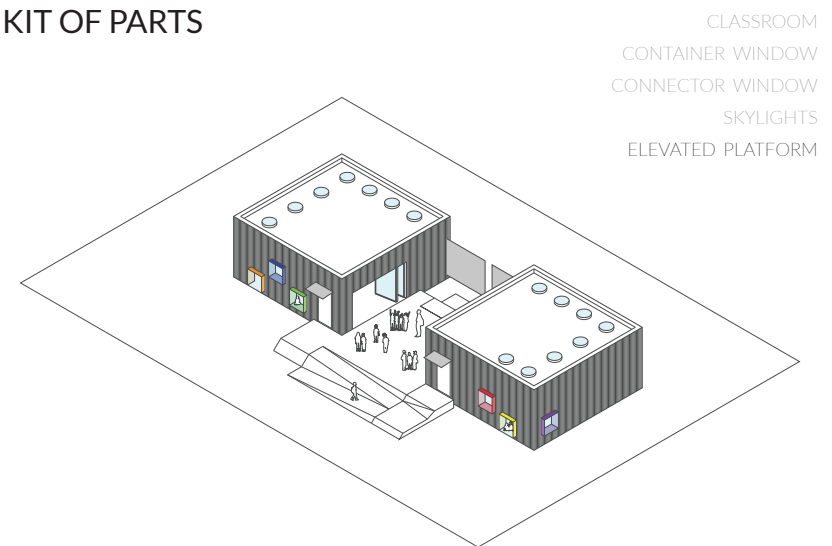


Figure 3.11 - elevated platform & vertical circulation modules

## **ELEVATED PLATFORM**

The elevated platform module completes the connection between multiple classrooms by providing continuous surface which several classrooms can expand onto creating exterior co-teaching and collaboration spaces. The platform surface consists of a series of folding planes (Figure #), while conceptually references the ground floor being lifted to meet the elevation of the classroom finished floor. Using a strategy of folding planes allow the ADA ramping to be more seamlessly integrated into the construction instead of being tacked onto the side of each module. (Figure 3.11)

## **VERTICAL CIRCULATION**

The last module is the vertical circulation (stairs, platform lift, and associated surfaces) up to the second level classrooms. This module also provides further spatial definition and protection from the elements for the shared exterior classrooms space created by several of the modules

(Figure 3.11). In addition, the surfaces of this module are to promote learning (Figure 3.12). The program of these surfaces can take on a number of different uses. It can be a writing surface, living wall, signage, public art, or something recreational such as a climbing wall. The only stipulation being that it encourages learning in some way.

## **KIT OF PARTS (COMPLETE)**

When all the modules outlined are designed to integrate with each other, the space they create is greater than the sum of their constituent parts. Gradients between individual and group education, formal and informal learning, interior and exterior educational space, and single to co-teaching approaches can be experienced when the kit-of-parts is thoughtfully applied. (Figure 3.12)

# KIT OF PARTS

- CLASSROOM
- CONTAINER WINDOW
- CONNECTOR WINDOW
- SKYLIGHTS
- ELEVATED PLATFORM
- VERTICAL CIRCULATION
- ALL THE THINGS

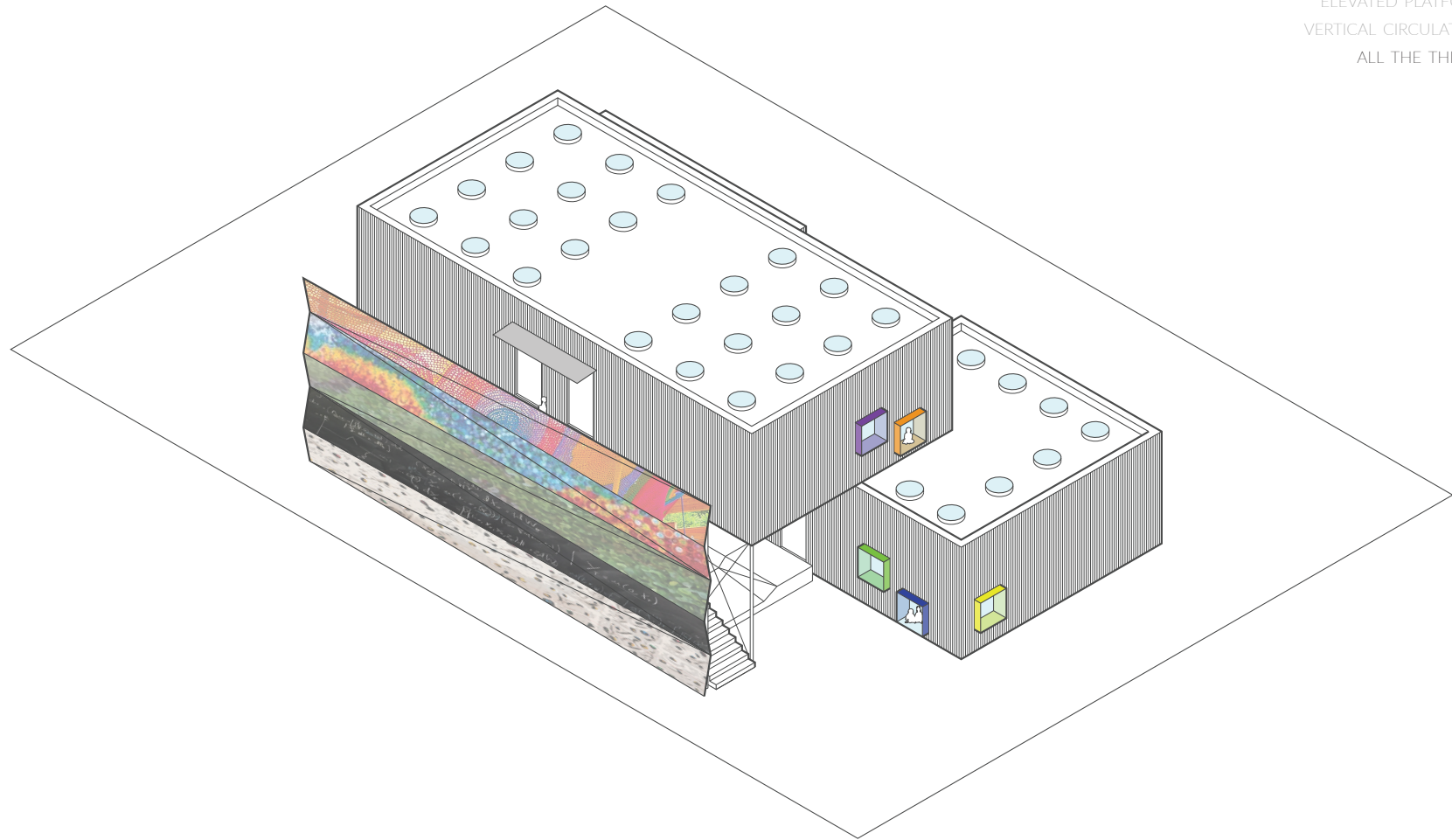


Figure 3.12 - composite kits-of-parts modules

## PROCESSES RECAP

With the design/fabrication, construction assembly, and kit-of-parts frameworks established, they will be applied on multiple case study sites to test their effectiveness. Two sites were selected within the Seattle School District, Laurelhurst Elementary and Kimball Elementary. Both sites have several modules on them which have been in use for multiple decades.

## CHAPTER IV - DESIGN CASE STUDIES

### LAURELHURST ELEMENTARY (EXISTING CONDITION)

Laurelhurst Elementary is situated in the single family neighborhood of Laurelhurst in Seattle. The original school is registered as a historic landmark and has been in use since 1928. The building has been expanded several times over the decades, but has reached its square footage limit on new permanent construction. The school's landmark status also complicates being able to do any kind of addition to or remodel of the existing school. For these reasons Laurelhurst turned to using 4 modular classrooms to house the 4th grade students. The modular classrooms currently in use have been on site since the 1960s (Seattle 2016). When the modular classrooms were introduced to the site they reduced the north playground area by 25 percent (Figure 4.1). With the way the modules are situated on site they confuse the physical boundaries of the school and its definition in the neighborhood. Many students and parents enter the site through this awkward

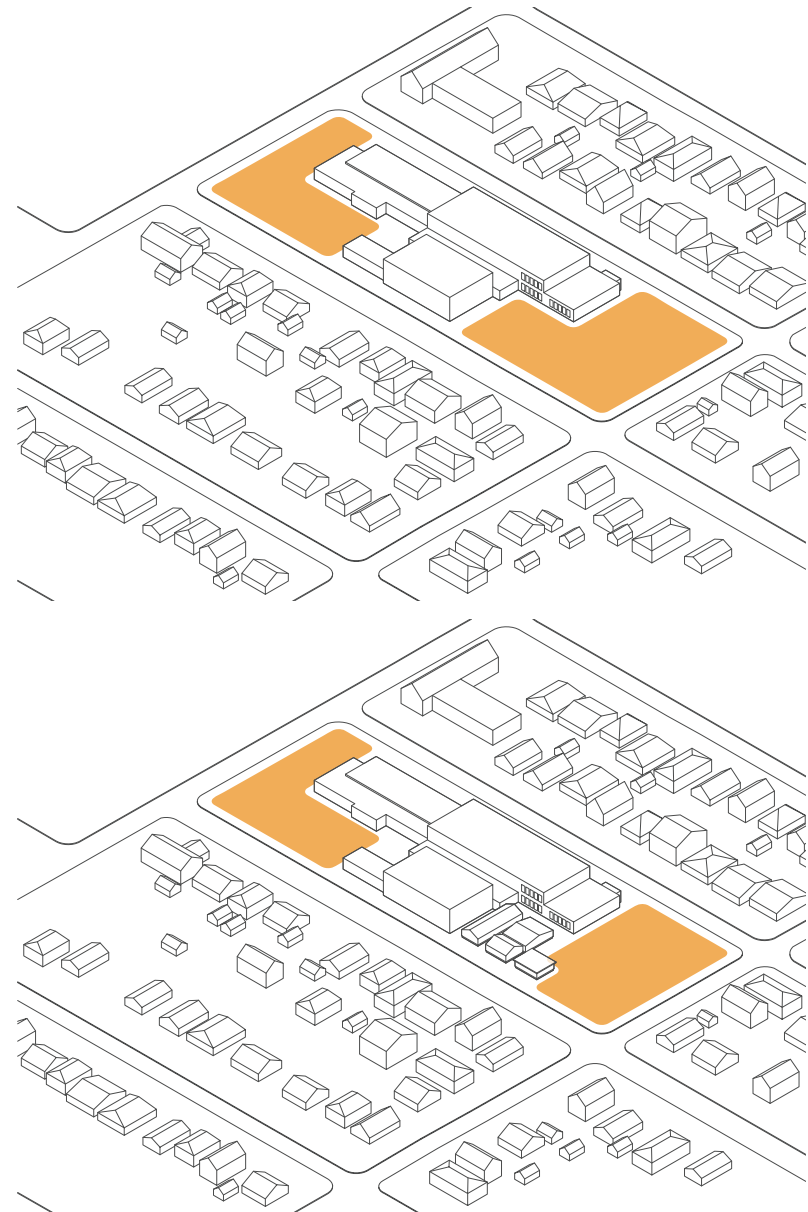


Figure 4.1 - previous (upper diagram) & existing (lower diagram) available playground

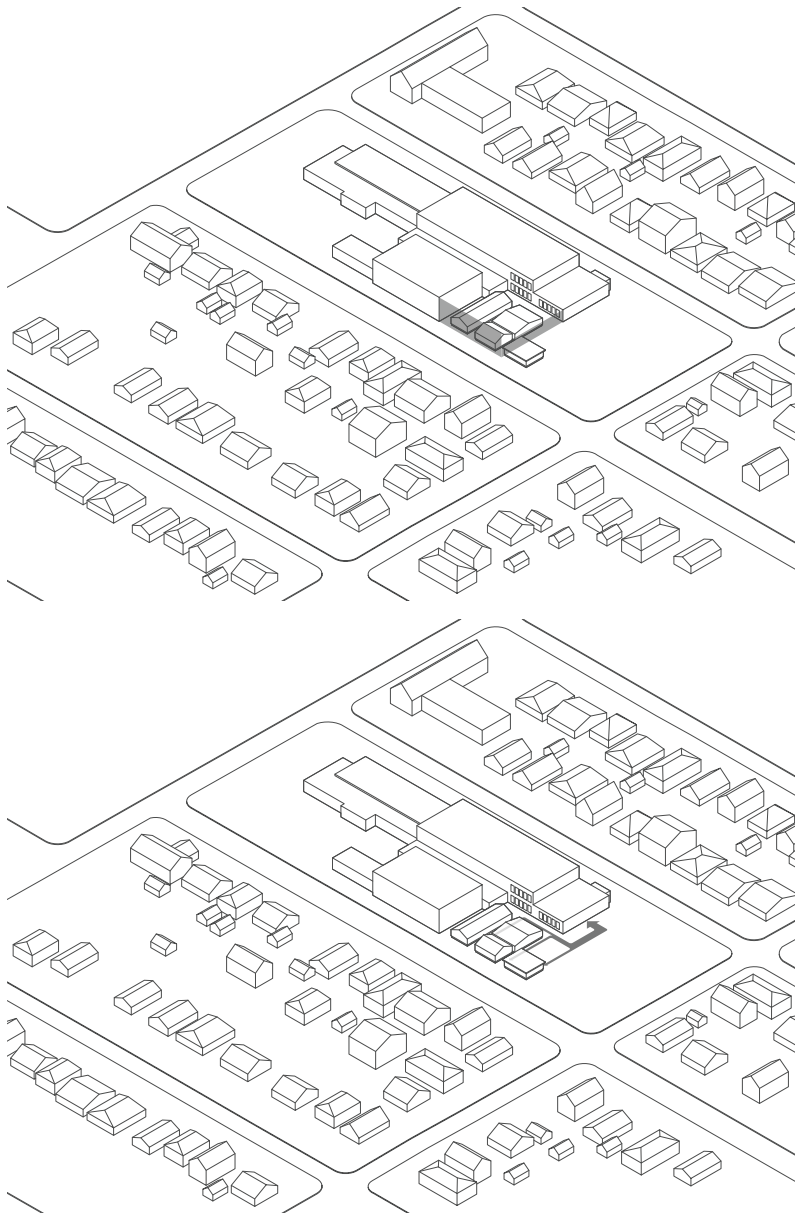


Figure 4.2 - existing module alignment (upper diagram) & circulation (lower diagram)

conglomeration of modules, creating an ambiguous presence on the northeast corner of the school. (Figure 4.2)

In addition to the confusing relationship the modules have to the existing building, their relationship to each other is awkward as well. Each module is 10' apart, this is wide enough to fit two entry ramps/stairs and a narrow 2' pathway between. This creates an entry sequence into each classroom that has the sensation of entering from an alley. It also creates a web of entrances and exits which allocates an inordinate amount of exterior square footage to circulation.

## LAURELHURST ELEMENTARY (NEW CONDITION)

The new proposal for the modular classrooms at Laurelhurst Elementary begins by addressing the current issues related to site context. The first site move was to give back as much of the north playground as possible. This meant employing a vertical layout strategy, stacking the modules on top of each other. Going vertical allowed for 14% of the exterior area to go back to playground space. With the way the modules are arranged a new exterior classroom was also provided. Figure 4.3

The second move was to clarify the physical boundaries of the school by defining its presence in the neighborhood. The modules were positioned so the outside facades fell in line with the extended planes of the existing permanent building facades (Figure 4.3) Lastly, an effort to simplify the circulation was made. Instead of having several entrances into the modules there are now two main entries that are generous enough in the pathway width double function as break-out or flex space (Figure 4.4).



Figure 4.3 - new module alignment

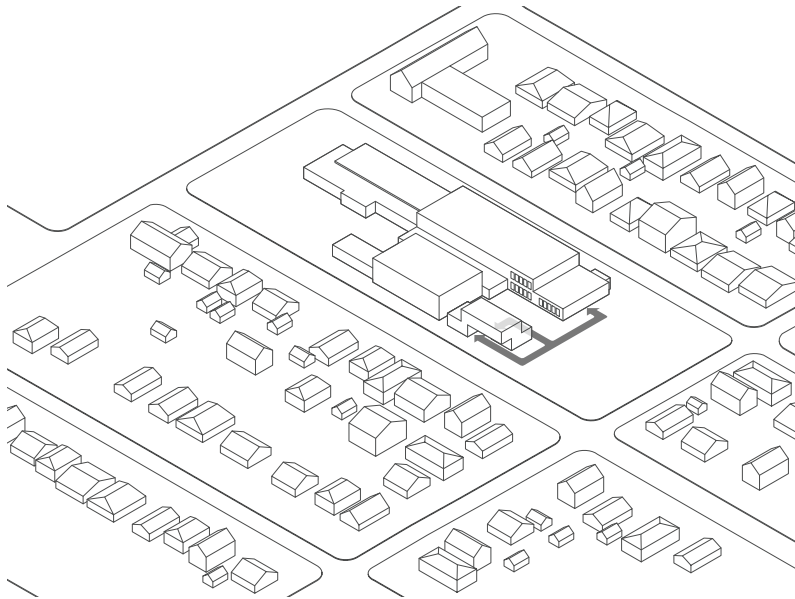


Figure 4.4 - new site massing (upper diagram) & circulation (lower diagram)

As can be seen in Figure 4.3 the decision to locate the modules in plane with the existing facades allows the school to now have a physical presence in the neighborhood without being overpowering. The signage on the screen as you enter the modules provides secondary way finding and notation for the school.

The light vertical wood slats were used to juxtapose against the permanence of the brick facades. The slats are scalloped to provide a layer of architectural dynamics and fun to a predominantly rectilinear form. Digital fabrication tools such as a CNC router are used to streamline this wood slat fabrication process. Also in the rendering little shots of color can be seen from the container windows to help break up the neutral facades.



Figure 4.5 - northeast approach to school

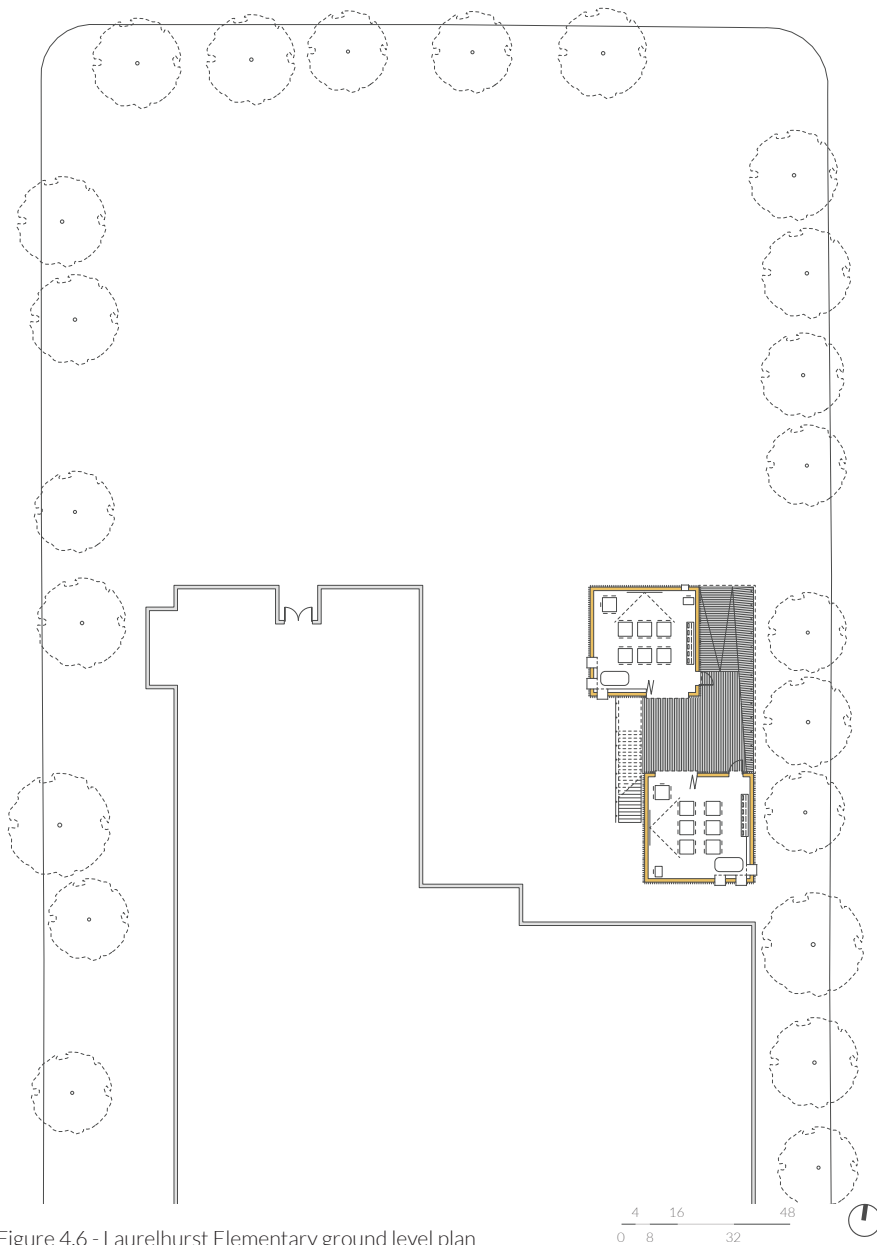


Figure 4.6 - Laurelhurst Elementary ground level plan

In plan the relationship between the two ground level classrooms can be seen. Their connector windows both open onto a generous shared exterior space where they can finally co-teach classes like they have been wanting to do for years. There are screens on the East and West ends of the elevated platform to help provide a level of visual separation as there is playground space and a roadway immediately on either side of the screens (Figure 4.07).

The second level classrooms do not have access to a shared exterior classroom space unless they use the one on the ground level. However, the two classrooms do share an interior partition wall that can be collapsed to grow the classrooms into one large shared interior classroom again allowing educators the opportunity to collaborate in educating their students. The desks are envisioned to be on casters so formal instruction can occur, but then they can be wheeled out of the way for informal learning or group activities (Figure 4.10).

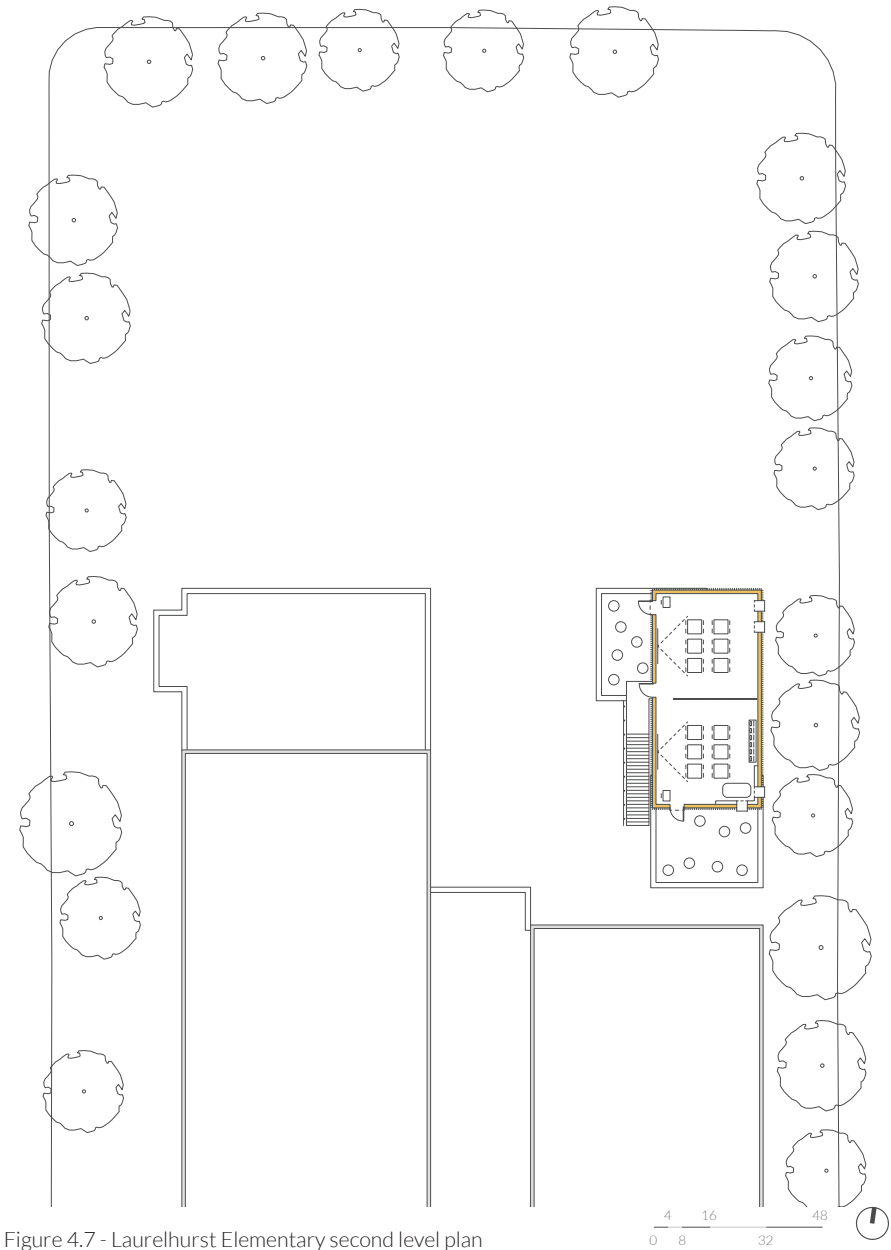


Figure 4.7 - Laurelhurst Elementary second level plan

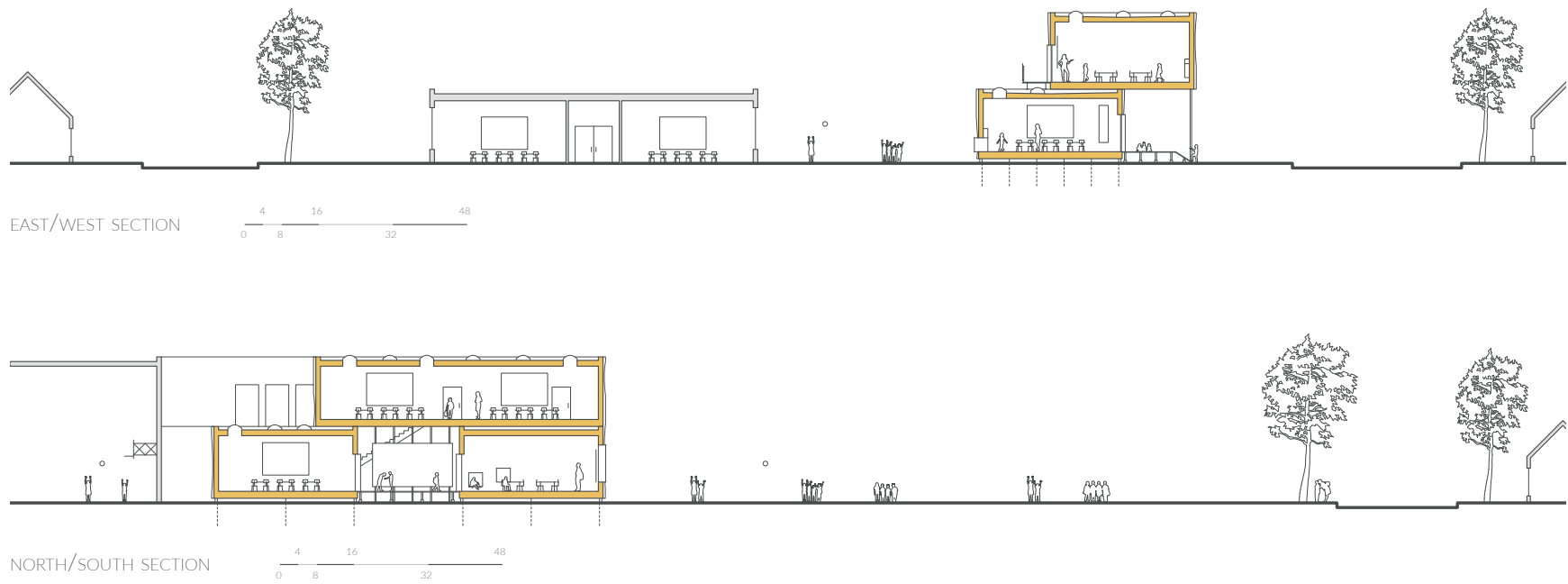


Figure 4.8 - Laurelhurst Elementary site sections

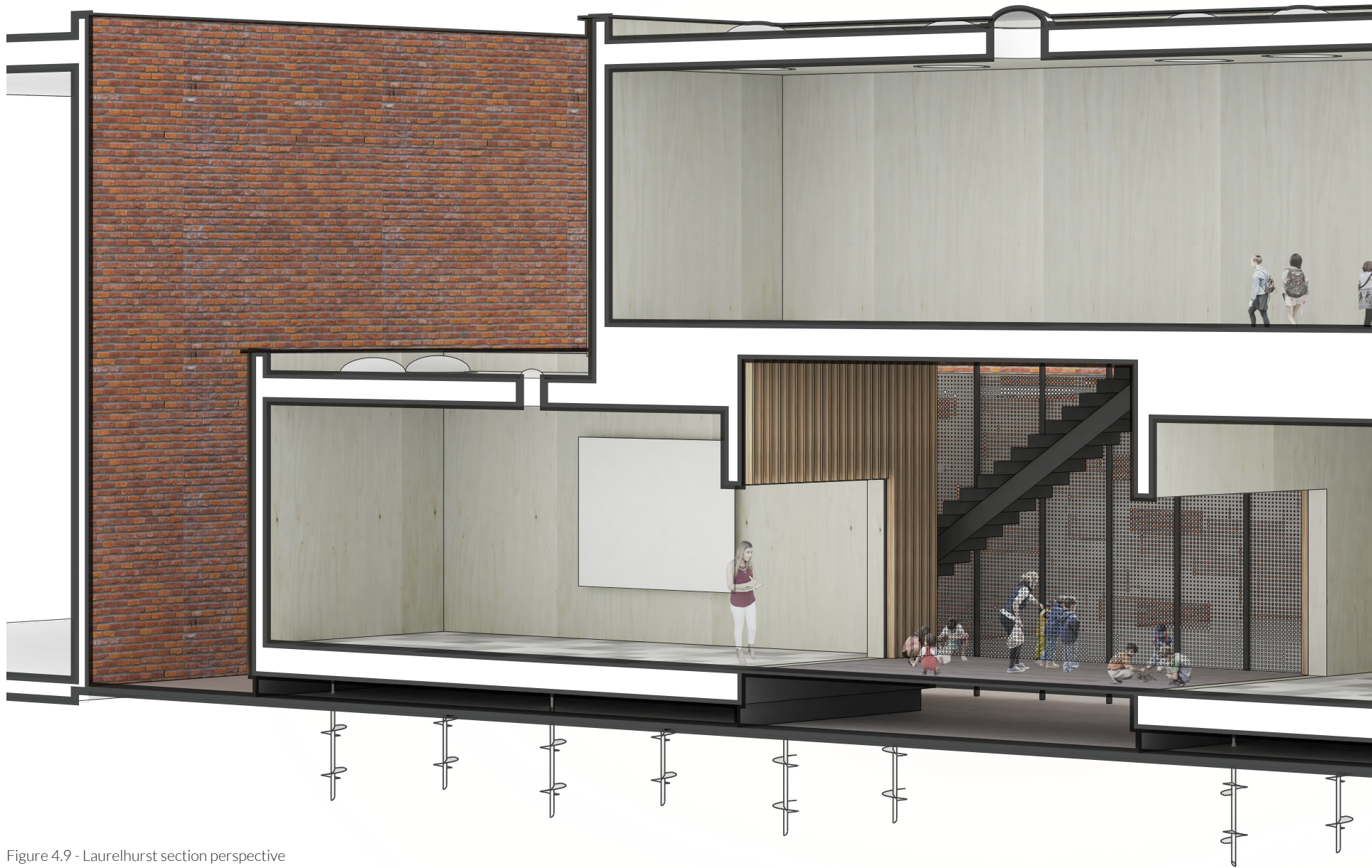


Figure 4.9 - Laurelhurst section perspective

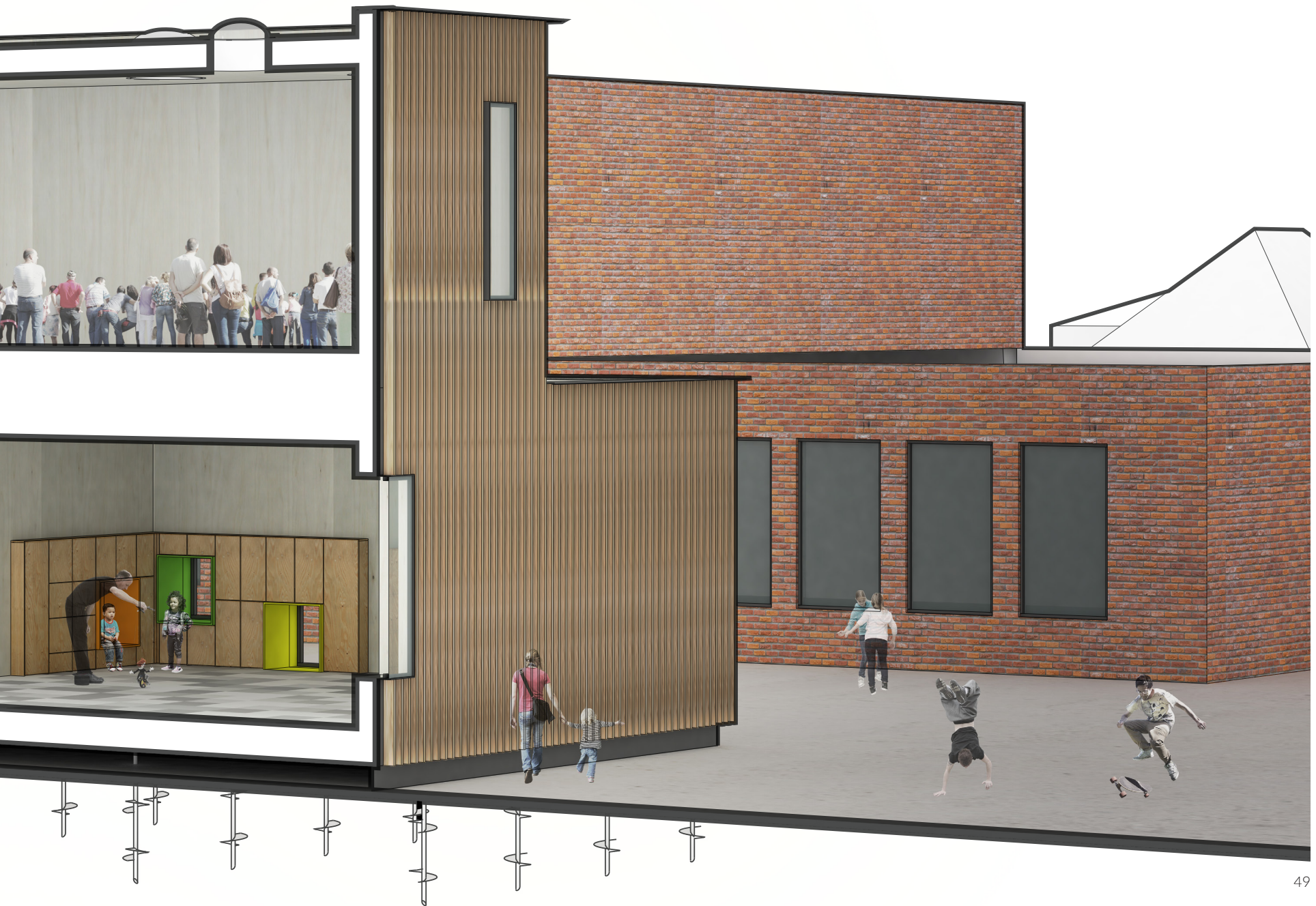




Figure 4.10 - typical interior classroom





Figure 4.11 - southeast approach to lower school ground level classrooms

## KIMBALL ELEMENTARY (EXISTING CONDITION)

Kimball Elementary has been operating in the South end of the Beacon Hill neighborhood in Seattle. The school has been operational since the 1920's, but the current configuration of permanent structure and modular classrooms has been around since the early 1970's. (Seattle 2016)

The steep topography of the site has created an upper and lower school. The upper school has the permanent school which houses classrooms, gym, library, etc. There is 14' of grade change between the upper and lower school. This, in conjunction with a heavily wooded hill, almost completely visually separates the two schools. Figure 4.12.

The lower school is comprised of 8 modular classrooms. 4 of those modules are individual classrooms, 2 are music classrooms and 2 are computer labs. The entire school uses the music classrooms, and

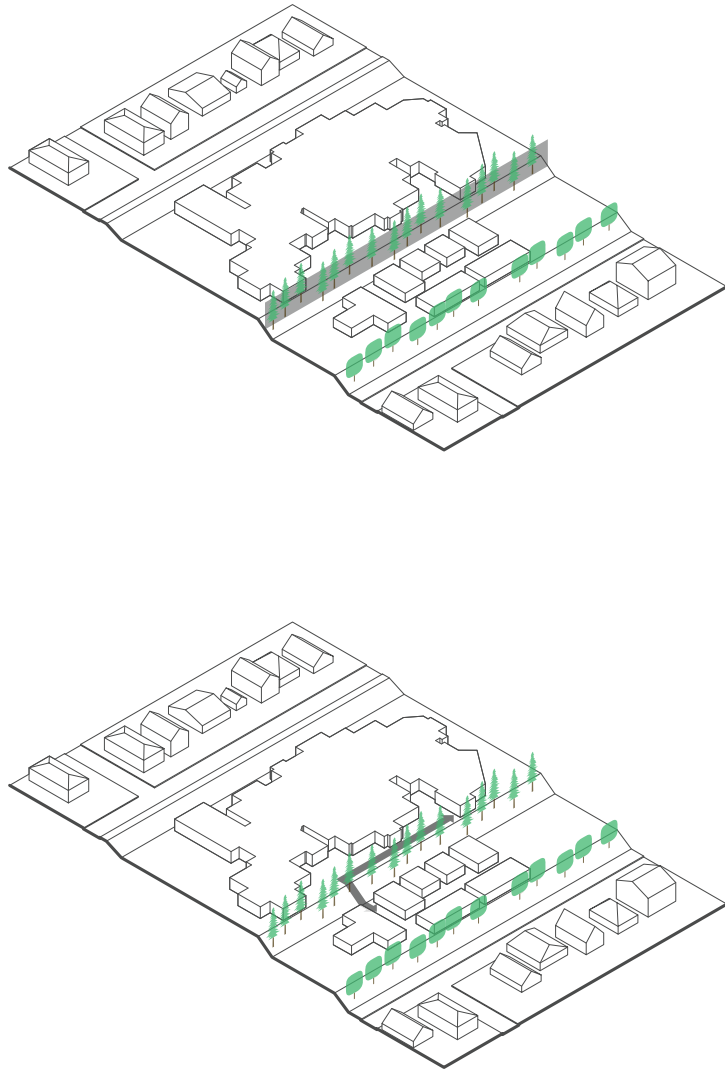


Figure 4.12 - existing visual connection (upper diagram) & circulation (lower diagram)

computer labs. Most of the students exit out of the back of the main school and around the modular classrooms then down a flight of stairs to get to the music classrooms and computer lab (Figure 4.12). This results in a disconnected form of circulation from the main school to the modules.

### KIMBALL ELEMENTARY (NEW CONDITION)

The first site response was to visually connect the upper and lower schools while making an effort to maintain a sense of seclusion the modules had because of the heavily wooded site. The visual connection was accomplished by stacking the modules on top of each other creating two levels of classrooms. The second level modular classrooms are rotated so a elevated walkway can telescope to the back door entry to the upper school. This approach provides a better visual connection to the school and clarifies the circulation paths (Figure 4.13). Rotating the second level modular classrooms also provides a framed view of Mt Rainer to the Southeast.

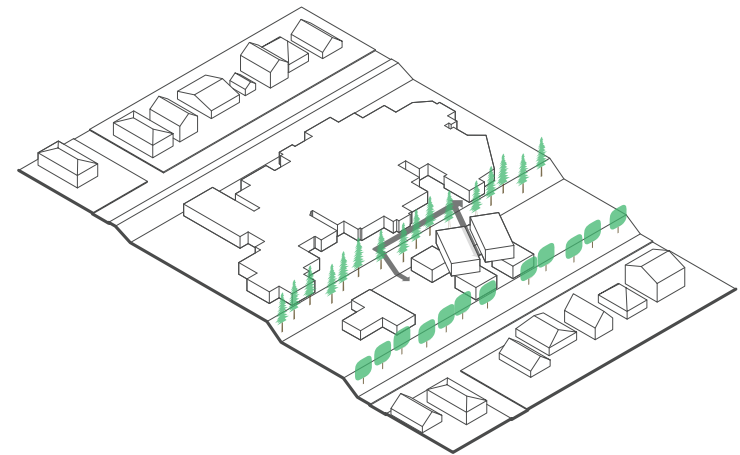
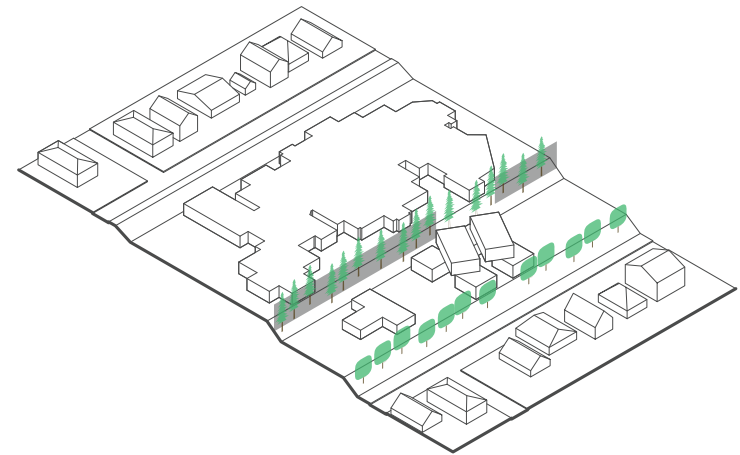


Figure 4.13 - new visual connection (upper diagram) & circulation (lower diagram)

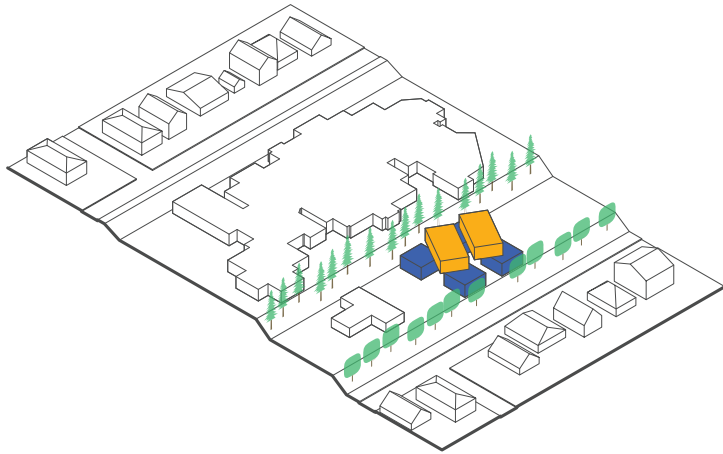


Figure 4.14 - new programmatic connection (orange = music/computer, blue = classroom)

Programmatically, the modules were arranged to improve connectivity between the upper and lower schools as well. The individual classrooms were placed on the ground level while the classrooms the entire school will utilize (music, computer) were placed on the second level. This allows for a more seamless transition into the music and computer classrooms while avoiding circulation around the individual classrooms and their shared co-teaching space (Figure 4.14).

The elevated walkway from the upper school to the lower school allows the student to pass through the tree canopy on a regular basis (Figure 4.15). This provides a unique spatial experience and an educational opportunity, such as discussing the different levels of seasonal forests.

The interior surface of the CLT is left exposed like on Laurelhurst Elementary, but the exterior facade is treated differently. Here vertical plank siding is used with a shou sugi ban treatment. Charring the wood improves its resistance to rot and insect damage which increases



Figure 4.15 - elevated walkway providing direct connection from upper school to lower school second level classrooms

its durability and longevity. The natural scaling that happens to the wood grain reflects an abstraction of the tree bark the new modular classrooms are surrounded by. Lastly, the dark color of the wood which results from burning it allows the modules to hide within the impressive trees they are in close proximity to.

The the ground floor plan (Figure 4.16) shows how all of the individual classrooms are connected by the elevated platform into one continuous shared exterior space. The spatial understanding of this space is further understood in Figure 4.18. The second level plan (Figure 4.17) shows the physical connection the elevated platform provides between the upper and lower schools.

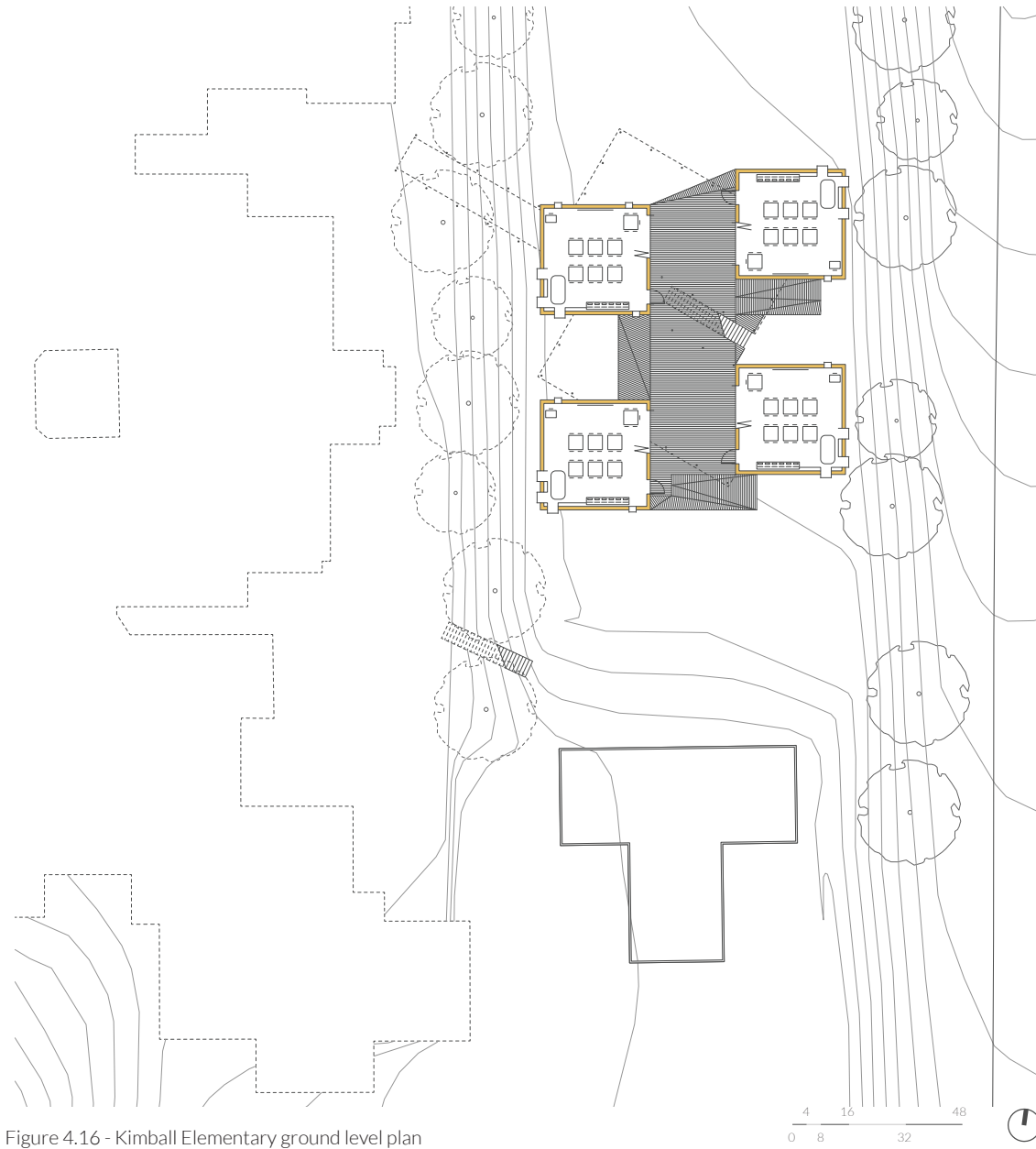


Figure 4.16 - Kimball Elementary ground level plan

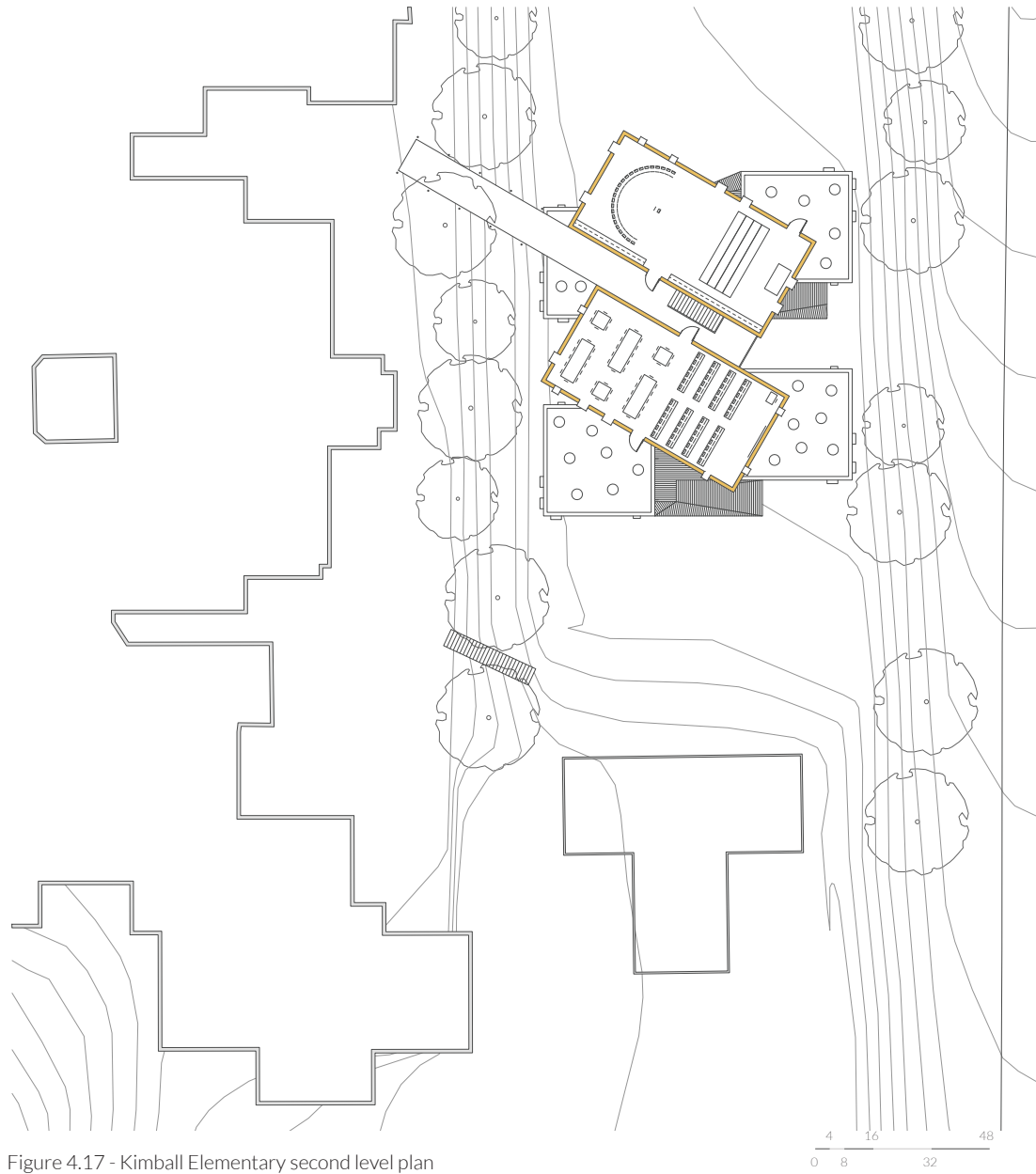


Figure 4.17 - Kimball Elementary second level plan

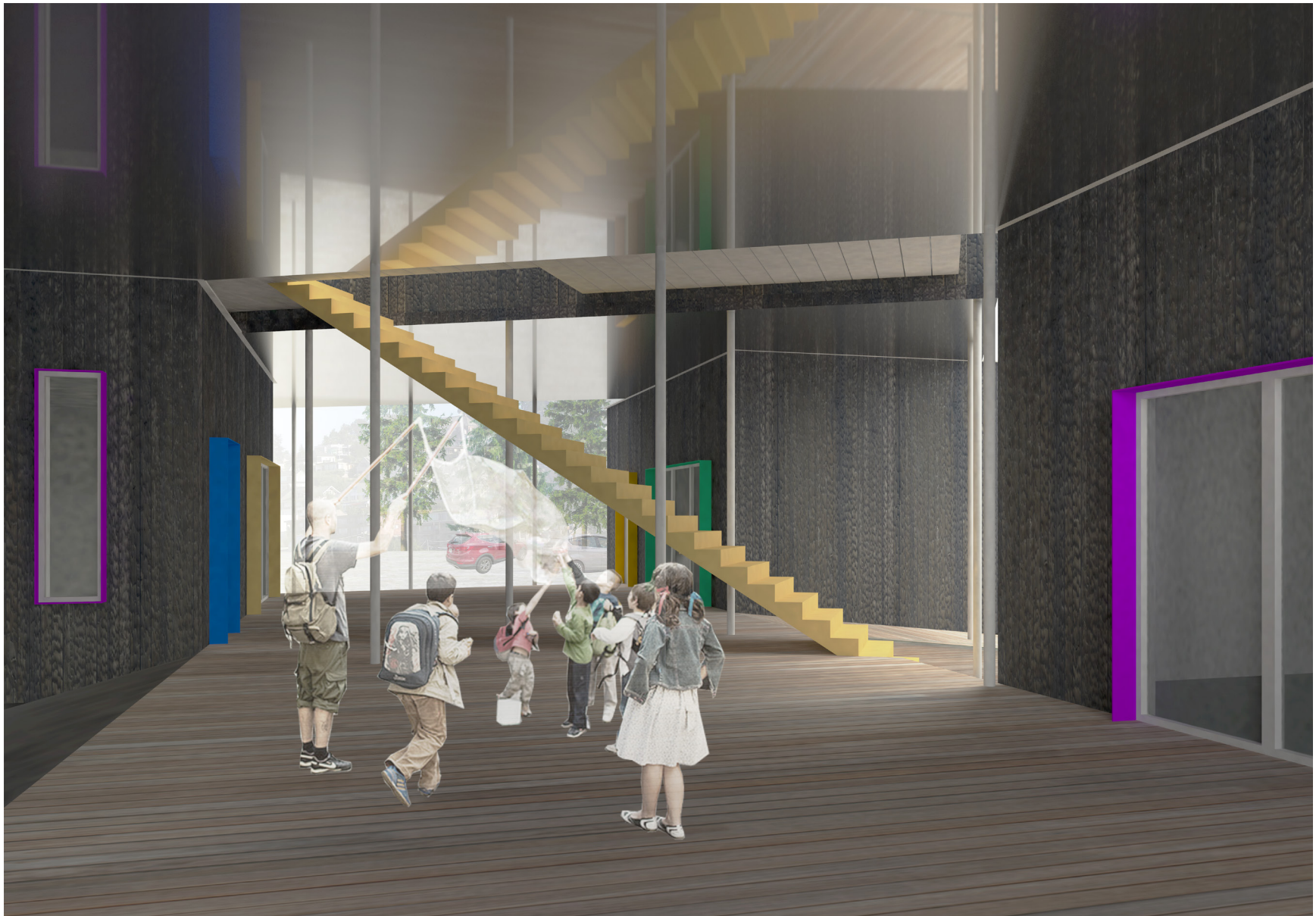


Figure 4.18 - exterior co-teaching/flex space

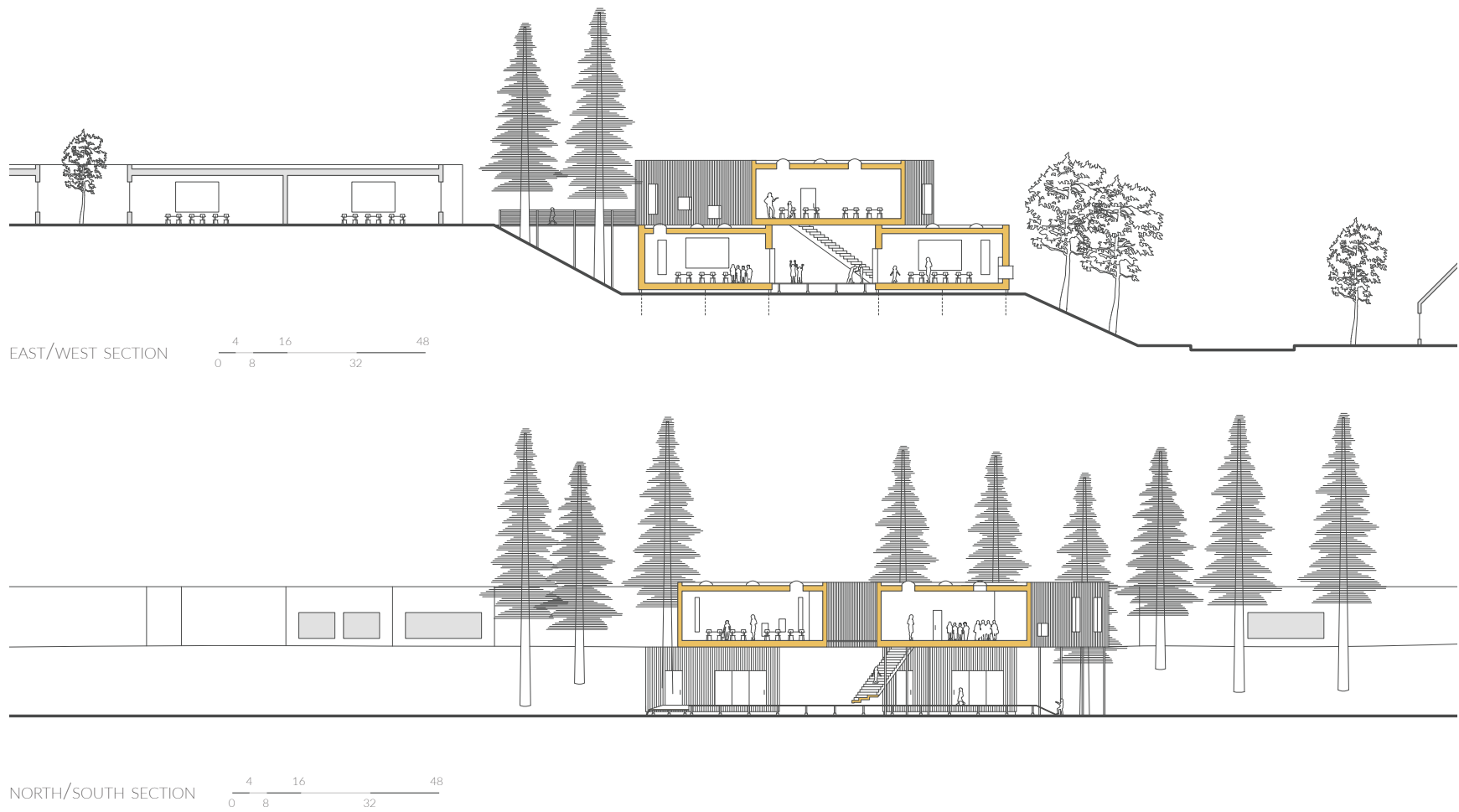


Figure 4.19 - Kimball Elementary site sections

## CHAPTER V - CONCLUSIONS

The new design, fabrication, and integration processes put forth in this thesis act as a visioning exercise for Seattle Public Schools, and the public, to comprehend the potential for modular classroom integration moving forward. The current proposal emphasizes design, fabrication, and integration process adjustments to modular classrooms as the most vital changes that need to be made.

The design case study sites of Laurelhurst Elementary and Kimball Elementary show the unique ability modular classrooms have at creating vibrant, collaborative, and connected learning environments through the use of the kit-of-parts modules established. An oscillation between individual and shared, interior and exterior, single and co-teaching spaces result from the thoughtful integration of the modules and site.

While “Education in Motion” focused specifically on a replacement framework for existing modular classrooms in the Seattle School District, moving forward the foundational stances established in this thesis can be applied to any new construction for schools. The pre-fabrication processes, coupled with digital tools and thoughtful site integration, provide schools the opportunity for quick, economical, durable, vibrant, and collaborative learning space. These opportunities need not be relegated to only replacing old modular classroom building stock. Permutations of the frameworks established in this thesis can be applied to disruptively innovate the future of educational space in the U.S.



Figure 5.1 - entry into second level classrooms, note framed view of Mt. Rainer

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