MOD-KIT:
modular solutions for a portable problem

Jesse Adam Belknap

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Rob Corser

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Acknowledgements

I would like to thank my thesis committee, the Robs Pena and Corser, for their support and dedication throughout the long slog of my thesis process.

I would also like to thank my wife, Anna, for her unconditional support and understanding.

I - Introduction

Fig. 1.1 - the current solution, or why we need a better option
image courtesy www.modulargenius.com

What is a “high-performance portable classroom”? Does it focus on environmental efficiency, basing its design on strategies that limit its use of energy and water? Or is the idea of human performance more important – that it gives students and teachers an exciting and inspirational place to learn while providing them with a sense of place, a space that its occupants can call home within the larger school? Or is feasibility the most important element, with the design focusing on creating a building that can be easily integrated into the budgets and construction systems currently in use by school districts around the country?

Yes.

The portable classroom is a necessity for school districts that need to respond quickly to unexpected increases in enrollment, but the standard design too often ignores the basic needs of the students and teachers who will be occupying it. The current standard for portable classroom design lacks access to good daylight and adequate ventilation, both of which have been shown to be critical to student performance. Portables are often too hot or too cold, and they waste energy through unnecessary heat loss and electric lighting. They often lack basic amenities, such as a sheltered entry, or storage for coats and boots. In addition, portable classrooms place a strain on shared resources such as bathrooms by adding student capacity without increasing the capacity of the supporting infrastructure. Finally, portable classrooms are seen as an eyesore, sitting forlorn in the unused portions of the schoolyard, detached from the larger school community. This can affect teachers who feel slighted by their assignment to a portable, and this will in turn affect the students in their class.

The goal of this thesis is to provide an affordable, realistic solution to the challenge of the portable classroom that is faced by school districts around the country. It will propose a multi-part solution that provides improvements in key areas such as daylighting, air quality, and community connection, while at the same time integrating smoothly with the existing portable classroom infrastructure.

II - Classroom Design: Background

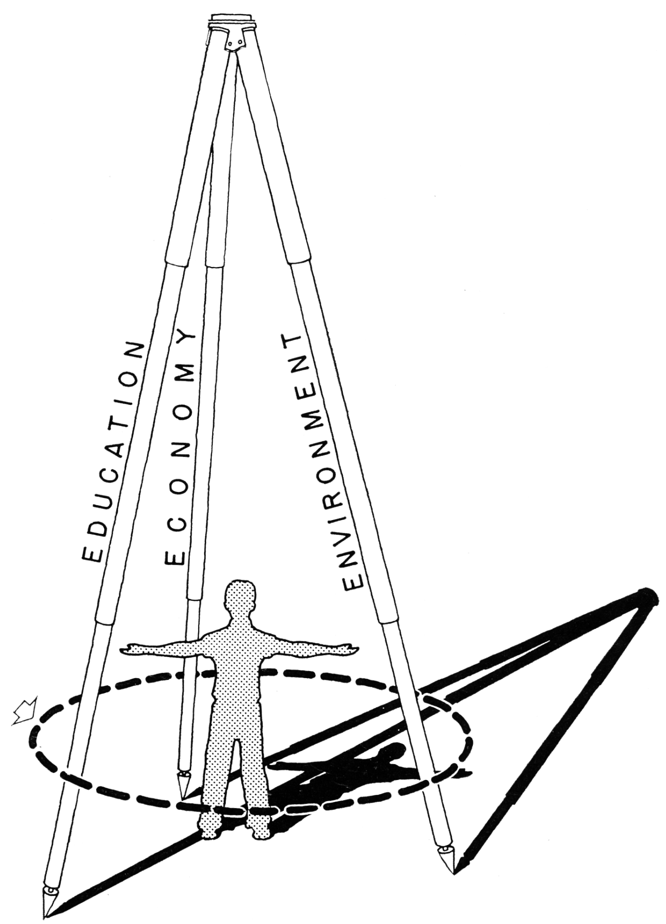


Fig. 2.1 - the balancing act of educational design
from William Caudill, *Toward Better School Design*, 20

In 1954, William Caudill separated the principles of school design into the headings of "Education, Environment, and Economy." For each, he described the how it affected the process of school planning, and represented the three as a tripod – the successful school being the one in which the three legs achieved a tri-lateral balance. "The first step in school planning," he wrote, "is usually to list the educational needs." Second is the leg of the classroom environment: "A listing of such factors as adequate lighting, sound conditioning, and proper ventilation and heating determined the length of this leg." Finally is the leg of economy, described, essentially, as the project budget. "Invariably," Caudill writes, "after programming is complete, school planners find that this third leg is much shorter than the other two…the planner can substitute a "happy balance" for "undesirable compromise", but only through a simultaneous consideration of all three factors – education, environment, and economy."

Written over half a century ago and relating to whole school projects, Caudill's tripod is remarkably applicable today. Taking the education leg to be the classroom and all that which supports learning, we can consider his "Environment" leg as part of the educational requirements – the classroom environment, after all, has been shown to be critical in the success of a student. This leaves the Environment leg available for sustainability. The leg of Economy, of course, is unchanged. This leaves us with a new tripod, with identical headings and slightly updated priorities. The need for a perfect balance, and the chances that the leg of Economy will come up short, remain the same.

Caudill described the importance of environmental factors to a successful education. His book describes in detail strategies for daylighting, natural ventilation, and acoustical controls. But less than a decade after its publication, air conditioning and fluorescent lighting came to control the design of schools, and windowless boxes pumped full of

Fig. 2.2 - better daylighting makes a better classroom
Capuano Early Childhood Center, Somerville, MA
image courtesy HMFH Architects

artificially cooled, recycled air became the standard (HMG 1999, p 4). This, incidentally, was the era in which the current models for portable classrooms were designed (Allen 2011). Only recently have school designers begun to understand exactly how important Caudill's imperatives were.

Current educational design thinking and research emphasizes many of the same ideas described in Caudill's book. We know that children's senses are sharper than those of an adult. Students, therefore, are more sensitive than adults to subtle differences in light, air quality, noise and temperature, and therefore more easily distracted by slight variations in their environment. These distractions are multiplied when a student is struggling to learn (Viscusi 2009, p 11). In a 1999 study, researchers found that natural daylight played a critical role in student success, with students in well-daylit classrooms progressing 20% faster in math and 26% faster in reading than their peers in classrooms without natural light (HMG 1999 p 2). The same study also found that being assigned to a room without daylight has the same effect on a student's performance as if they were to miss ten days of school. In a follow up study, the same group discovered that not only daylight but natural ventilation and views had a noticeable impact on student performance. Students in rooms with operable windows improved 7-8% better than students in closed rooms, regardless of whether or not the rooms in question had air conditioning (HMG 2003 p 3). This implies that it was the natural air and the connection to the outside, not the temperature control that it provided, that helped the students' performance. This connection to the outside world is important for teachers as well - as one teacher interviewed for the study put it, "When I've had it with the kids and I can't answer another question, I just take a minute, look out the window at the view, and I'm OK. I'm calm and ready to go back to the fray." (HMG 1999, p 28)

Current school designs also reflect the ways in which educational theory has

Fig. 2.3 - widened hallways allow for breakout space
Eastgate Elementary School, Bellevue, WA

changed in recent years. Good school spaces have evolved around new kinds of instruction, with buildings reflecting the teaching that goes on inside them. Just as a school built at the turn of the last century would reflect a lecture-centric teaching method, today's schools reflect an education system that is based on individualized learning. Schools are designed to support collaboration, cooperation, community, teamwork and transparency, all qualities that are now seen as critical to a child's education (Linn 2009, p 78). Some schools have begun opening hallways to allow for breakout sessions between classes, and many new school designs now arrange classrooms in clusters or pods to allow for collaboration between different classes within a grade level.

These recent changes in the theory of educational design have left portable classroom designs struggling to keep up - if they have even tried to keep up at all. Some changes are relatively straightforward - more light, more air. But others create more complicated dilemmas. How does a school foster a sense of cooperation, community and transparency when each class resides in its own individual building? How do teachers collaborate effectively across outdoor connections? It is the goal of this thesis to address and provide answers to these questions.

III - Case Studies: High Performance Classrooms

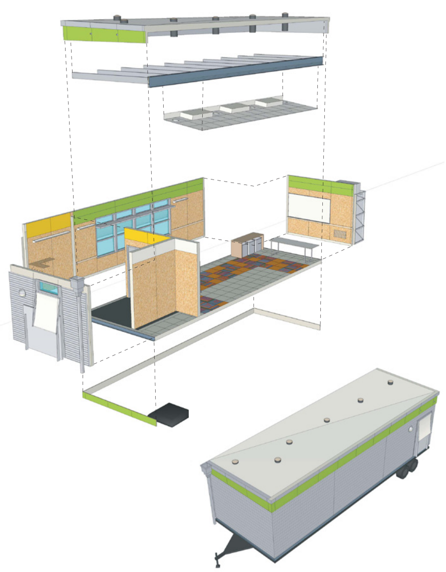


figure 3.1 - SmartSpace - exploded
image courtesy Architectural Resources Cambridge

figure 3.2 - SmartSpace - exterior
image courtesy Architectural Resources Cambridge

figure 3.3 - SmartSpace - plan, sections and elevations
drawings courtesy Architectural Resources Cambridge

Designed for Portability: SmartSpace Modular Classroom

Triumph Modular and NRB, Inc. with ARC/Architectural Resources Cambridge

In 2006, Montgomery County, Maryland teamed with the USGBC and the Council for Educational Facility Planners to sponsor the Portable Classroom Design Challenge, a competition requesting energy-efficient solutions to the portable classroom problem (Zajac 2007). The winning classroom was a design dubbed the “SmartSpace” –“an innovative and flexible 938 square foot, portable unit designed for sustainability, versatility, comfort and aesthetic appeal“ (Triumph 2006). A prototype was built and installed at the Carroll School, a private school for special needs students, in Lincoln, Massachusetts (Laird 2011).

The classroom departs from the a typical model even in its exterior aesthetic, its flat roof and corrugated metal siding giving it more of an industrial feel than the residential look common to many portables. The entrance incorporates a small vestibule for energy efficiency, and the classroom itself is full of daylight, with large windows on two walls and sun-tube style skylights near the center of the room. The SmartSpace also differs from other portables in its incorporation of multiple rooms – in addition to the vestibule and classroom, the unit also contains five small rooms that can be used as offices or spaces for independent learning (NRB 2006). The design team also worked closely with the manufacturer to ensure that the dimensions specified would result in as few cuts – and as little waste – as possible (Laird 2011). Finally, the SmartSpace classroom differs from the standard design in its integration of axles and trailer attachments into its framing, resulting in a more portable structure and quicker, cheaper installation (NRB 2011).

figure 3.4 - Billings MS - exterior
Jesse Belknap photograph

figure 3.5 - Billings MS - courtyard
Jesse Belknap photograph

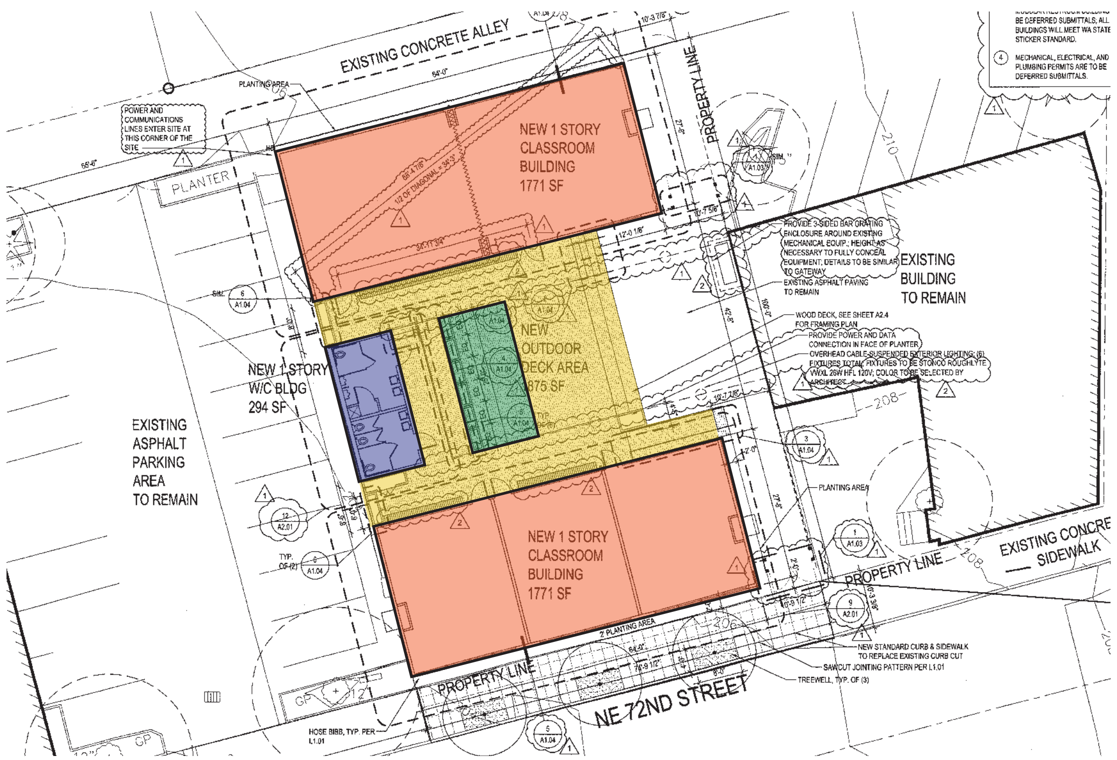


figure 3.6 - Billings MS site plan
drawing courtesy Brian Hanners/Billings Middle School

Creating Community: Billings Middle School East Village, Seattle, WA
Mithun

The Billings Middle School East Village project was a modular response to an immediate need for more classroom space by a private school which could not justify a standard portable solution to their tuition-paying student base. At the same time, however, a state of the art portable was beyond the financial means of the school. Billings worked with Mithun to develop a solution that met both the financial and spatial needs of the school and its students. The classrooms themselves are similar to the standard portable, but the changes that were made have a profound difference on the feel of the classrooms. The classrooms have far more glazing – and therefore much better daylight – than a typical portable and the panelized exterior cladding helps to move away from the "modular look" (Connolly 2011). Walking down 72nd street, the buildings still read as portables, but the glazing and exterior sunshades help to improve their visual appearance. Where Mithun's design especially excels, however, is between the classrooms, where a sunny deck surrounds a rain garden and creates a protected space where the school community can gather for movies, meetings, and school events (Connolly 2011). While it may not have the impressive energy performance numbers or super-sexy design features of higher-priced examples, the Billings East Village is an example of high-performance classrooms where teachers are happy to teach and students are happy to learn.

figure 3.7 - Bertschi Living Science Building - exterior
image courtesy Living Future 2011

figure 3.8 - Bertschi Living Science Building - water diagram
image courtesy Living Future 2011

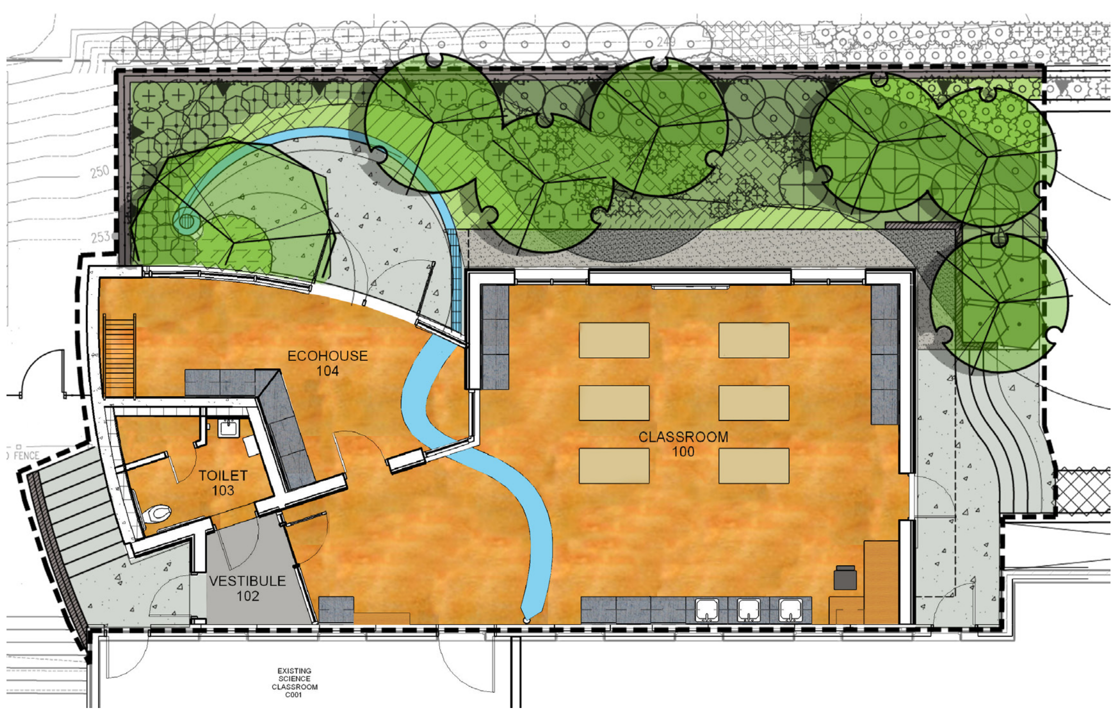


figure 3.9 - Bertschi Living Science Building - plan
drawing courtesy Chris Hellstern/KMD Architects

The Green Standard - The Bertschi School Living Science Classroom, Seattle, WA
KMD Architects with GGLO and Rushing Company

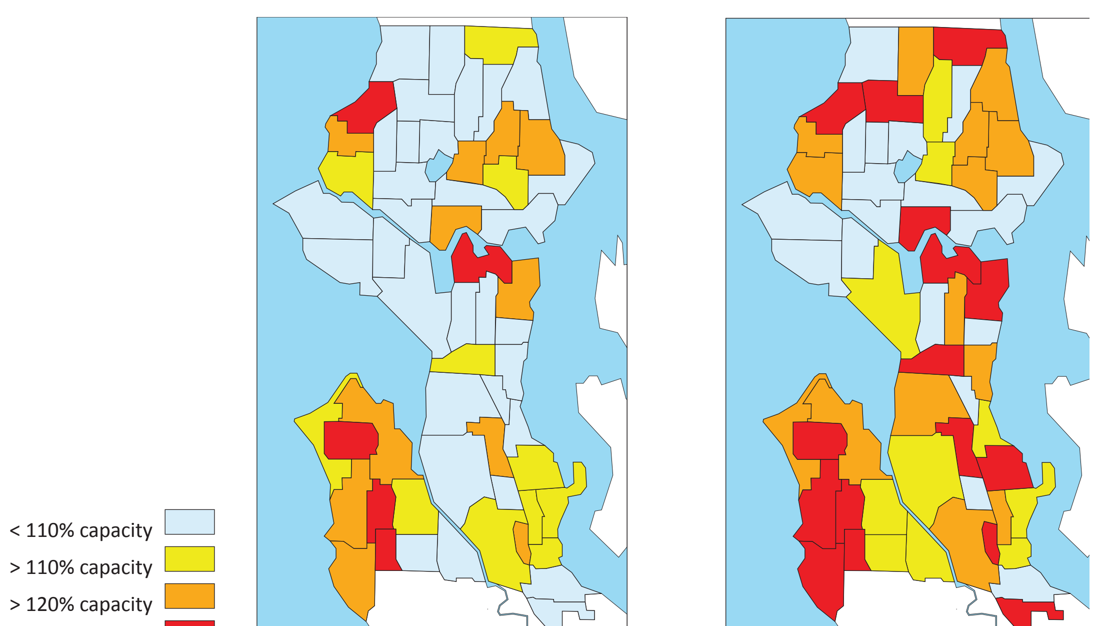
The Bertschi Living Science Classroom is not a portable classroom, but its unique sustainable qualities make it an important building to study as a part of this thesis. As of this writing, it is on track to become the first urban building certified under the Living Building Challenge. Additionally, its function as an add-on classroom to an existing school make it particularly relevant to this project.

The Science Building encloses 2200 square feet, about 1500 square feet of it within the classroom itself. In addition to the classroom, the project includes an entry vestibule, an “ecohouse” with an interior green wall for treating gray water, and a bathroom with a composting toilet. In accordance with the Living Building Challenge, the building is net-zero in both energy and water use, and the materials were meticulously selected to avoid materials included in the Living Building Challenge red list (Hellstern 2011).

Many potentially useful design elements can be found in this project. The green wall and composting toilets offer waste water solutions that could be indispensable in a portable that is unable to connect to city sewers. The building also does an excellent job of projecting its environmental lessons into the learning environment – Bertschi has in fact designed a fifth-grade science curriculum that integrates the building into its lesson plans (Bertschi 2011)

Unfortunately, the science building is also a reminder that all of this does not come cheap. When the extensive site and landscaping costs are included, the building totaled over $1 million (Richardson 2011) – far beyond the means of a public school in a budget crunch.

IV - Site: The Seattle public Schools



school year 2011-12
elementary school capacity usage

school year 2015-16
elementary school capacity usage
(projected)

Fig. 4.1 - elementary school capacity use
data courtesy Seattle Public Schools

Siting and the Repeatable, Portable Structure

This thesis proposes a structure that is as siteless as a building can be. A portable classroom must be almost infinitely adaptable, ideally able to function on any site in any orientation as if it were designed specifically for that location. As such, this proposal is not designed for any specific site. However, an examination at the Seattle Public Schools, as well as a look at one specific elementary site, is important in terms of setting the stage and showing the need for such a proposal.

The Seattle Public Schools

The Seattle Public School District encompasses the entire city of Seattle and is the largest K-12 school system in Washington State, serving more than forty-seven thousand students. It includes ninety-one schools, including fifty-four elementary schools, ten K-8 schools, nine middle schools, twelve high schools and six alternative schools. The Seattle Public School District employs over three thousand teachers (www.seattleschools.org).

The Capacity Crisis in Seattle

The Seattle Public Schools are currently facing a capacity crisis. In the summer of 2011, the district faced over $40 million in budget cuts (Enfeld 2011), and demographic projections showed forty of the fifty-four elementary schools operating above capacity by the 2015-16 school year, the earliest possible date at which construction of a new school might begin. Five schools are already operating at 40% over capacity, with that number expected to increase to sixteen by 2015 (Seattle Public Schools 2011).

With the capacity issue reaching crisis proportions and no permanent construction options available for at least four years, the district is exploring options to house the over-

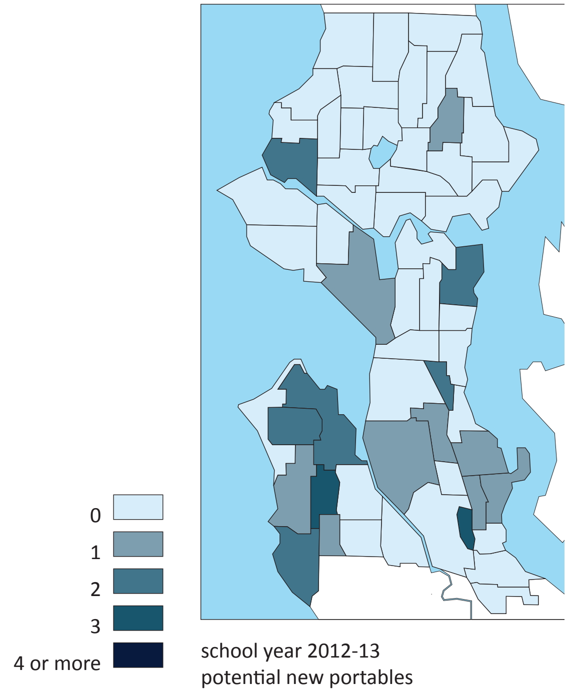


Fig. 4.2 - potential new elementary school portables, 2012-2013
data courtesy Seattle Public Schools Capacity Planning

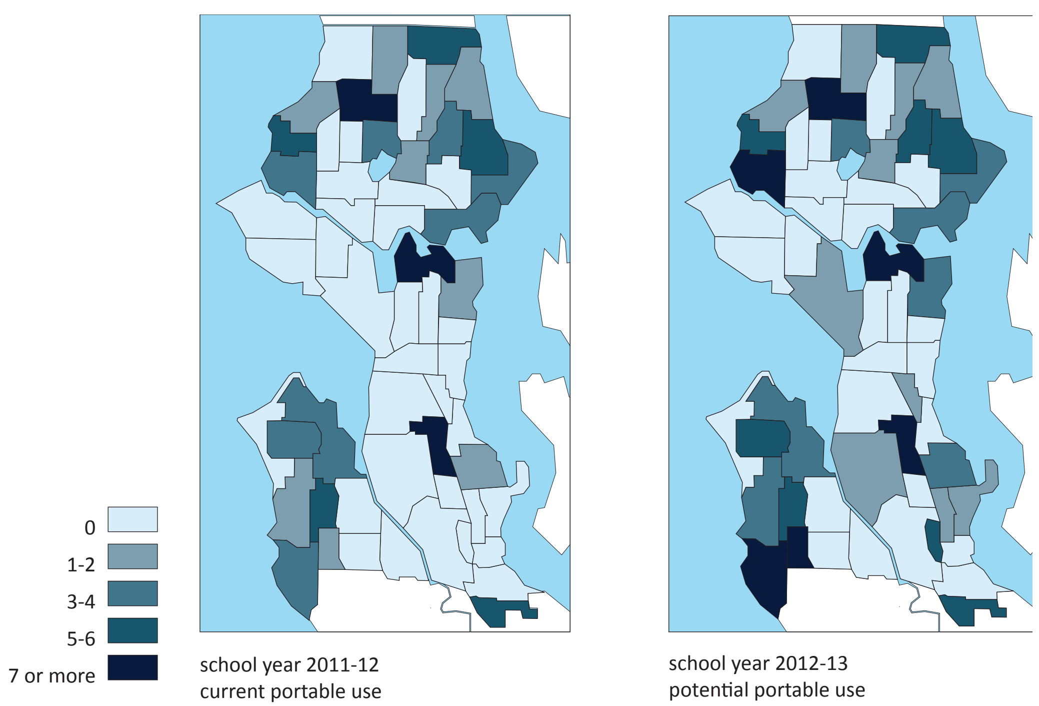


Fig. 4.3 - elementary school portable distribution
data courtesy google earth/Seattle Public Schools

flow, including the addition of as many as 27 new portable classrooms for the next school year alone (Seattle Public Schools 2011). Most, if not all, of these classrooms will be built according to an inadequate standard design. While these classrooms are not intended to be a permanent solution, many classrooms in the city have been at their sites for over twenty years, and it seems as if they are unlikely to go anywhere soon.

Given this current state of affairs, the time is right for a portable solution that can provide students and teachers with a learning environment that is as good or better than the classrooms in the main school building. If the same thought, care and energy that goes into the design of brick and mortar schools is put into a portable solution, that portable will do more than simply providing an temporary space while the districts explore long-term options for capacity management. It will BE that long-term option.

Wedgwood Elementary School

In the initial stages of this thesis, my goal was to create an actual built prototype that would be installed and occupied on the site of one of Seattle's Elementary Schools. For a variety of reasons, Wedgwood Elementary was chosen as this site. While it became clear part way through the thesis project that this was not going to happen before the completion of the thesis, the administration at Wedgwood continued to work with me and provided me with valuable information that has informed the project even in its current, theoretical form. Because of this connection with the project, Wedgwood Elementary was used as a case study site to explore the possible constraints and opportunities that a real site would bring to the project.

The main school building that now houses Wedgwood Elementary School was opened in 1955, but students had been learning on the site at what is now NE 85th Street

figure 4.4 - Wedgwood Elementary School location in Seattle

figure 4.5 - Wedgwood Elementary School, entry
Jesse Belknap photograph

figure 4.6 - schoolyard panorama showing three portable classrooms
Jesse Belknap photograph

and 27th Avenue NE for two years, housed in a collection of portable classrooms designed to alleviate overcrowding in the adjacent neighborhoods. When the new school building opened in June of 1955, just weeks before the end of the year, students were overjoyed to finally have a full-sized cafeteria, auditorium, and gymnasium (www.seattleschools.org).

In addition to the main building, the site currently houses students in three portable classrooms – one newer, between ten and fifteen years old; and two older, built sometime in the 1970s (Cronas 2011). These forty-year old classrooms are further evidence to the permanence of portables in the Seattle Schools. Indeed, the older classroom design seen at Wedgwood is prevalent throughout the city – many schools are still using classrooms that are from the same era as these.

Plans for new portables

Wedgwood Elementary, like many of the elementary schools in northeast Seattle, has seen significant growth in the size of its student body over the past few years. This growth is likely to continue, especially give the recent completion of a large apartment complex just a few blocks from the school. In order to allow for this new influx of students, the school will be expanding its footprint further this summer, adding two more portables in addition to the three that are already on the campus (Cronas 2011). While I was meeting with administrators from both Wedgwood and the district about the possibility of building a prototype on the Wedgwood campus, I was able to gain some insight into the potential locations for these new classrooms.

The first and most likely option is to use the two newer potables to form a cluster with the newest of the existing classrooms. When the total area of a group of portables is less than 4000 square feet, they are treated as a single building by the fire code, allowing

figure 4.7 - site plan showing potential new portable sites
background image courtesy google earth

setbacks to be ignored and the classrooms to be place as closely as the installers can get them (Donelson meeting). Clustering classrooms also has other advantages, including the possibility of installing a single new electrical panel to serve all three classrooms and eliminating the connection through the main school building's panel, which is increasingly overtaxed by the growing needs of the external classrooms (Barrett 2012). Clustering classrooms certainly has advantages, but this siting strategy calls into question the wisdom of using sidelight windows as the classrooms' primary daylighting strategy. It also begs the question of how these tightly-packed classrooms will relate to each other, and the answer seems to be "very little" - they will most likely have separate ramps, stairs, and entrances, quite possibly on different sides of the cluster.

The other potential sites are further from the main school, leading to additional problems. Site 3 puts the classrooms a full hundred yards from the main school, adding to the already complicated logistics of moving a class from portable to main building and back again. These issues are further emphasized by the fact that these, like most portables in Seattle, will be dry and students will need to return to the main building for bathroom breaks. Finally, the Wedgwood principal, pointed out that with these classrooms so far from the main building, he would most likely assign older students to the portables, which would mean putting larger class sizes (and larger students) in an already cramped portable (Donelson meeting).

V - Case Studies: Standard Portable Classrooms

figure 5.1 - old Wedgwood portables
Jesse Belknap photograph

figure 5.2 - old Wedgwood portable interior
Jesse Belknap photograph

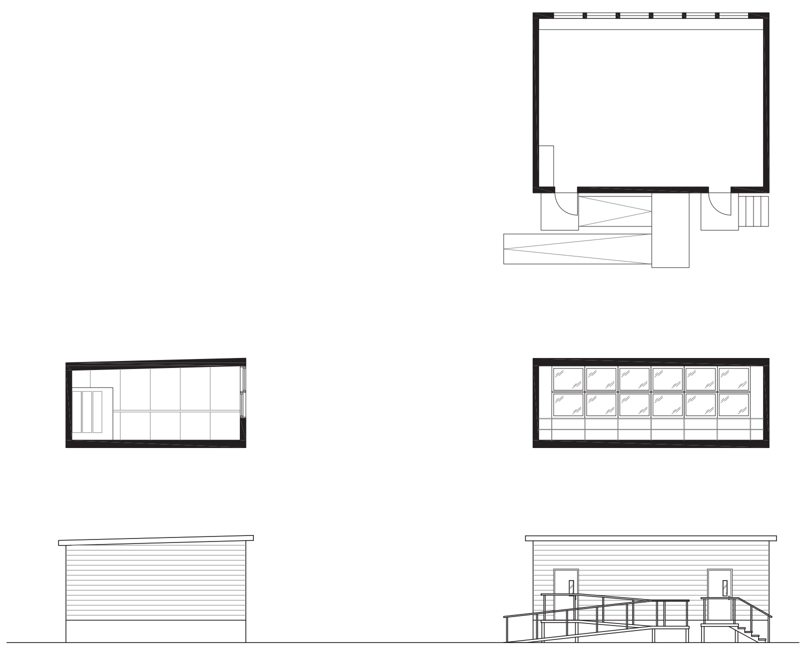


figure 5.3 - old Wedgwood portables plan, sections and elevations
Jesse Belknap drawings

1970s Portable Classrooms, Wedgwood Elementary School, Seattle, WA

Two of the portable classrooms currently located at Wedgwood Elementary have been there since the 1970s. These classrooms are similar to classrooms from the same era at schools around the city, and overall, they are not poorly designed. They have identical 24' x 32' rectangular plans, with large, north facing windows filling one long wall. Daylight is good at the north side, near the windows, and adequate on the south wall. The high ceilings - over nine feet at their highest point - add a sense of openness to an otherwise small space, and the large and numerous operable windows provide a connection to outside. The classrooms have hardwood floors, and the ceilings support glued-on acoustic tiles and surface mounted fluorescent fixtures.

Beyond the wear and tear of forty years of elementary school abuse, there are other drawbacks. The classrooms are far too small for a fifth grade music class of 30 students, although it was worse when one of the classrooms housed a group of 22 first graders in a previous year. The switch was made with a newer, larger classroom in order to limit the time that any one class spends in the old portable (Cronas 2011). The heat rarely works and the nearly flat roofs often leak. Security is also an issue, as portables are easier to break into that the main building, and computers have disappeared in the past. The school's solution has been to install a chicken-wire grate over the windows, which detracts from what would otherwise be lovely views of the schoolyard.

More than anything, these classrooms speak to the need for durability in a so called "temporary structure". They have been in place for over forty years, and most of their problems – the heat, the leaky roofs, and their shabby appearance – can be attributed to that age. The basic design, apart from being too small, is not bad.

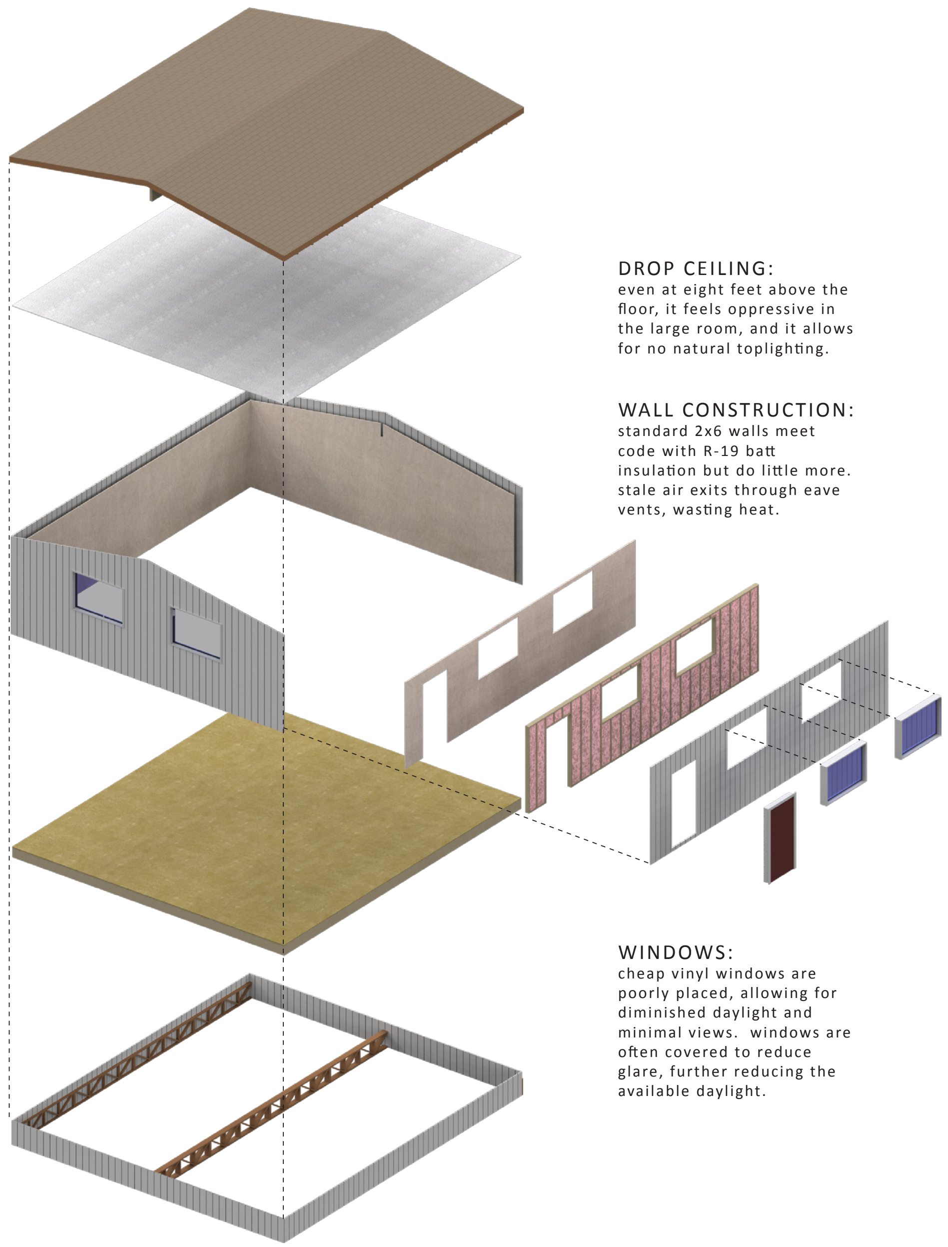


figure 5.4 - new Wedgwood Portable/KCDA standard exploded axonometric
Jesse Belknap diagram

figure 5.5 - KCDA standard portables at Thornton Creek Elementary
Jesse Belknap photograph

figure 5.7 - new(er) Wedgwood portable
Jesse Belknap photograph

figure 5.8 - new(er) Wedgwood portable interior
Jesse Belknap photograph

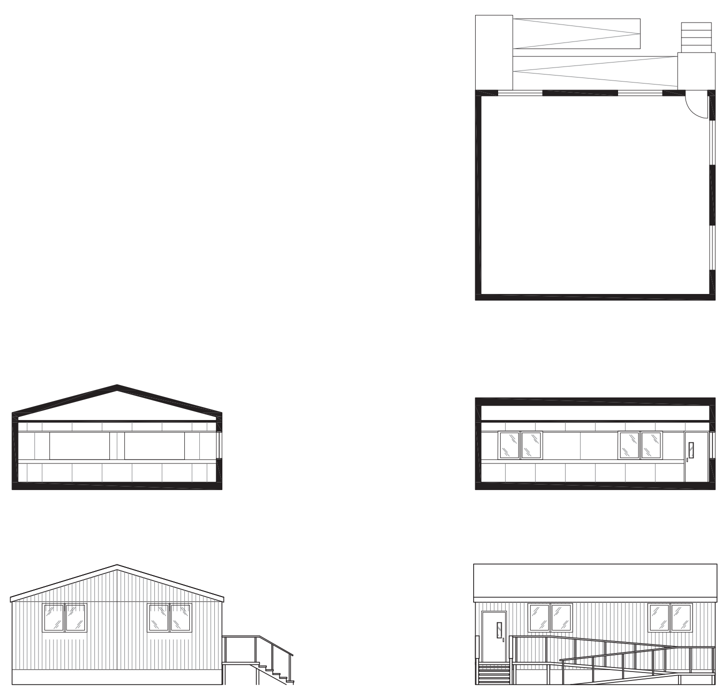


figure 5.9 - newer Wedgwood portable plan, sections and elevations
Jesse Belknap drawings

New(er) Portable Classroom, Wedgwood Elementary School, Seattle, WA

The third portable classroom on the Wedgwood campus is much newer than the other two, installed between ten and fifteen years ago. The new classrooms that will be added to the site in the near future will likely be identical to this one. It is a standard 28' x 32' two-piece modular with a 2 in 12 slope gabled roof. Inside, the eight foot drop ceiling feels much lower, perhaps because of the expanse that it covers. The one door is accessed by a ramp and staircase made of pressure-treated lumber. There are four windows; two each on the north and east walls, and daylight in the southwest corner is woefully inadequate. These windows actually represent an upgrade over the standard classroom specification, which calls for a single window (Nichols 2011). The windows are covered on the outside with an expanded metal mesh that appears to be factory installed. Its heavier gauge adds to the prison-bar effect seen on the older classrooms.

The principal spoke to me about this classroom without much emotion. "It's adequate," he said. The heating and cooling work, the roof keeps the rain out, and it is big enough for one of the school's smaller classes. It has held up well for the time that it has been in use, including a move across the yard when it was discovered that its original location conflicted with the fire code (Cronas 2011).

This classroom is based on a design that originated in the late 1980s and has only had minor design shifts for code compliance since then (Allen 2011). It does exactly what is expected of it. It provides shelter and warmth and allows a teacher to teach her class. It does so at a minimum of initial cost to the school. It is the standard – the status quo that this thesis intends to replace.

VI - The Portable Problem

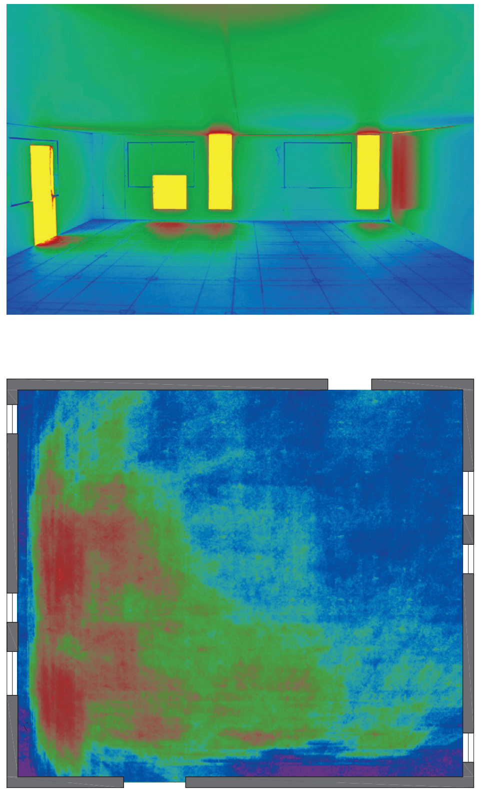


Fig. 6.1 - daylighting maps for KCDA standard classroom
Jesse Belknap diagram

Fig. 6.2 - a standard interior with “adequate” lighting
image courtesy Seattle Public Schools

The problems with the current standard in portable classroom design can be boiled down to a few key issues. There are problems with lighting and ventilation which stem largely from inadequate windows in the classroom. Additionally, portables place a strain on resources that are shared with brick and mortar classrooms, such as bathrooms. Finally, portables have a problem with their perception in the school community, due to these problems of environment as well as a pure aesthetic problem - portable classrooms are ugly. In order to improve the portable classroom, we must first examine what is wrong with it.

Windows

As mentioned previously, recent studies that looked at windows in classrooms have found that access to both natural light and views to the outside can have a profound effect on the quality of students’ learning (HMG 2003). The current standard classroom specification has neither. The Seattle Public Schools’ standard contract with the King County Director’s Association (KCDA) calls for portable classrooms to have a single four-foot square window with a sill height 2’-8” above floor level (Nichols 2011). This is not only woefully inadequate for providing natural light to the classroom, but it puts most of the window above the eye level of the classroom’s smaller potential occupants, depriving of them of views as well. Even when the numbers of windows are increased, as in the Wedgwood classroom, placements are such that daylight is unable to penetrate to all corners of the classroom. Even the Seattle School’s capacity planning presentation, attempting to convince the public that portables are a reasonable option, admits that the lighting is merely “adequate”, and shows an image of a windowless classroom lit by overhead fluorescent panels (Seattle Public Schools 2011).

The problem of glare further complicates the issue. Since portable classrooms are

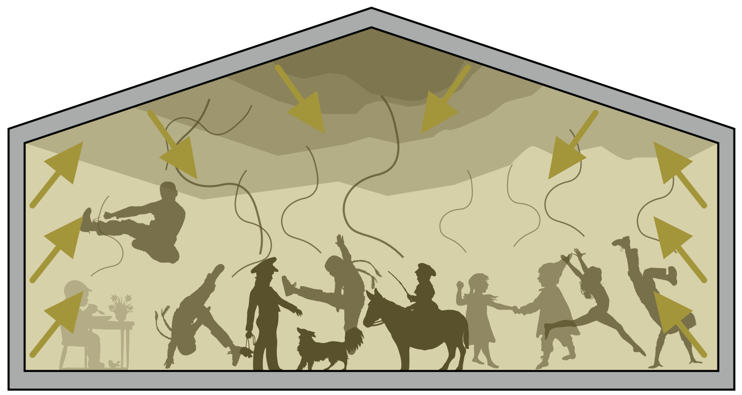


Fig. 6.3 - classrooms have many sources of “bad air”
Jesse Belknap image

Fig. 6.4 -
comparison of portable space to permanent space at Thornton Creek Elementary School
background image courtesy google earth

designed with without a specific site or orientation in mind, there is no way of knowing which direction the windows will be facing or where the sun will be coming from. Because of this, windows often end up pointing in exactly the wrong direction, and a lack of shading devices leads the teachers to pull blinds that eliminate both the glare and any possibility of natural light. With the blinds pulled on the east facing windows for the morning sun, the Wedgwood portable’s four windows effectively become two.

Ventilation is the second major issue with the current portable classroom design. In the newest models, ventilation, heating and cooling are all handled through an external wall mounted heat pump, which is often inadequate for the needs of a room full of students. A study of environmental health conditions in classrooms found that portable classrooms were far more likely to have problems with their HVAC systems than their permanent counterparts. The same study found that portables generally had higher levels of formaldehyde than their traditional counterparts, due in large part to the materials used in their construction (CARB 2004). These statistics suggest that it is critical that new portables be designed with better materials and easily maintained systems. The fact that the air quality in portables is often worse than that in traditional classrooms also suggests a need for better ventilation systems to be included as part of the standard.

Overtaxed Infrastructure

Portable classrooms also contribute to problems that affect the larger school community, not simply the students and teachers who are occupying the portable. By increasing a school’s capacity for students without increasing core capacities, portables put a strain on shared resources, such as bathrooms, cafeterias and gymnasiums. Since nearly all portable classrooms in Seattle are installed dry, the bathroom issue is of particular

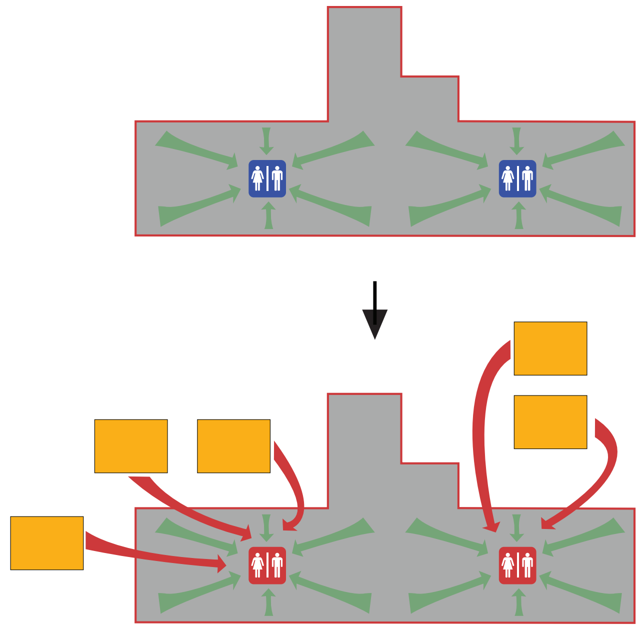


Fig. 6.5 - portables can overload bathroom infrastructure
Jesse Belknap diagram

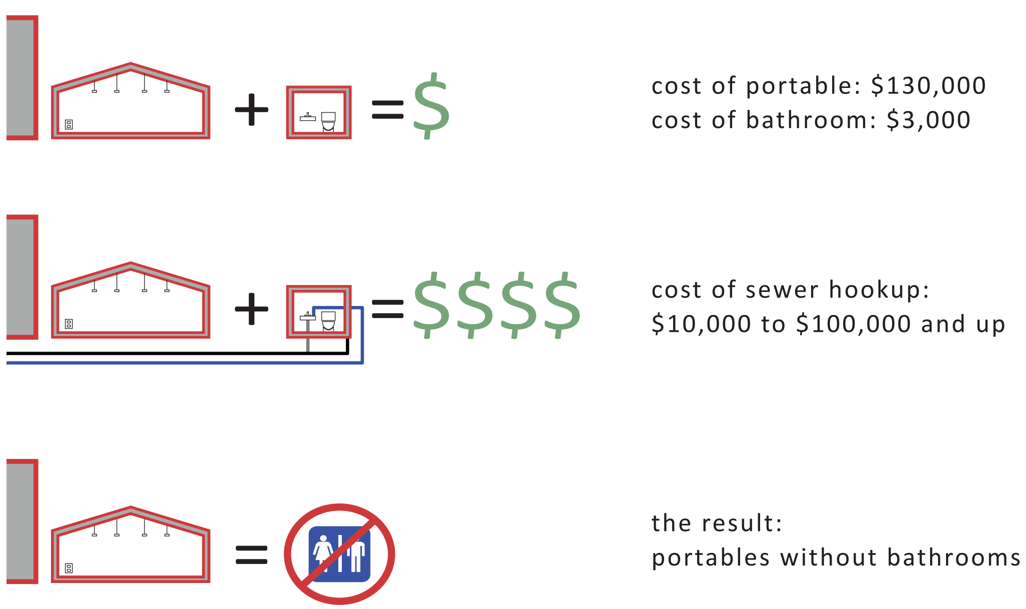


Fig. 6.6 - the reasoning behind the lack of bathrooms
data sources: Seattle Public Schools and Pacific Mobile
Jesse Belknap diagram

concern (SPS capacity management meeting 2011). This problem occurs when the capacity of a school that has been designed for a set number of students is suddenly expanded with portable classrooms. The bathroom capacity, which was designed for the number of classrooms in the original building, remains the same, however, and this results in bathrooms being required to serve far more students than they were originally intended for. This problem is particularly troublesome at smaller schools, where just a few portable classrooms can expand the classroom capacity by a large percentage. Parents from Thornton Creek Elementary in northeast Seattle complained that the hallways of their school often smell of urine from the overloaded bathrooms. Thornton Creek, which has the unlucky combination of being a small school on a very large site, has been expanded considerably through the use of portables, and parents had to fight to avoid having more placed there for the upcoming school year (SPS capacity management meeting 2011).

The reasoning behind portable classrooms being installed without plumbing, despite the myriad issues that it causes, is almost entirely financial, and the cost of the bathroom itself is not the driving factor. At around $3000, the cost of a bathroom would be a relatively minor add-on to the $135,000 cost of a new portable (Allen 2011). However, that cost is insignificant when compared to the cost of hooking up to city water and sewer lines, which can range from $10,000 to $100,000 and up, depending on the portable's proximity to existing infrastructure (Barrett 2012).

Fig. 6.7 - the old and the new
image courtesy www.speedofcreativity.com

The "Ugly" Problem

The final problem, and possibly the largest stumbling block to the acceptance of portables as a viable long-term solution, is that of public perception. A schoolyard full of portable classrooms is often viewed as an eyesore, a health hazard, and a sign of district incompetence (Gast 2006). Overcoming this problem of perception is critical to the success of this thesis.

While the problem of perception may have been formed because of years of sub-standard conditions in portable classrooms, it is perpetuated largely because of the simple fact that portable classrooms are physically ugly. The image in figure 6.7 shows an excellent example: In the background we see a time, quickly being pushed to the background, when the architecture of educational spaces mattered. In the foreground are the portables, overtaking the past with a future that cares only about getting roofs over as many desks as possible, as quickly as possible, for as little money as possible.

Research has found there is no significant difference in student achievement between portable and permanent classrooms, and while there are indeed health and safety concerns with classes in portables, the same concerns exist in many permanent structures as well (Chan 2009). In fact, there are aspects of portable classrooms that contribute positively to a child's school experience. One parent commented that her son particularly enjoyed the time he spent walking outside to get to his class in a portable classroom, and noted that discussions in those classes seemed livelier, perhaps due to the pick-me-up that students got from their brief trip in the outside world (Gast 2006).

Despite these surprising revelations about the positive side of portables, the negative perception remains. Chris Cronas, the principal at Wedgwood, told me, "No teacher wants to be stuck in a portable." Since students are amazingly good at picking up on

figure 6.8 - this should not be the future
Jesse Belknap photograph

their teacher's mood, a classroom that negatively impacts the teacher's perception of their work environment can only have a negative effect on a class full of students.

In many ways, the perceived problems with portable classrooms are in fact simply classroom problems that are more visible because of their existence within a structure that is perceived as "not supposed to be there." If the portable structures expressed more of the excitement for learning that is going on inside them, students and teachers would be happy to take the walk outside to get to them.

I believe that this long-standing negative perception can be changed. I believe that portables do not need to be an eyesore, that they can contribute rather than detract from the schoolyard landscape. I believe that portables should be thought of, and designed as, a long-term capacity management solution, with the same thought, care, and planning that goes into a permanent school. Most "temporary" portable classrooms end up being effectively permanent anyway. With a little help, the portable classroom can become an effective long-term tool that gives a school district flexibility throughout its lifespan, even allowing the district to save money by decreasing the need for "permanent", full-school construction solutions.

VII - The Design

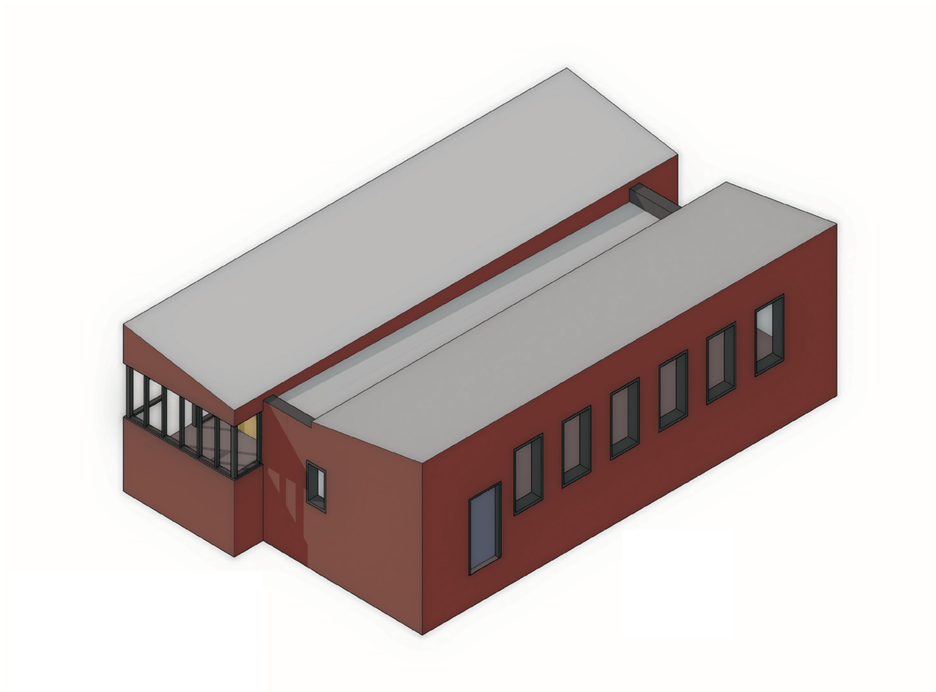


figure 7.1 - preliminary design I

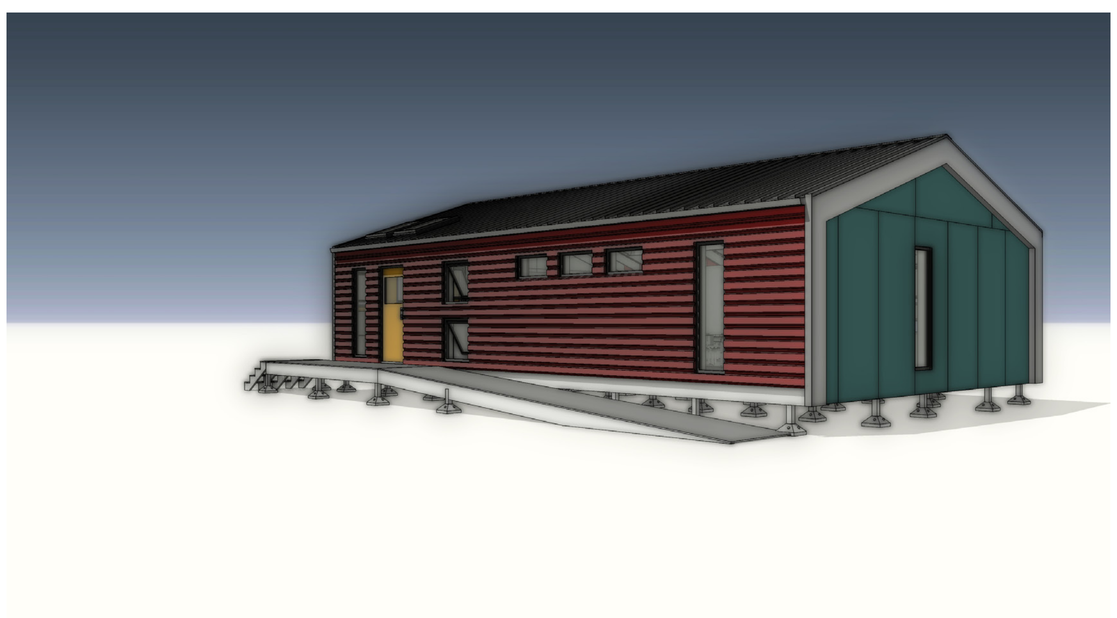


figure 7.2 - preliminary design II

The solution to the portable problem begins with a better box, a new and improved version of the portable classrooms. This is where I began my design explorations. My initial designs focused on a replacement for the KCDA standard, something that could be phased in gradually as the current portables needed replacement.

Early designs focused on reshaping the space within the classroom, adding glazing, and developing sustainable systems. The design process began as an extreme departure from the standard classroom, but gradually moved back towards the typical form and dimensions as cost, constructability and the limitations of the school district were considered. Early concepts were considerably larger than the standard portable, which raised some eyebrows within the school department (Donelson meeting).

Eventually my design strategy began to shift as I came to a critical realization about how this project could effect change within the Seattle schools. *Simply improving the box is not enough.* Designing a replacement classroom does nothing for the thousands of portable classrooms already in use around the country. The trends in Seattle are clear, as shown by the forty-year old classrooms at Wedgwood Elementary - once a portable is in use, it will continue to be used until it can no longer hold students. The lifespan of these classrooms is long, so even if every new portable, starting today, was built to new, better standards, it would still be decades before every old, inadequate space was replaced.

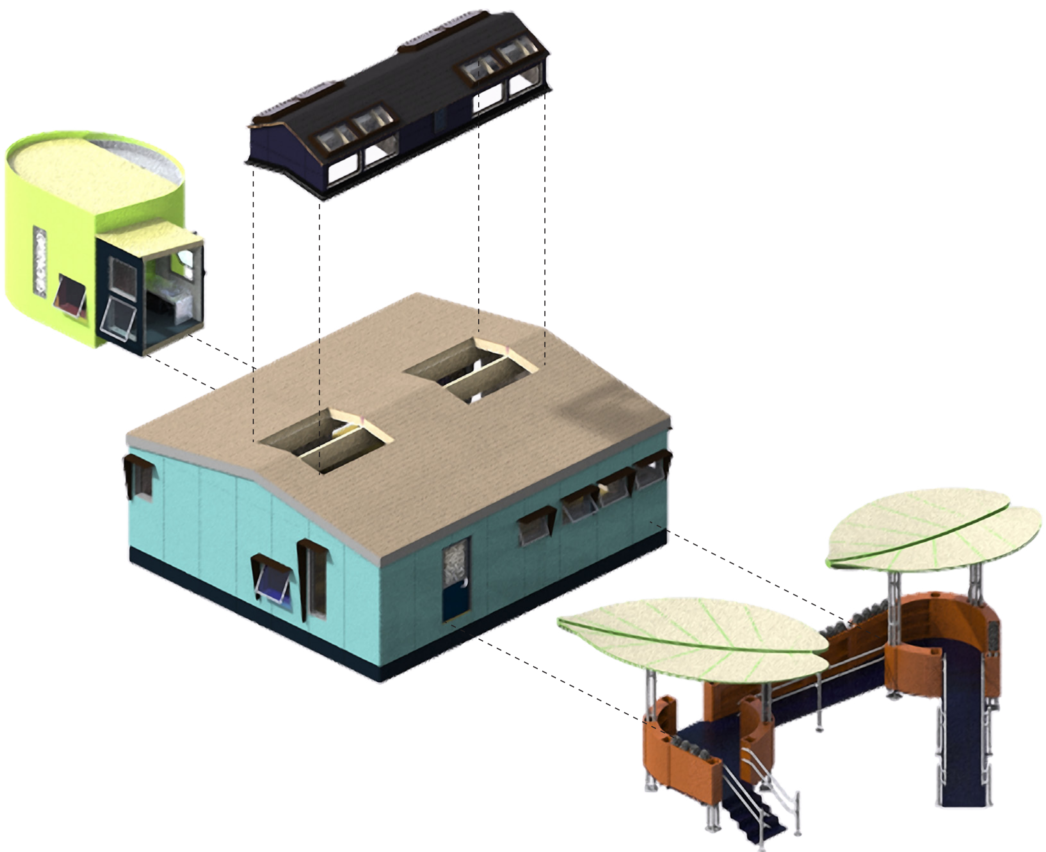


figure 7.3 - a four-part solution

figure 7.4 - the solution in context

In light of these facts, this project proposes three retrofit solutions in addition to a new portable standard, add-on modules that can be applied to either the new standard or the old KCDA design. The first is a rooftop system that provides controllable daylight and greatly improves ventilation and air quality within the classroom. The second intervention is a self-contained bathroom pod that can meet the "wet" needs of the classroom without requiring expensive hookups to city water and sewer lines.

Finally, the project proposes a new ramp system that helps to shape outdoor space while providing a sense of fun and excitement that is sorely lacking from the current classroom design. Through these modular solutions, this project aims to give school districts realistic, affordable options that can add long-term flexibility to capacity planning, rather than simply acting as a stop-gap between construction levies.

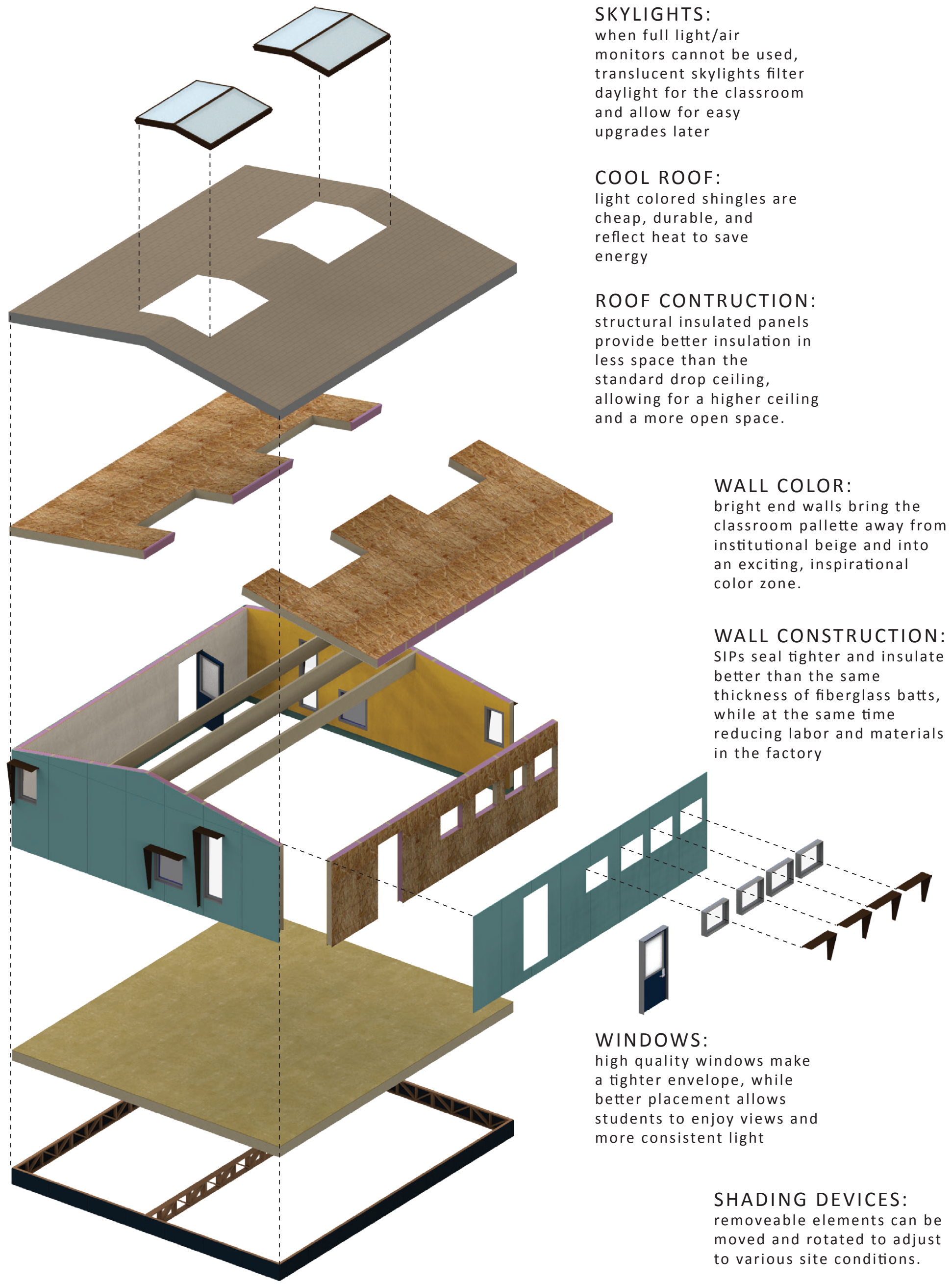


figure 7.5 - betterBOX exploded axonometric

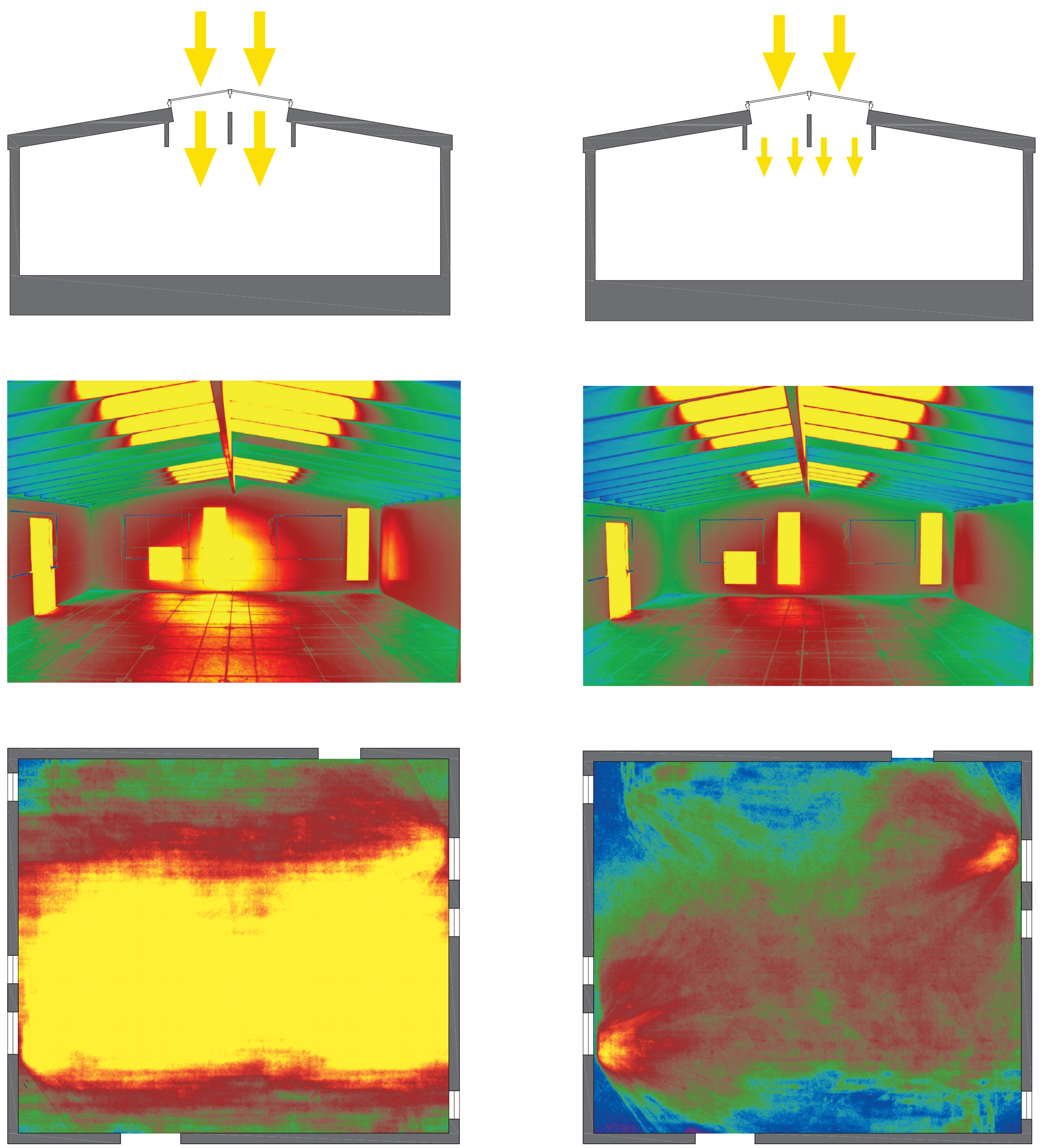
figure 7.6 - the stand-alone betterBOX

betterBOX: a better, tighter, brighter classroom

This design does begin with a new standard, a proposal for a new basic classroom design that can be used with or without the three intervention pieces, if a district's budget requires that limitation. Even in its stand-alone form, the betterBOX provides a greatly improved learning environment over the standard KCDA portable.

The first improvement is the least visible, but represents a complete shift in the construction techniques used in the production of the classroom. Instead of the 2x6 stick-framed walls used in the current standard, the walls of the betterBOX are constructed as structural insulated panels (SIPs). Because they are constructed with better insulation and less thermal bridging, SIPs have a higher rated R-value for a given wall thickness, in this case R-22 as opposed to R-19 in the stick-framed wall. This difference is more pronounced in real-world testing, which takes into account installation conditions, temperature extremes and thermal bridging. In these tests, the SIP wall held steady at R-22, while the effective R-value of the stick-framed 2x6 wall dropped as low as R-11 (www.sips.org).

SIPs provide other advantages over traditionally framed walls, including sealing the building tighter and allowing less air infiltration. In the case of the betterBOX, this allows more control over the airflow to the classroom. While the betterBOX on its own still uses a wall-hung heat pump system, the lower levels of infiltration allow the unit to be fitted with an energy recovery ventilator, greatly reducing the electricity needed to condition the space.



with open skylights

with translucent skylights

figure 7.7 - betterBOX
skylight lighting studies

figure 7.8 - interior view

SIPs are also used in the roof of the betterBOX. Using a ten-inch SIP for the roof provides an R-value of nearly forty in much less space than the R-30 blown-in cellulose found in the KCDA specification. The use of SIPs also allows the form of the roof to be expressed in the interior of the classroom, opening the space. In addition, the elimination of the drop ceiling allows skylights to be used as a daylighting strategy.

The addition of skylights is key to the other major advantage that the betterBOX has over the standard portable classroom design, which is the levels of daylight that can be achieved. Since the drop ceiling is eliminated and toplighting is an option, translucent skylights are installed to bring glare-free daylight into the space. Figure 7.7 shows the importance of the translucency in overcoming glare. Without it, the classroom is simply too bright, which studies have show is just as detrimental as not having enough light (HMG 1999 p 12).

Along with the addition of skylights, the design of the betterBOX seeks to improve the quality of its windows over its standard counterpart. The window placement is more thoughtful, oriented to the size of the students who will be occupying the space (figure 7.11). Windows are placed with a purpose - a row of windows provides a connection to the entry ramp, while another window washes the teaching wall with light. The purposeful placement of the windows in the betterBOX results in much better light within the

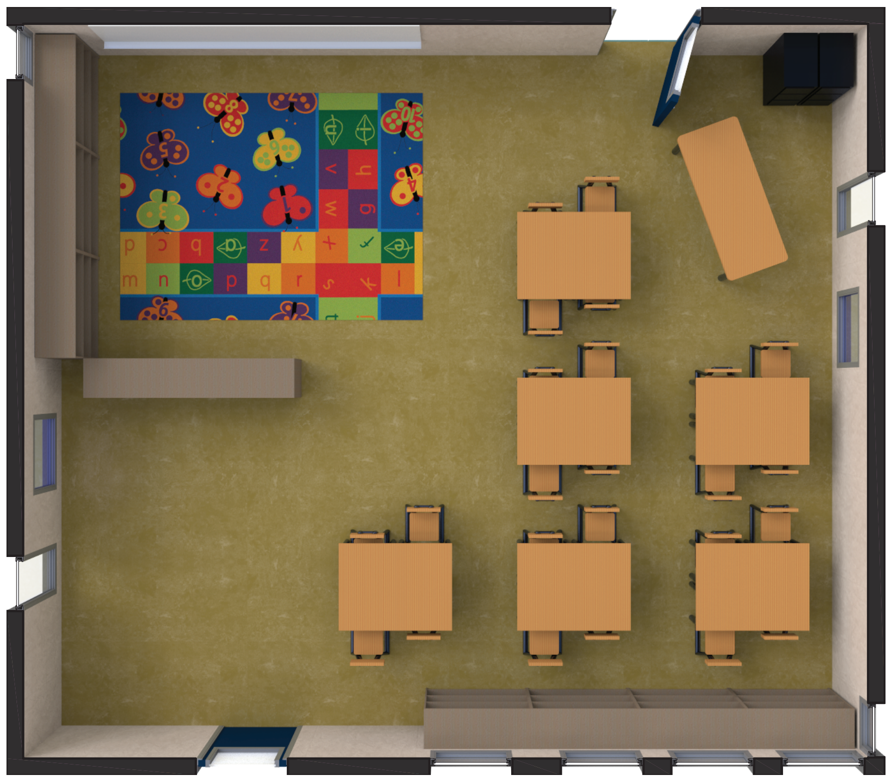


figure 7.9 - betterBOX plan perspective

figure 7.10 - betterBOX section perspective

figure 7.11 - betterBOX window section

classroom, despite the fact that the betterBOX actually has *less* glazed area than the four 4x6 foot windows in the Wedgwood classroom. This means that the new classroom has more light and better views than its predecessor, all without sacrificing any of its valuable wall space or reducing the insulation in its envelope. Finally, the betterBOX provides a simple shading solution that can be rotated, relocated, and flipped as necessary based on the site orientation of the classroom. These simple shading devices should eliminate the need for teachers to pull the blinds in order to block glare, resulting in better overall daylighting levels in the classroom.

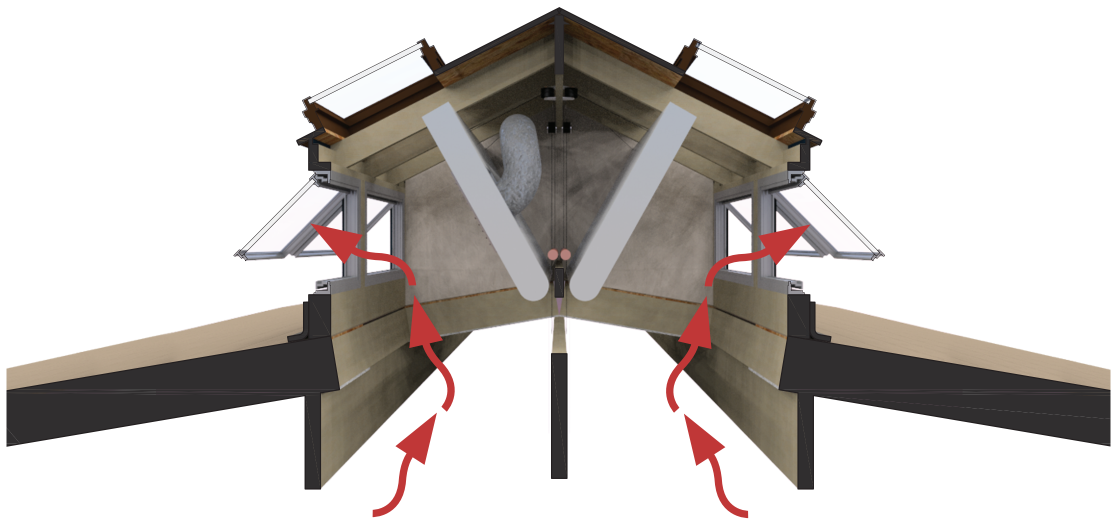


figure 7.12 - lightHATCH
natural ventilation strategy

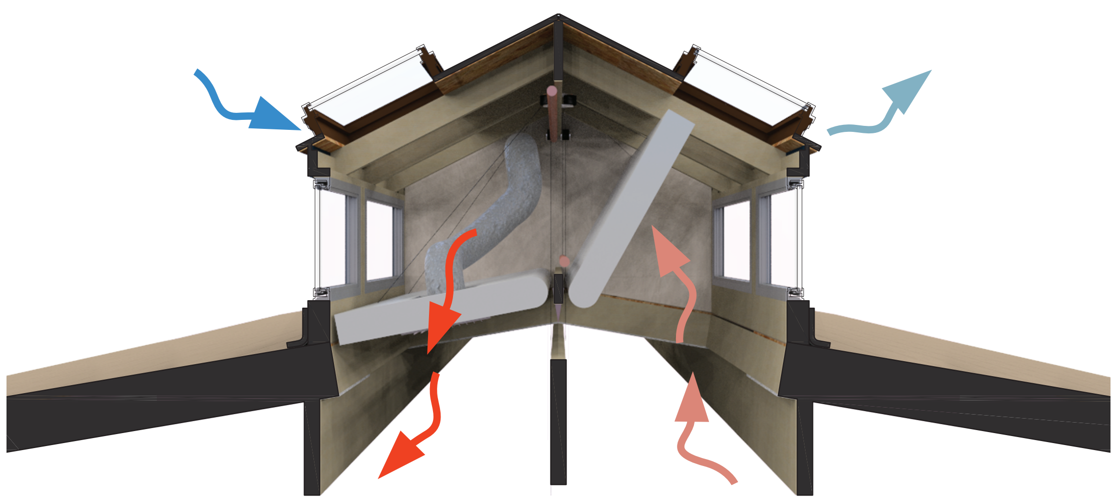


figure 7.13 - lightHATCH
mechanical ventilation strategy

figure 7.14 - betterBOX section with lightHATCH installed

lightHATCH: a breath of fresh air from above

The first add-on piece is the lightHATCH, a roof monitor that provides controllable daylight and greatly improved ventilation to the classroom. It replaces the wall-hung heat pump, saving the cost of the unit in the short term and providing long-term energy savings. The lightHATCH is twenty-four feet long and divided into three eight-foot sections - light monitors on either end and a mechanical space in the center. Each light monitor is made up of a combination of operable windows and fixed skylights, allowing for natural ventilation when the outside temperature allows. The flow of air is increased by a chimney effect that is created when the sun heats the dark, uninsulated roof of the unit, causing warm, stale air to be drawn up and out of the classroom.

The lightHATCH provides a full mechanical ventilation solution in addition to its natural ventilation capabilities. The central mechanical space houses an energy recovery ventilator that is capable of handling the fresh air requirements of even the largest class while recovering up to 70 percent of the heat energy from the air before it is exhausted (Mitsubishi). Combined with the increased insulation from the SIP walls and roof, this efficiency makes it likely that the betterBOX will need only minimal supplemental heating after the heat-producing effect of the students is factored in.

ROOF:
thermally improved aluminum skylights take advantage of seattle's high overcast skies, while dark shingles and minimal insulation warm air, creating a chimney effect.

FRAME:
standard wood framing is easily contructed and strong and light enough for transport

ERV:
energy recovery ventilatior provides fresh air with a minimum of heat loss when natural ventilation is not an option

SHELL:
operable windows provide natural ventilation when the outside temperature allows

CONTROL:
insulated shutters limit night-time heat loss and are manually operable by students via a cable and pulley system, allowing for daylight control during school hours.

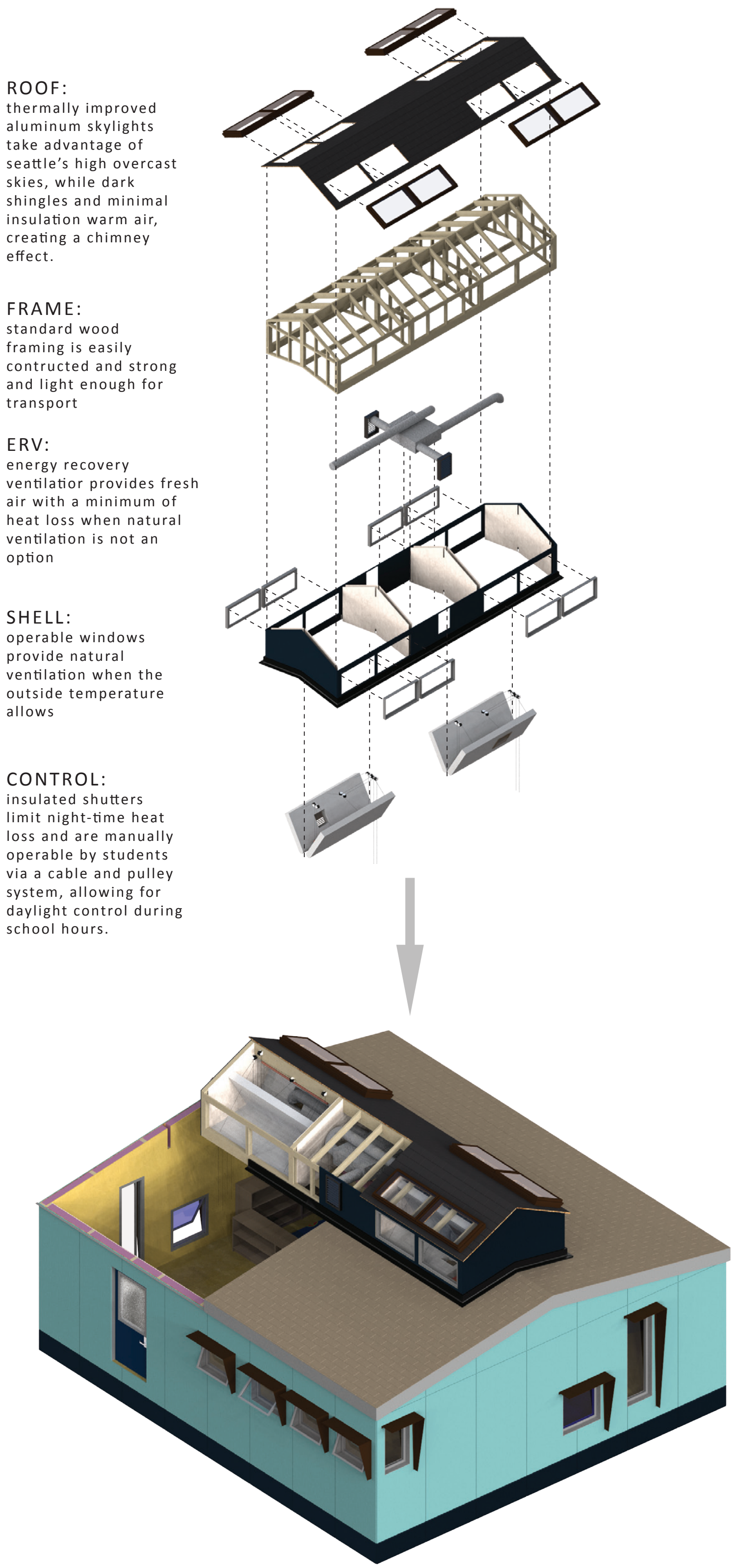
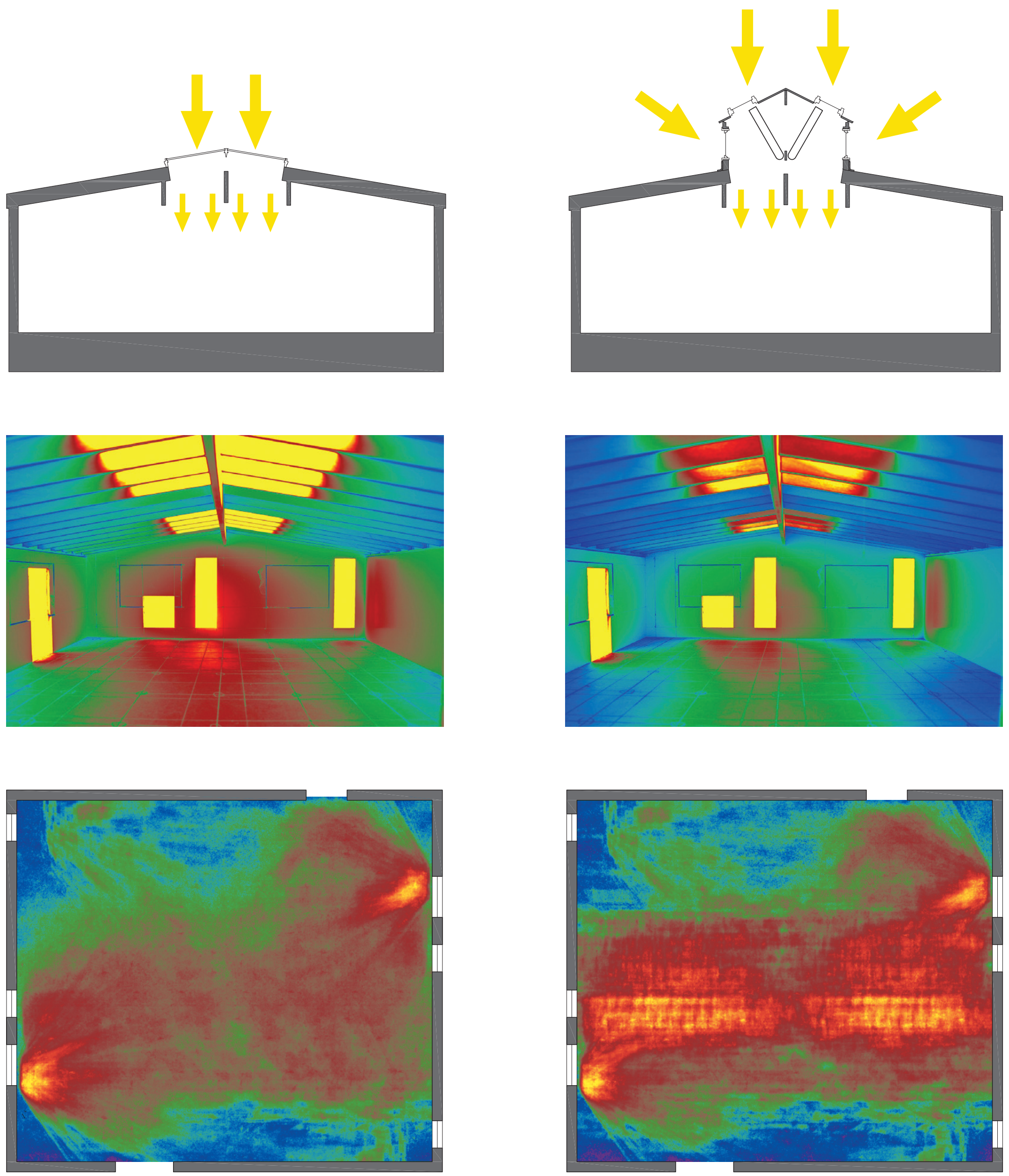


figure 7.15 - lightHATCH exploded axonometric

figure 7.16 - lightHATCH skylight view



with translucent skylights

with lightHATCH

figure 7.18 - lightHATCH skylight lighting studies

The lightHATCH also serves another important purpose, and that, of course, is to light the classroom. Due to the tight clusters that portable classrooms are often arranged in, using toplighting as a primary daylighting strategy is critical. In addition to the windows used in the natural ventilation configuration, each light monitor section of the lightHATCH contains skylights to allow a maximum amount of daylight to enter the room. Each monitor section is also equipped with two manually operated insulating shutters. These shutters, which are essentially a six-inch thick rigid foam panel with a light colored plastic laminate skin, are designed to be left in the open position for the majority of the classroom's operational hours. They can be closed at night to prevent heat from escaping through the large glazed areas of the lightHATCH, and a system of counterweights and pulleys makes this task easy enough that students can assist with the operation of their classroom, furthering their education. The shutters can also be used to control light in the classroom throughout the day, closing if darkness is required for a movie or quiet time.

The quality of light produced by the lightHATCH will be excellent for the learning environment. In a study that looked at daylight in classrooms, researchers found that even, diffused light - quality light - is more important than the quantity of light (HMG 1999, p 14). Looking at the results of lighting studies (figure 7.18), we see that the lightHATCH's system of multiple apertures and reflective shutters fills the classroom with more light that is just as evenly distributed as the light from the translucent skylights in the betterBOX alone.

figure 7.19 - peePOD plan

figure 7.20 - section

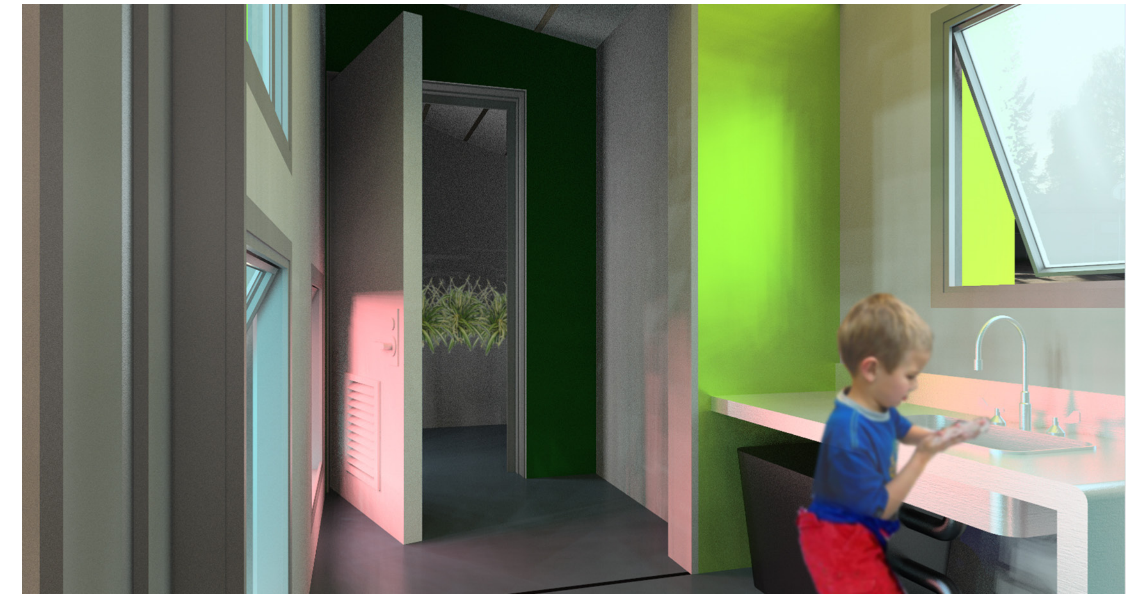


figure 7.21 - peePOD connector interior

peePOD: building a better bathroom

To address the issue of portable classrooms overloading the bathroom infrastructure, this project proposes the peePOD. This module is a completely self-contained, transportable bathroom unit that can be connected to the school's portable classroom infrastructure in various ways.

The peePOD treats all of its waste, both liquid and solid, within its walls. Toilet waste is treated in an Envirolet vacuum-flush toilet which does not need gravity in order to flush. This toilet system has been used successfully in the Bertschi School Living Science Classroom, showing its viability as a classroom solution (Bertschi 2011). The toilet looks like a traditional flush toilet, but flushes instead to a composting tank where it is gradually decomposed into compost that can then be used in any non-edible garden application, teaching students about biological cycles and re-use of waste. In the peePOD, the composting tanks (one primary and one overflow) are visible behind a low wall, contributing to student awareness of the systems that they are using.

The water used in the peePOD's sinks is also treated within the structure. Water enters the system when a 200-gallon storage tank, enough for roughly a month of normal use, is filled using a hose. Since the hose water is coming from the city water system, no extra treatment is needed, although small point-of-use reverse osmosis filters are used as an extra precaution. If the school was interested in creating a truly net-zero water system,

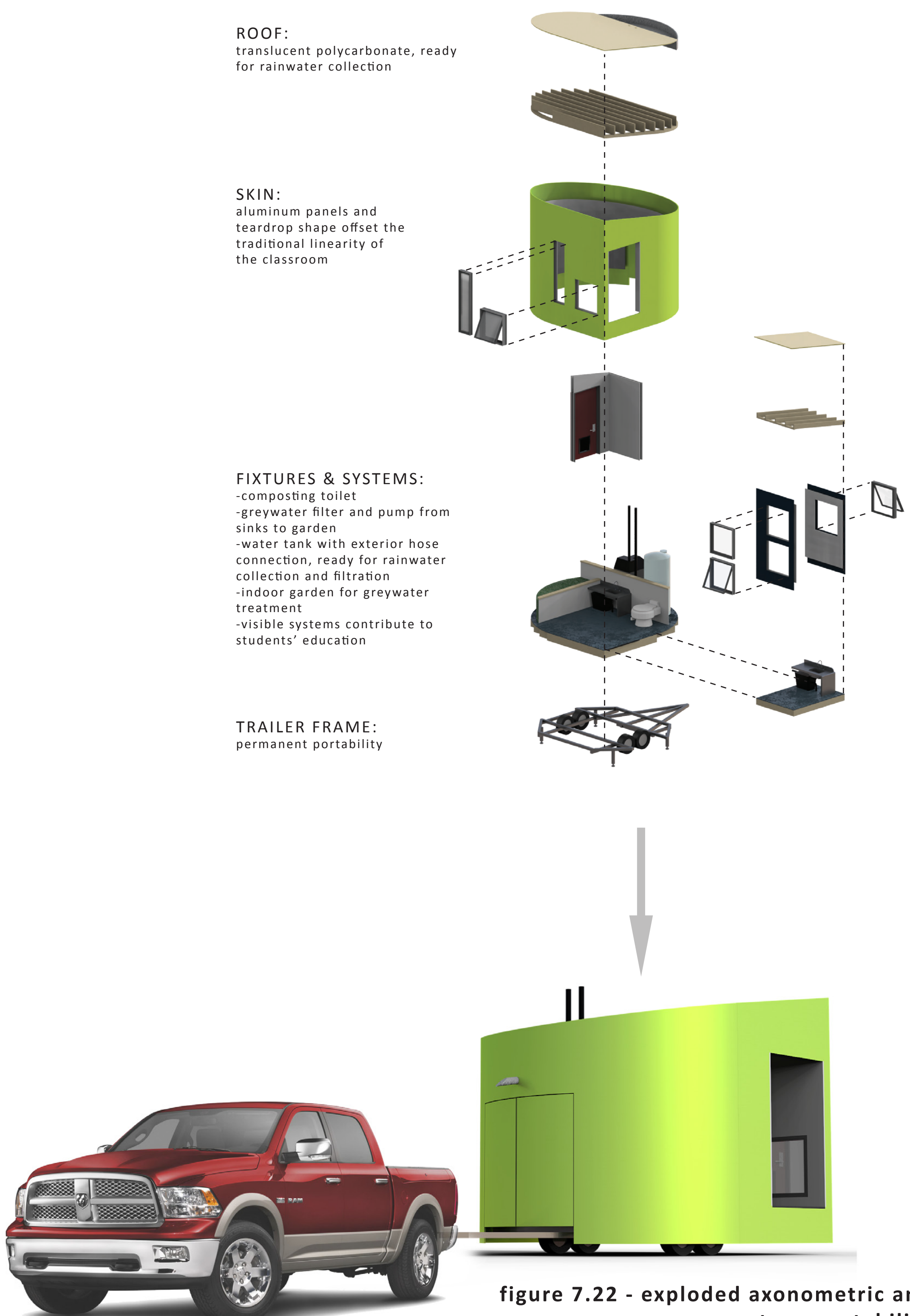


figure 7.22 - exploded axonometric and transportability

the roof is designed to drain to a single point above the water storage area, allowing for the introduction of a more complex rainwater cachement and filtration system. Initially, though, using a hose to connect to the city's infrastructure is a more economical solution. Water from the tank is fed to sinks, one in the bathroom itself and one in the optional connector, as well as to the toilet, which uses approximately one cup of water per flush (Envirolet.com). Once the water is used in the sinks, it flows through a series of filters below the sink and is pumped to an indoor greywater garden, where it is further filtered as it is absorbed by the plants and dirt and eventually released as clean vapor through evapotranspiration. Again, all components of this system - the storage tank, the filter/pump units, and the garden, are visible from inside the bathroom, increasing the students' awareness of the systems that they use every day.

The other key aspect of the peePOD is its portability and flexibility. The whole structure sits permanently on a trailer frame that can be towed from site to site with no modifications. This allows the structure to be used in multiple configurations. Figure 7.23 shows how the peePOD, depending on its configuration, could serve a single classroom as a dedicated bathroom, the larger school community as a stand-alone unit that could be used during recess or other outdoor events, or be connected to the ramp system of a classroom cluster. The ease with which it can be transported also means that a single peePOD module could be connected to a single classroom one year, but detached and connected to the ramp system the next year as the portable community expands. Also, since all systems are contained entirely within the unit, there is no need to reconnect any systems when the peePOD is relocated, unlike with a traditional wet classroom that needs connections to city water and sewer infrastructure. This could result in a savings of tens of thousands of dollars each time a classroom is moved (Barrett 2012).

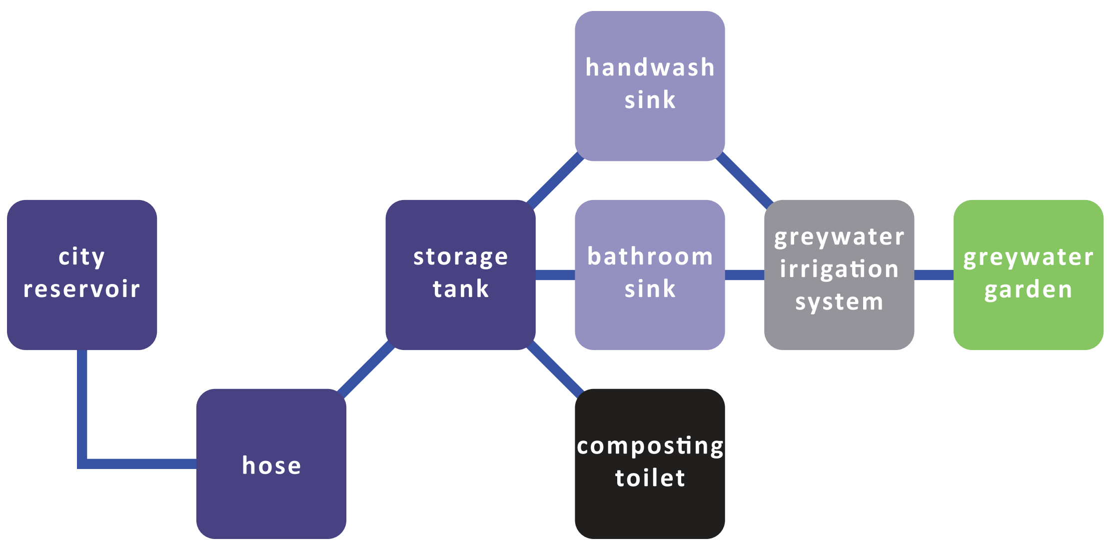


figure 7.23 - the peePOD water cycle

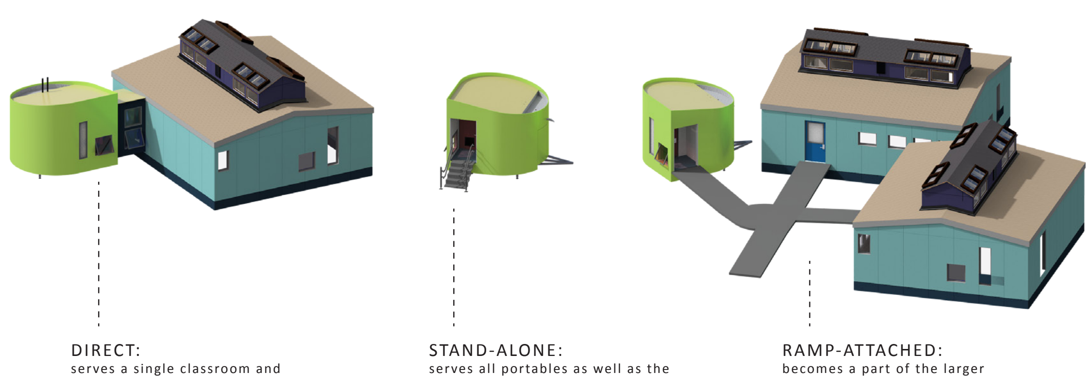


figure 7.24 - connection options

figure 7.25 - peePOD connection to a single classroom

figure 7.26 - playground equipment at Wedgwood Elementary

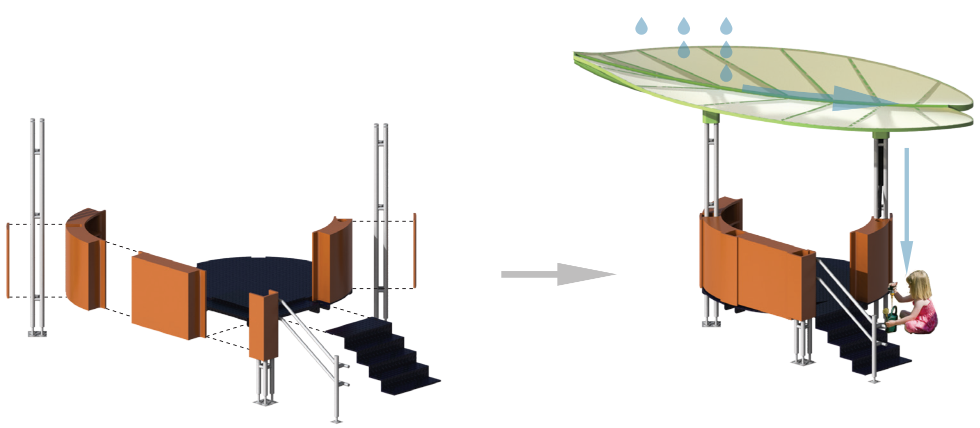


figure 7.27 - greenPATH - components and water collection

figure 7.28 - view looking up the greenPATH

greenPATH: rethinking the ramp

The final piece in the kit of parts proposed by this thesis is a new ramp system called the greenPATH. This ramp serves many functions beyond the basic need for vertical transport and ADA accessibility. It provides the ability to shape the outdoor space next to the classroom, allowing the learning space to be extended out of the classroom. It provides shelter from inclement weather for a class waiting to enter the room, and storage for student lunches and outdoor accessories such as boots and playground equipment. It provides students with another opportunity to capture and use rainwater to grow plants and further extend their learning outside of the classroom. By extending these aspects of the learning environment into the outdoors, the greenPATH can help to make up for the limited space inside a portable classroom. Finally, the greenPATH, through its bright colors and exciting shapes, provides a sense of fun that expresses excitement for the learning that happens inside the classroom far better than the standard beige box ever could.

In order to acheive the desired sense of fun and excitement, the greenPATH takes many of its design and construction cues from existing examples of playground equipment. The materials used, including steel, aluminum, and high-density plastic, are standards in the playground industry and could be manufactured largely from recycled materials (www.playmart.com). In addition, the forms of the ramp system were inspired by a combination of the natural world and these existing play structures. The leaf-shaped roofs, which provide

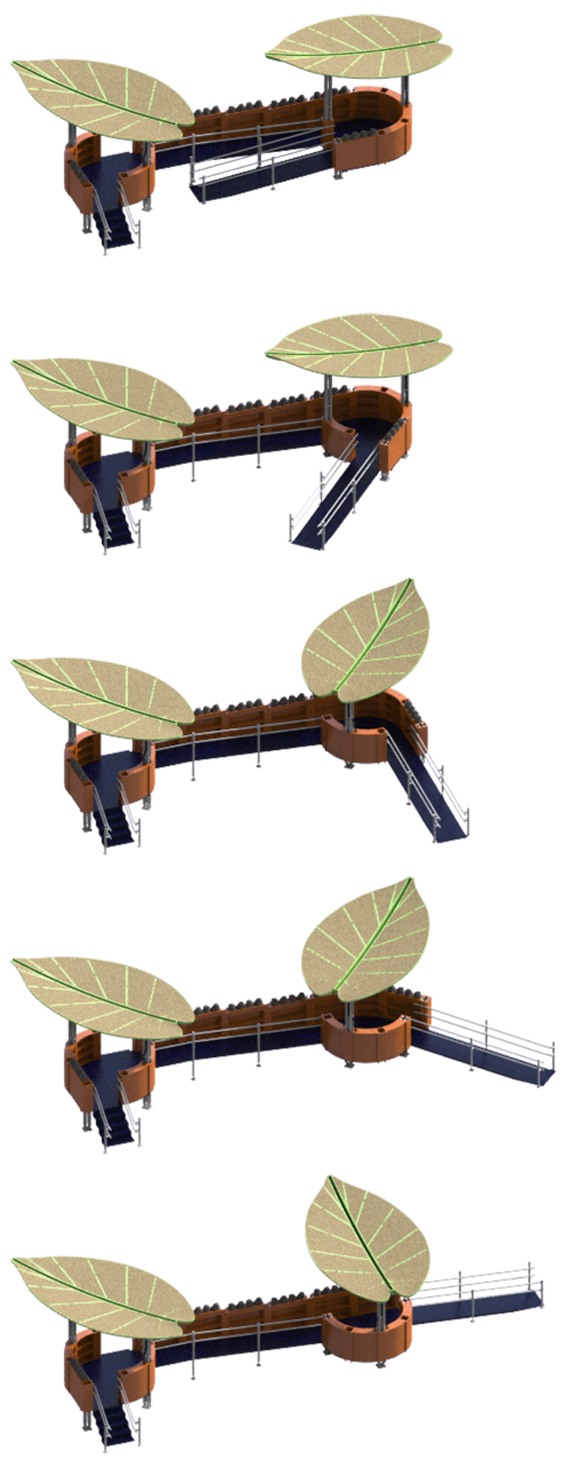


figure 7.29 - greenPATH
ramp configuration diagrams

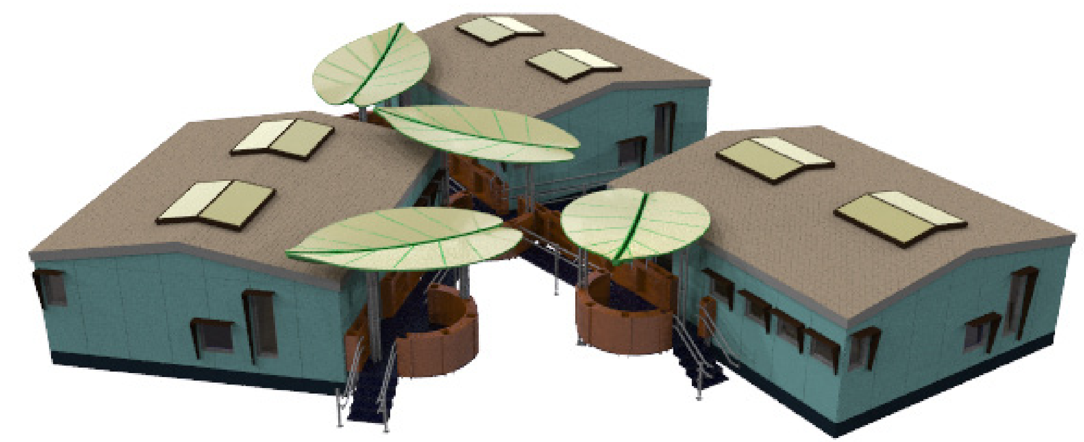


figure 7.30 - greenPATH
classroom connection opportunities

shelter, shade, and water collection capabilities, are a response to both the functionality of the natural form and the practicality of designing to smaller repeatable parts. They also add the critical element of playfulness to the structure that helps to meet the goals of fun and excitement.

The inclusion of water collection to the greenPATH allows it to also include real green, in the form of planted boxes that line the wall of the classroom. After flowing from the roof into the central gutter, water is collected in tanks that form part of the curved wall at each landing (figure 7.27). This water can then be used to nurture the plants that are an integral part of the ramp system. These elements - water and plant - can inform lessons and educational units that further incorporate the students' environment into their education.

The greenPATH ramp system can play an important role in shaping this educational environment in how it adapts to site conditions and frames the outdoor space accordingly. Since the ramp and stair sections can attach to the landings at a variety of angles, the outdoor space that is captured within the system can be varied depending on the requirements of the classroom and the site (figure 7.29). This flexibility also allows for multiple ramps and classroom entrances to connect to a single platform node, helping to connect classrooms and foster a greater sense of community within the portables (figure 7.30). One can even imagine a scenario where entire grades are clustered in a group of three or four classrooms with two peePODs, creating a school made entirely from this system.

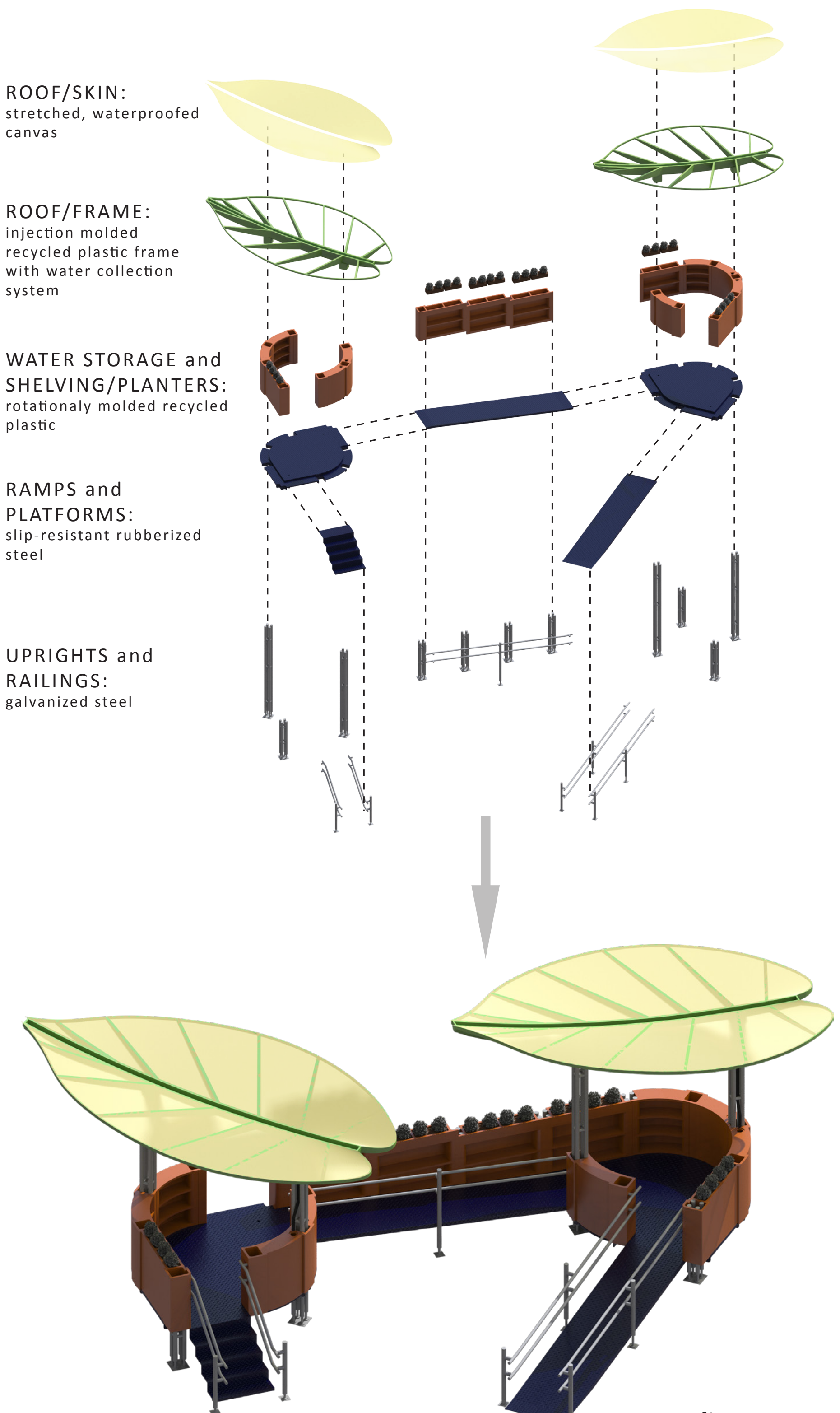


figure 7.31 - greenPATH exploded axonometric

figure 7.32 - greenPATH landing and entry

VIII - Conclusions and Continuations

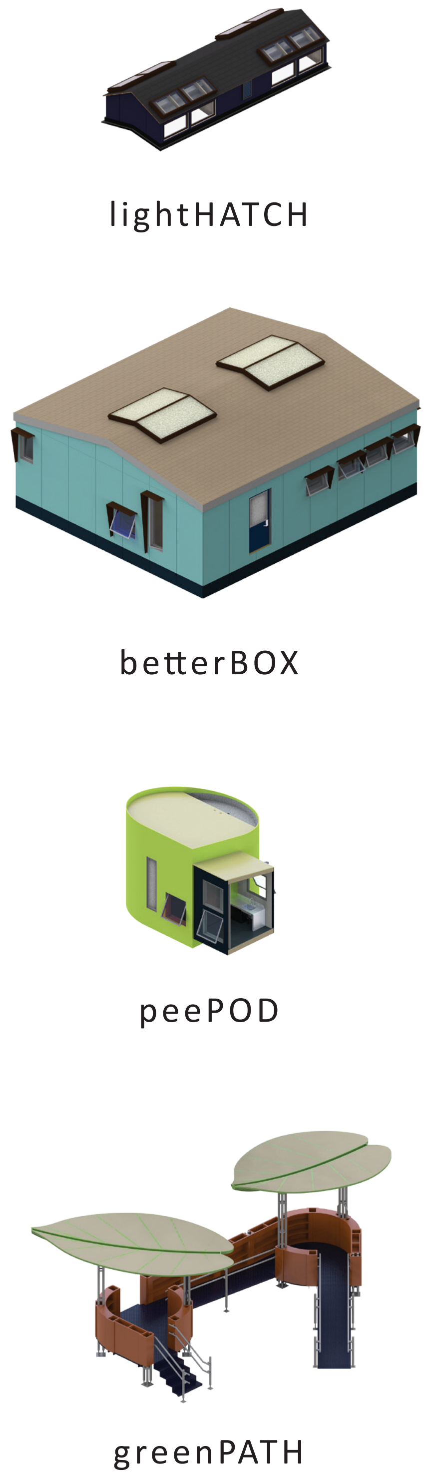


figure 8.1 - Mod-Kit - four parts

figure 8.2 - Mod-Kit front view

The elements of the Mod-Kit can all come together to create a place where portable classrooms are no longer a stop-gap, temporary solution, but a viable long-term expansion plan. They offer a flexible solution that provides students with well-lit learning spaces that offer as much of a sense of community as the larger school building. These interventions - whether used with a new betterBOX or added to an existing classroom village - will allow districts the flexibility advantages provided by portables without sacrificing the ultimate goal of creating dynamic, inspiring learning spaces.

While the thesis portion of this project is coming to a close, the ultimate goal remains unrealized. I plan on continuing to pursue the Mod-Kit as a real project, and hope that through continued collaboration with the Seattle Public Schools a prototype can be built. The immediate next step is to work with modular building manufacturers to develop a realistic cost estimate for the project, at which point I will be able to pursue funding opportunities. I believe that this project has the potential to have a significant positive effect on the learning environment for many Seattle schoolchildren, and my intent remains to pursue every opportunity to make it a reality.

Thank You

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Brendan Connolly

The Bertschi School
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Stan Richardson

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