The UW Integrated AEC Studio:
Pedagogy, course structure, and insights from 2009 - 2016

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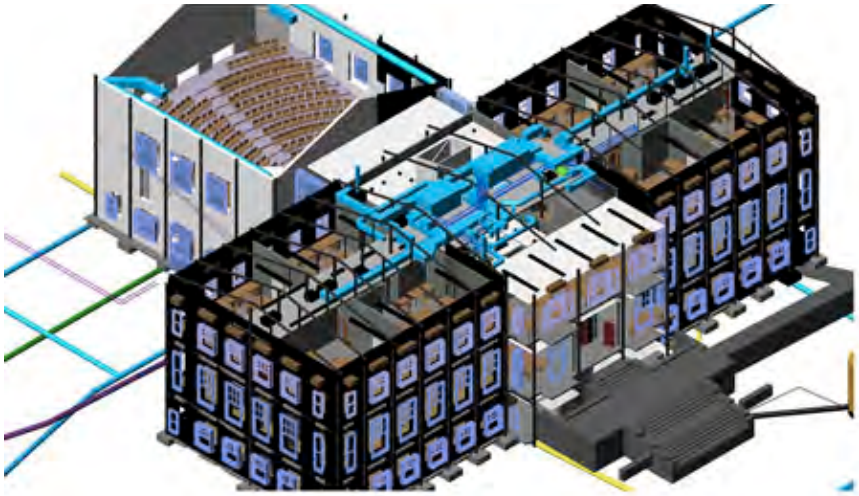
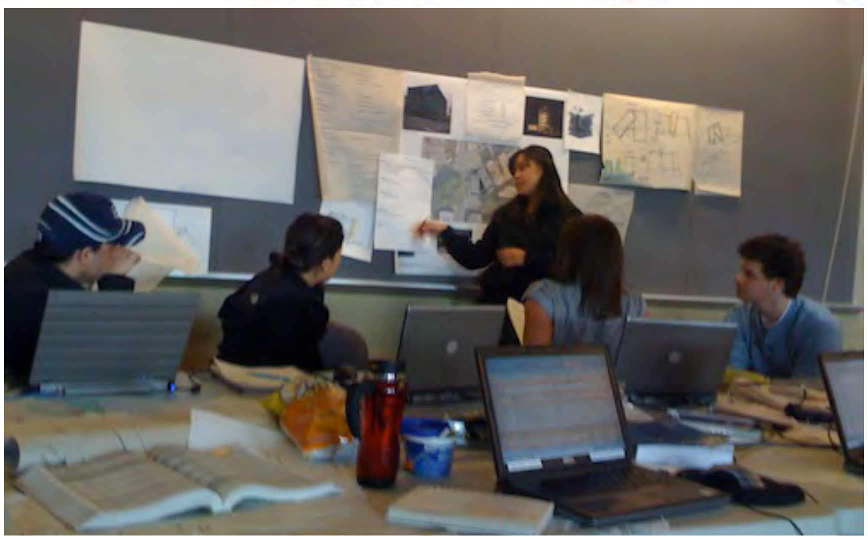
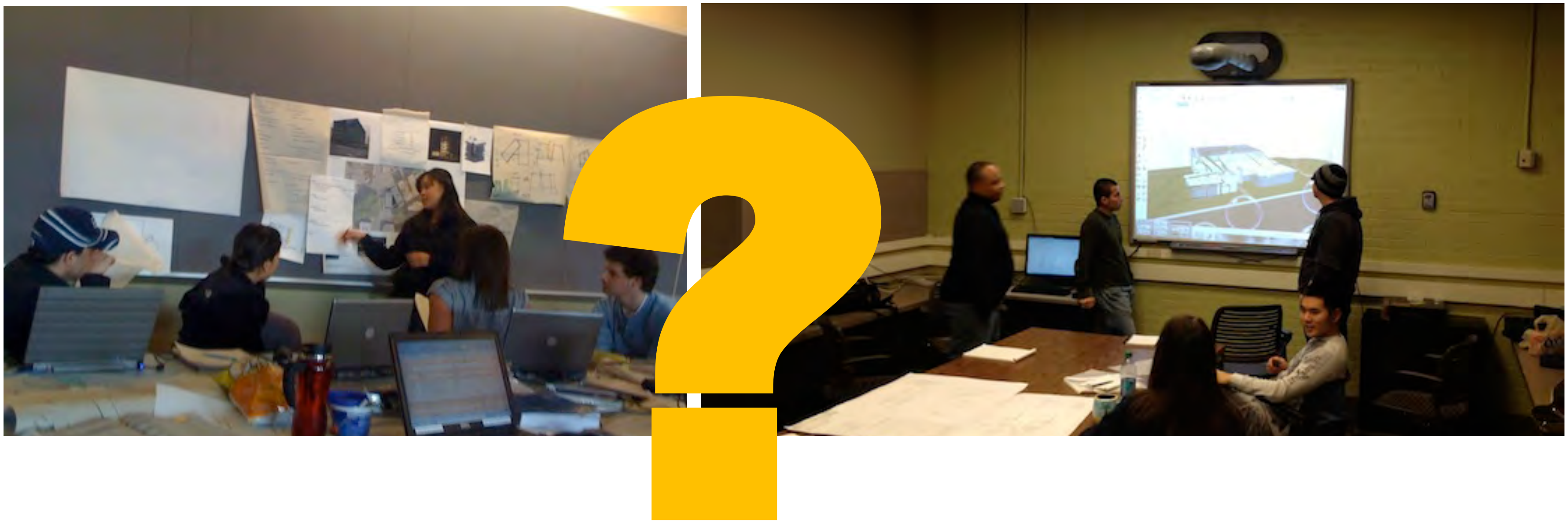
COLLEGE OF BUILT ENVIRONMENTS

High performance buildings require **collaboration**





Education Processes, Infrastructure, Curricula



How can AEC students be engaged across studio/non-studio disciplines with different credit hours and curriculum requirements?

UW Integrated AEC Studios

- Begun Winter Quarter 2009
- Teams of 3-10:

  Architecture, CM, Civil, Structural, Landscape Arch.,

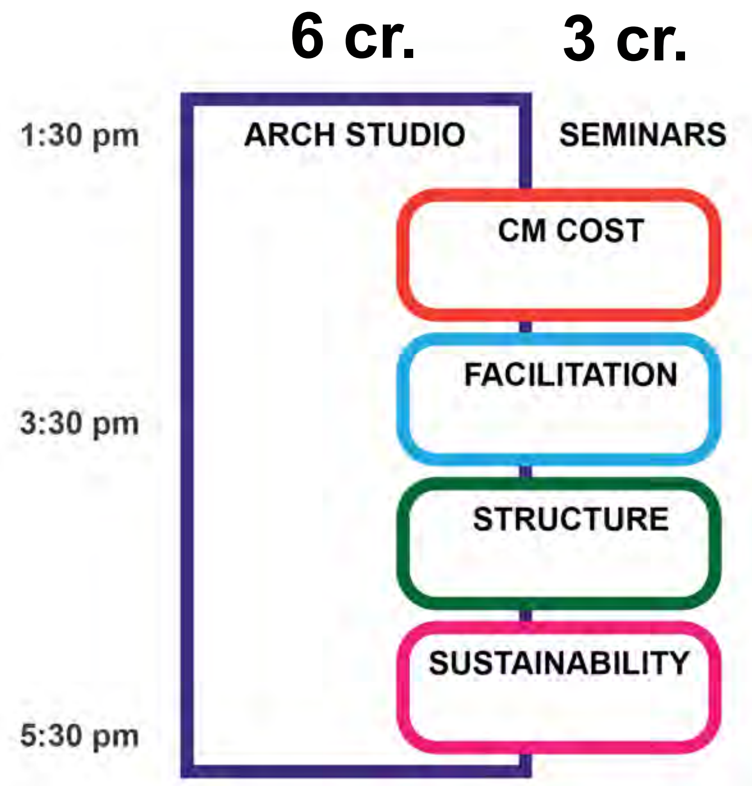
  Real Estate, Sustainability, Facilitation
- Experiments with different projects, studio spaces, course schedules
- since 2014: 6 cr Arch studio + 3 cr seminars structure
- 10 week quarters

2009: Net Zero Office

2013: Modular Multi-Family

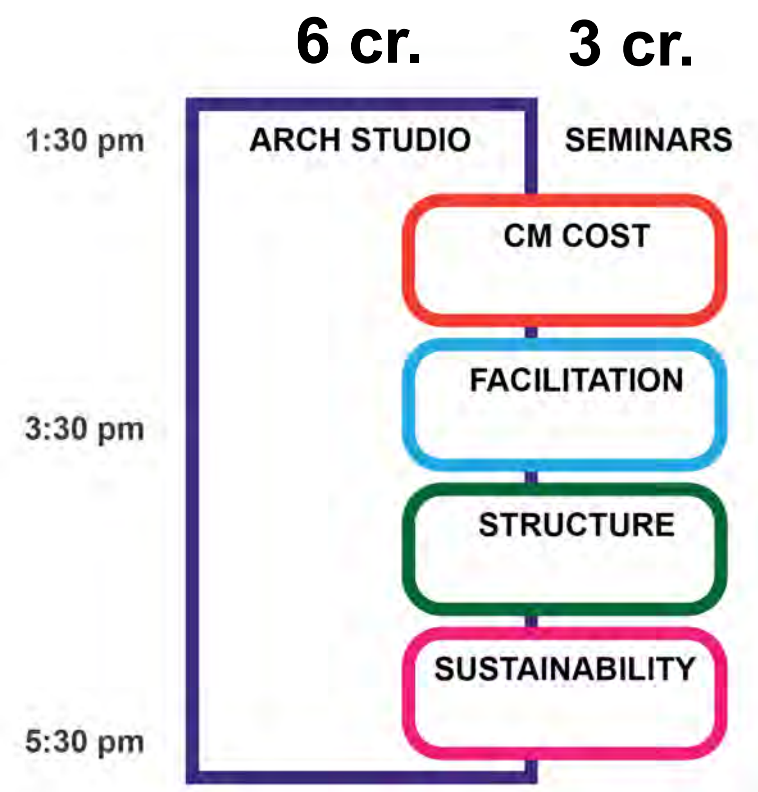
UW Integrated AEC Studios

- Arch Seniors—5th of 6 required arch studios
- Required for Arch/CM dual majors 4th year
- Four seminars—AEC content
- CM Seniors/5th year dual — right before their capstone
- Others take 3 cr. Seminars
  - Usually fulfills elective credits



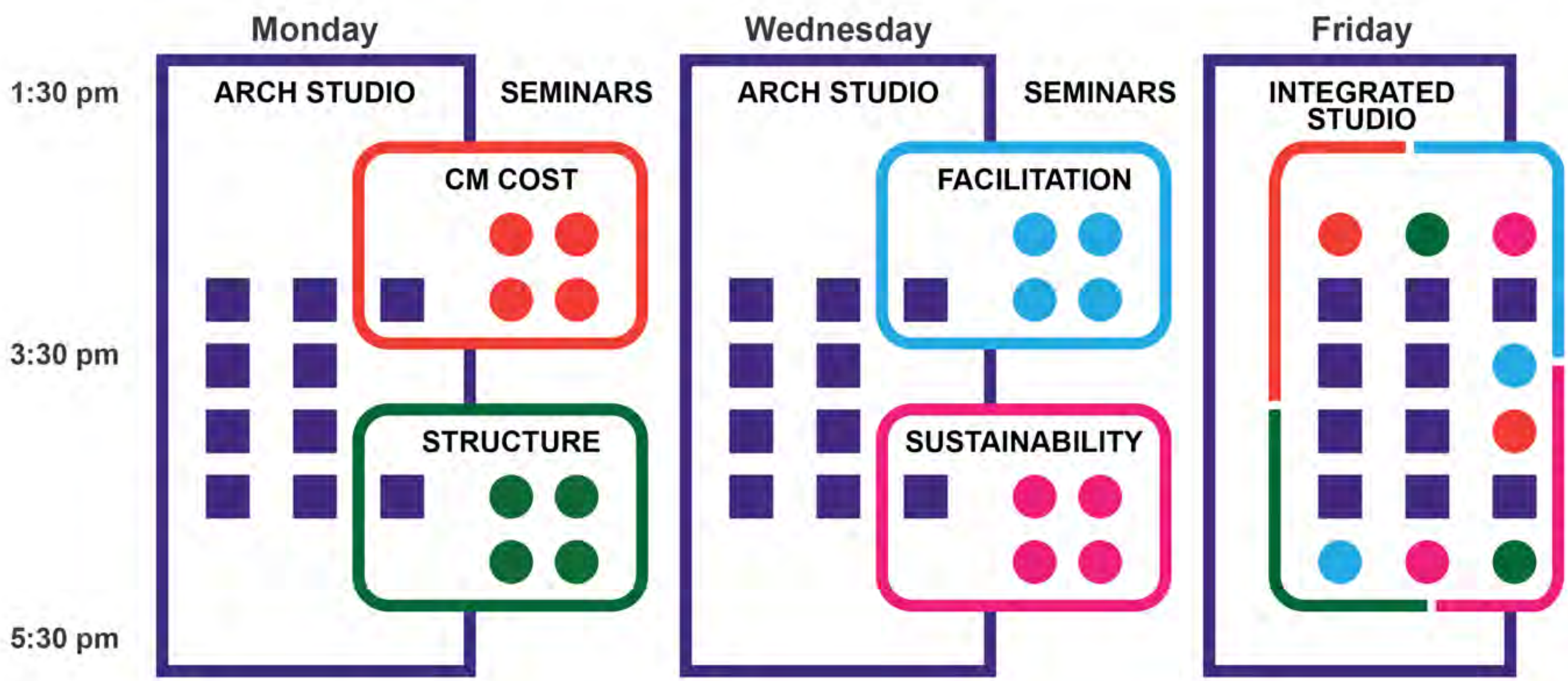
Course Design: Studios and Seminars

- Traditional arch studio
  - 1 faculty member
- 4 seminars
  - 2 faculty members
  - Teach seminars alternate days
- Seminar students have not had prior studio experience
  - Issues: research, proposition, multi-variate problem solving
  - Pin-up discussions (“out”), research for future (“in”)
  - Architecture student “process mentors” for studio habits



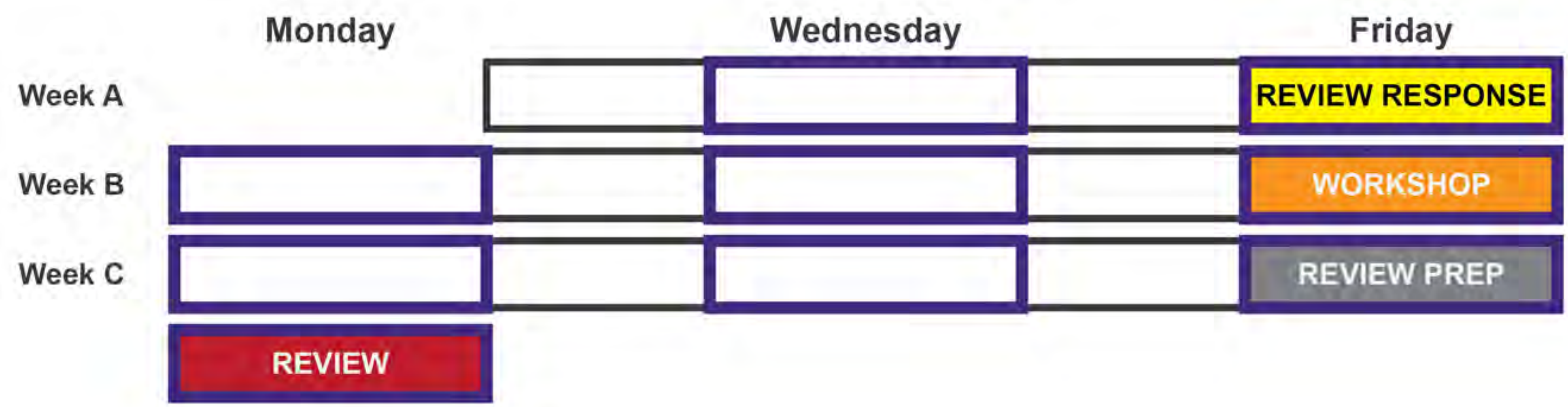
Course Design: Studios and Seminars

- Meet MWF, studio/seminars overlap, Friday team day
- Architecture student "lead" attends seminars



Course Design: “Cycles”

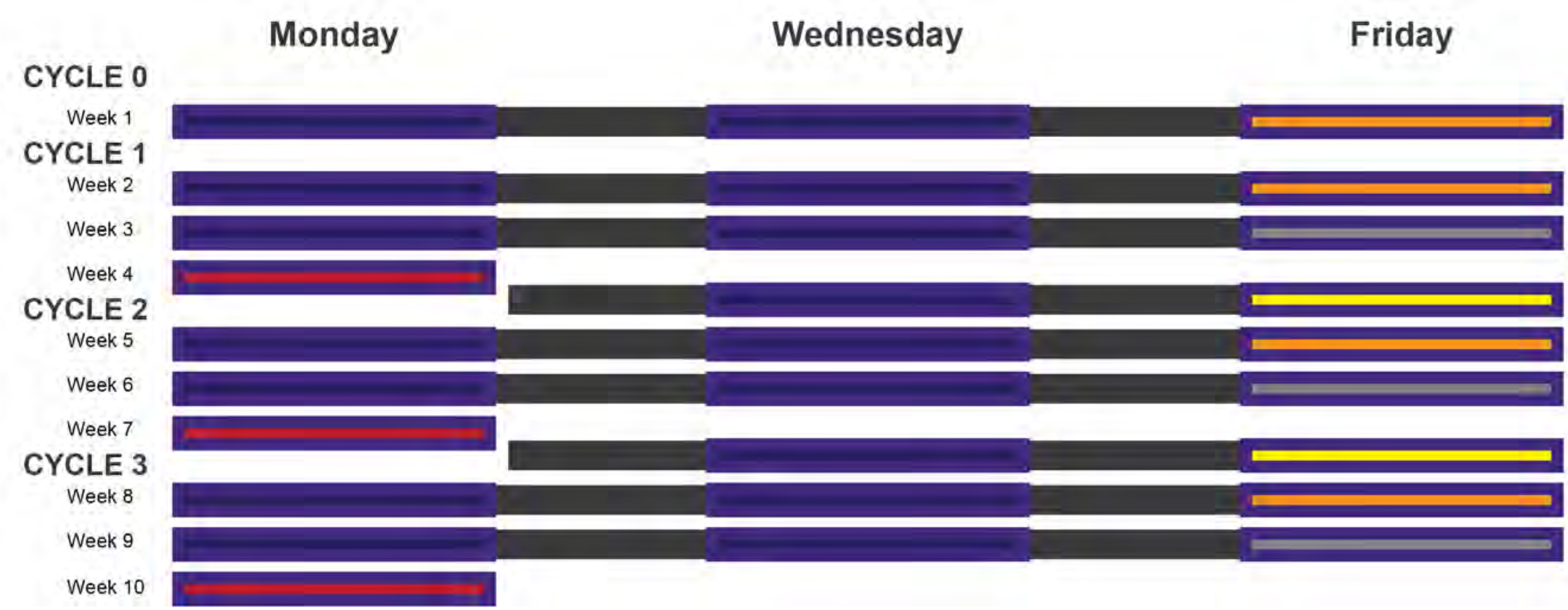
- Content “Cycle”—A) introduction [and review], B) design and integrate, team workshop, C) develop/prepare for review



  - Reviews include industry experts and outside faculty
  - Review responses are team reflections on information learned at reviews
  - Facilitation includes team planning, peer assessment

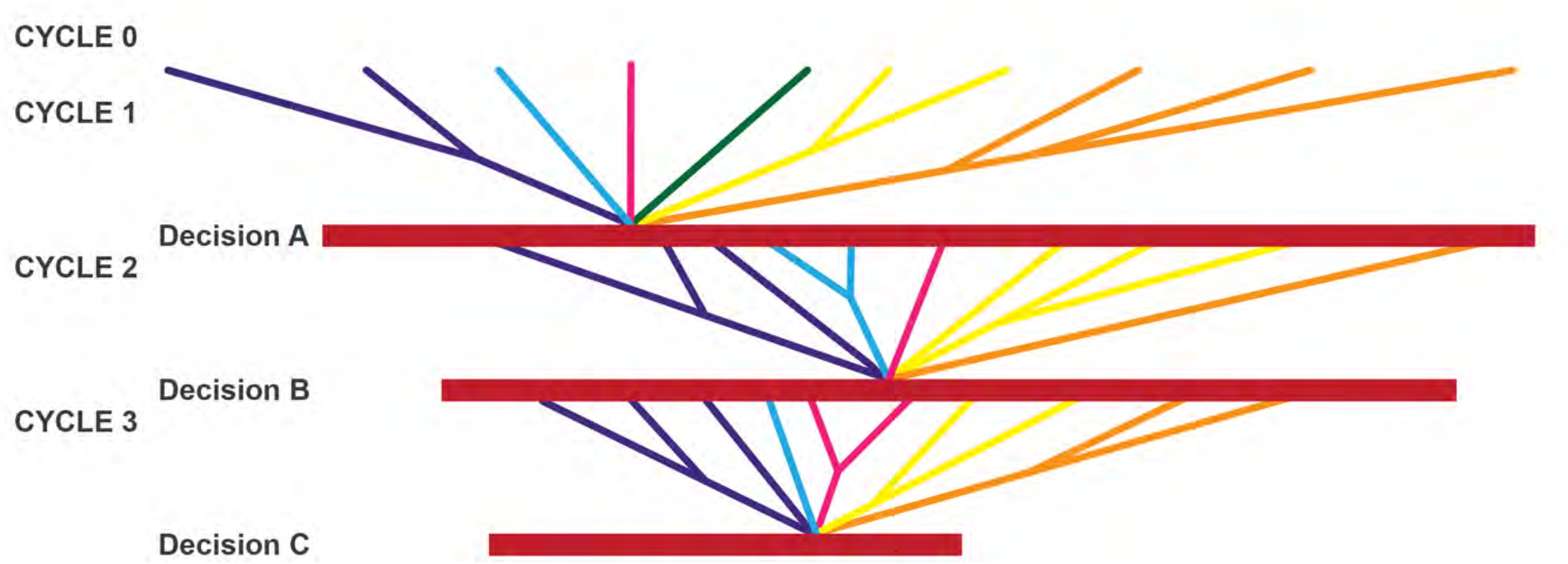
Course Design: “Cycles”

- Content Cycle 0: Intro & analysis, Cycle 1: structural system, Cycle 2: façade/envelope, Cycle 3: “deep dive” system development



Course Design: "Cycles"

- "set-based design"—developed from "set-based concurrent engineering" Sets of possible solutions considered concurrently, narrow possibilities, converge on final interim solution. New questions posed. (Toyota; Smith, 1997).
- Parallel to LEAN process, fast-track design/construct, IPD



2016 Studio—Timber Frame Office Building

Stone 34 project:

Just-built developer office building in Freemont

Performance meeting Seattle

Deep Green Pilot program

Studio challenge: reconsider design with timber frame structure

Metrics: cost, square footage, sustainability, constructability

Integrated AEC team design process

2016 Studio—Timber Frame Office Building

Work environment:

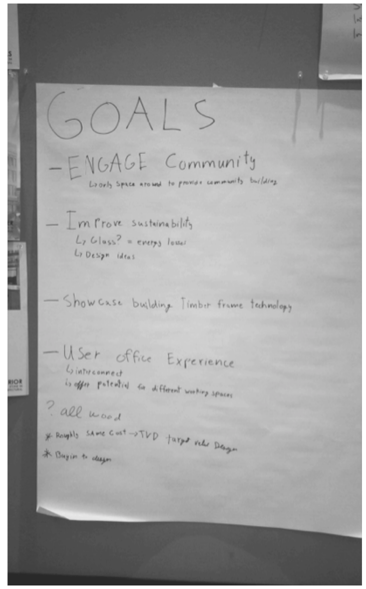
Studio space +

Two adjacent seminar rooms

Work ethic:

Team buy-in on project goals

Team-driven work periods



Studio instruction:

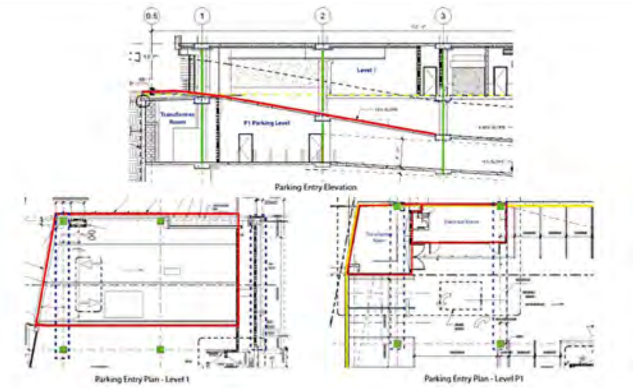
Full design team crits usual for M & W

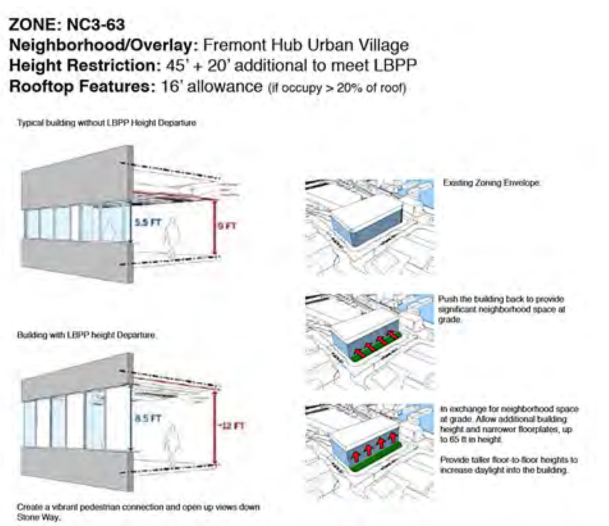
Review project progress and discuss options

Fluid full-team work time most F sessions

All instructors stopping in as able to assist

2016 Studio—Cycle 0: Analysis



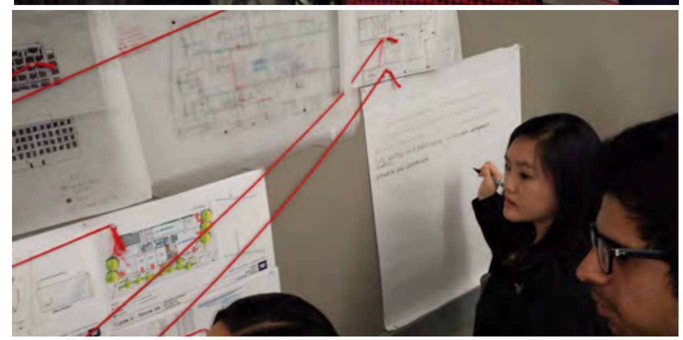


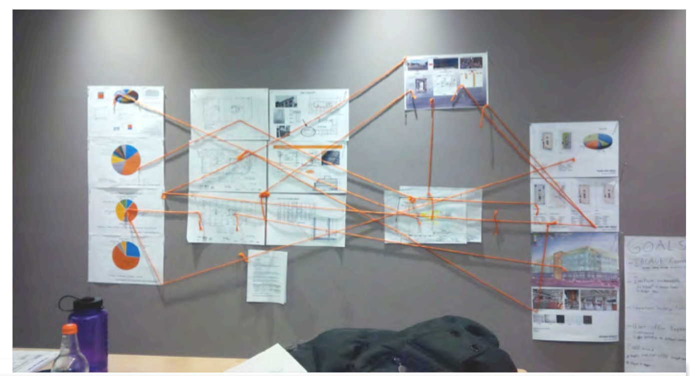
Week 1 of 10:

Each discipline analyzed documents and gathered information on the Stone 34 project

In a Friday workshop, students pinned up work and shared findings across disciplines

Teams looked for connections between issues identified

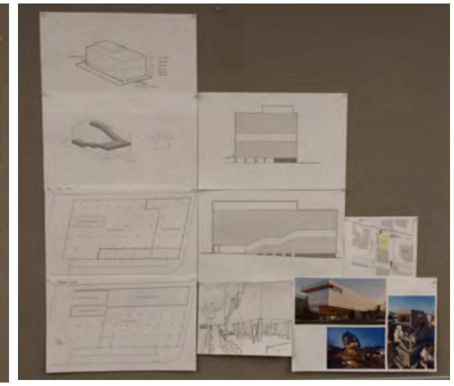




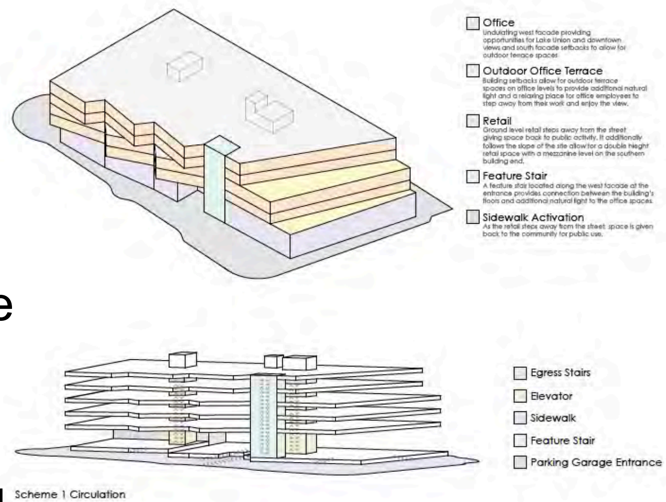
2016 Studio—Cycle 1: Structural System

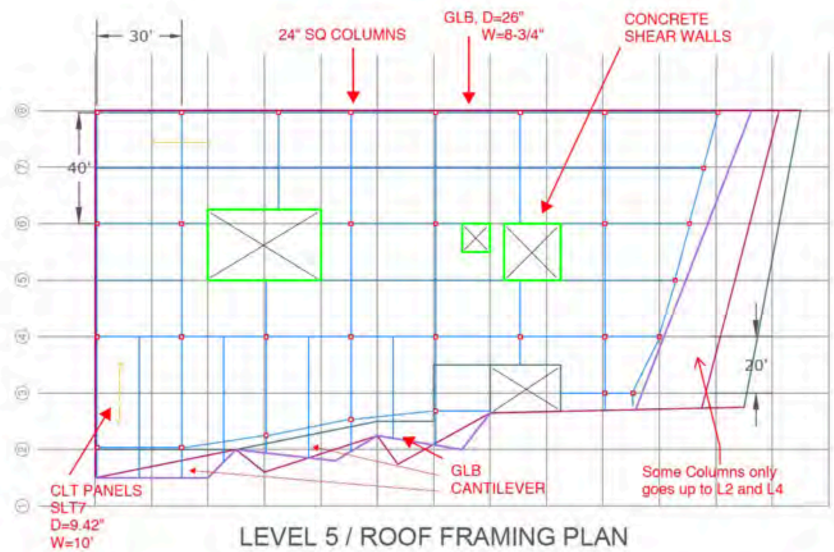
Weeks 2, 3, and 4 of 10:

Teams started with 2-3 massing schemes for preliminary framing analysis



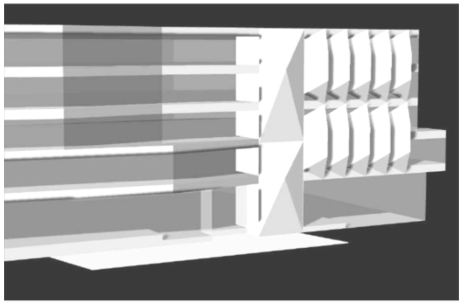
Review at end of cycle 1 was meant to help students use the structural issues to select the best scheme

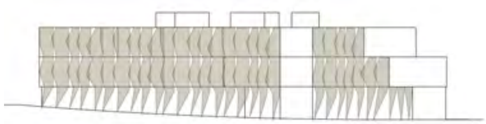




Decision not uniformly logical

2016 Studio—Cycle 2: Façade and Envelope

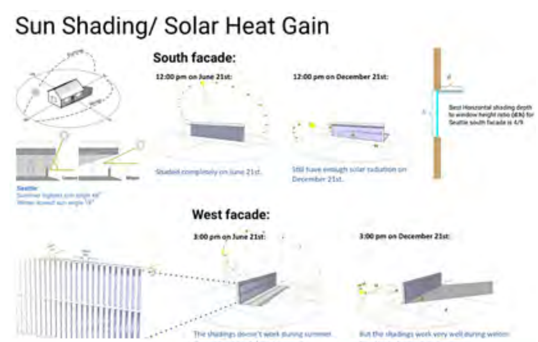




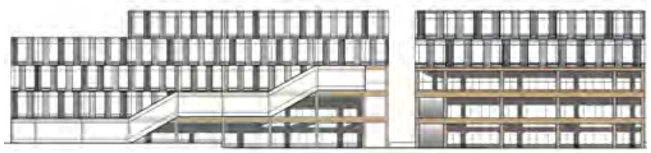
Weeks 4, 5, and 6 of 10:

Design exploration was assisted by information gathering for materials and assemblies

Sustainability factors & strategies were evaluated

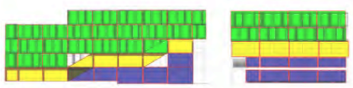


2016 Studio—Cycle 2: Façade and Envelope

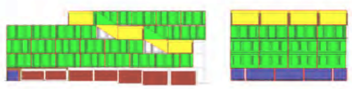


Estimation

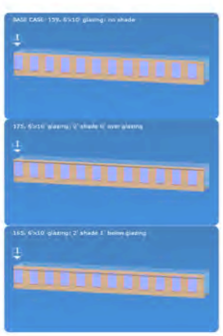
- **Stone 34 Envelope**
  - **Total SF:** 54,124 SF
  - **Total Cost:** $ 3,277,696
  - **Cost/SF:** $ 60.56



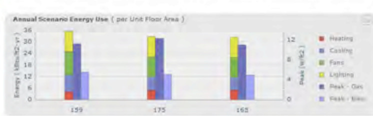
- **New Design Envelope**
  - **Total SF:** 49,050 SF
  - **Total Cost:** $ 3,129,708
  - **Cost/SF:** $ 63.81



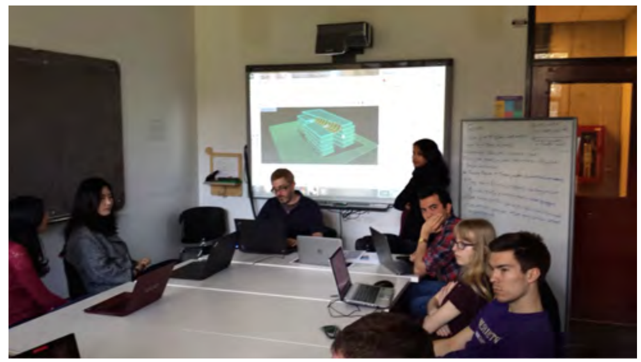
HORIZONTAL SHADING OPTIONS

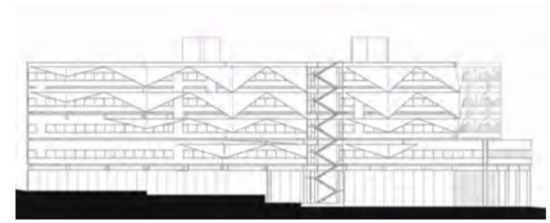


Model	Heating	Cooling	Fans	Lighting	Total
159.	3.97	8.87	12.14	10.7	35.68
175.	4.73	6.98	10.41	10.7	32.82
165.	4.94	6.67	10.16	10.7	32.47



- Horizontal 2' deep shades provide energy benefits to South-facing wall
- Shading below top of glazing produces maximum efficiency





Exterior Cost Comparisons

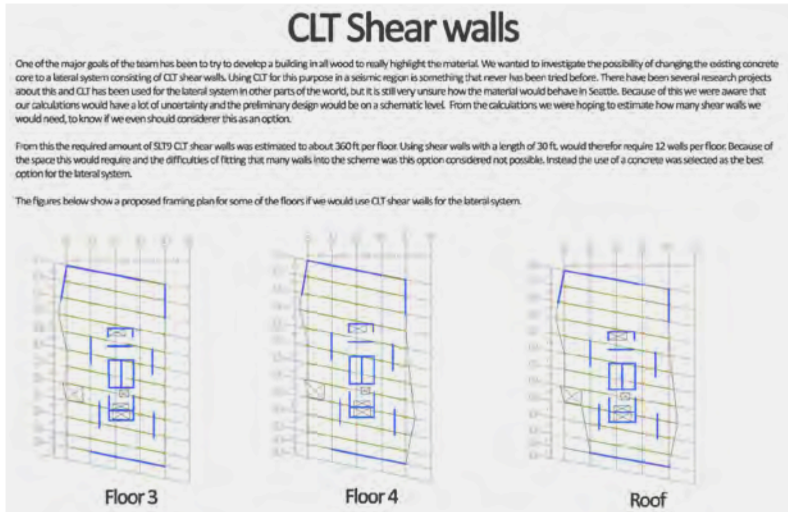
Final design options were analyzed for energy, daylighting, and cost

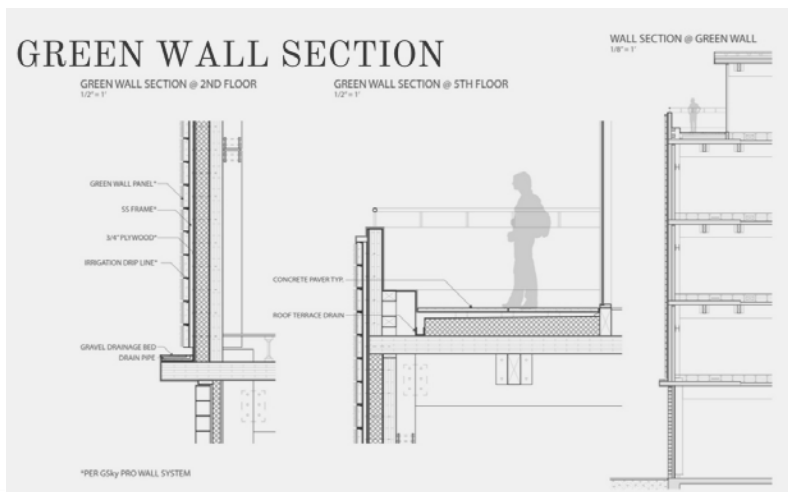
2016 Studio—Cycle 3: System Development

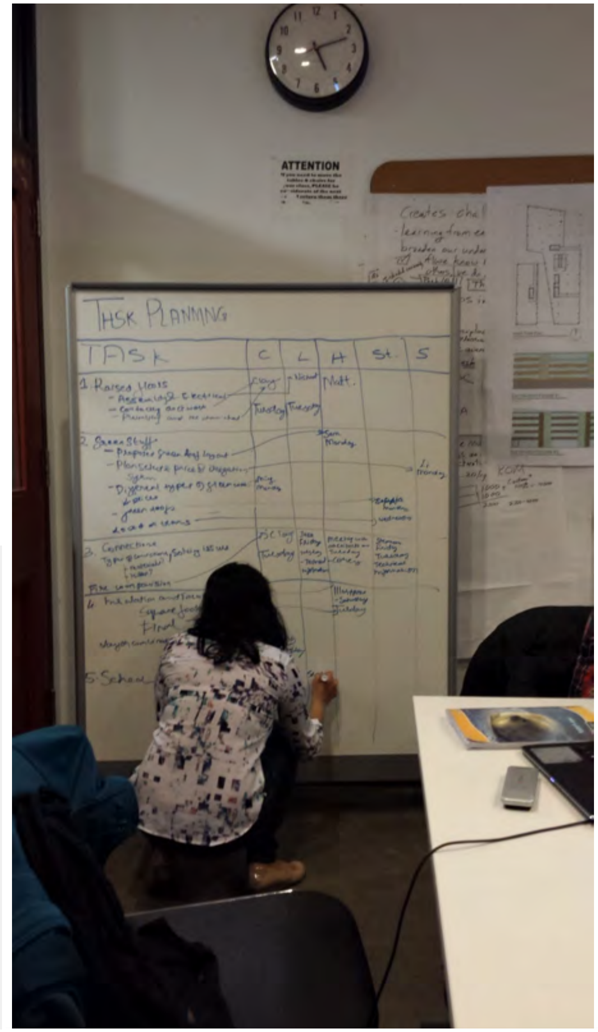
Weeks 8 & 9:

Partnerships within teams to explore in-depth some aspect or feature in the conceptual design

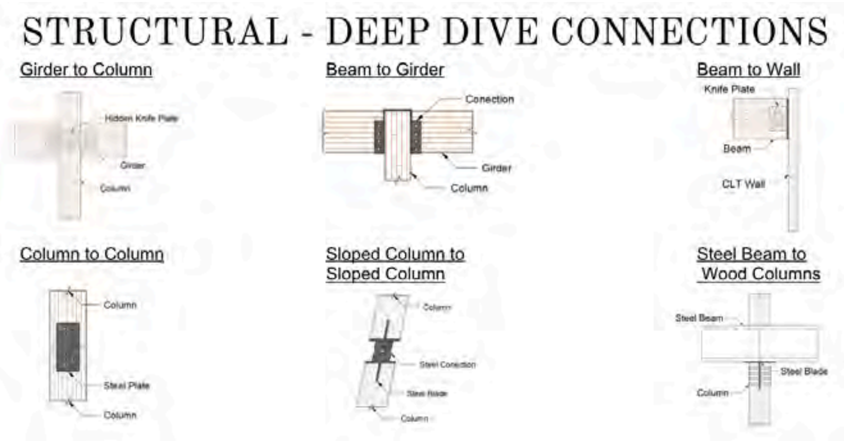
Each "deep dive" feature should ideally be understood from multiple perspectives

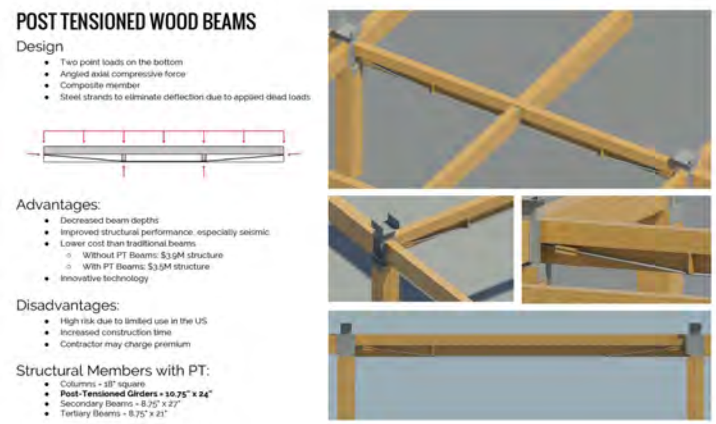


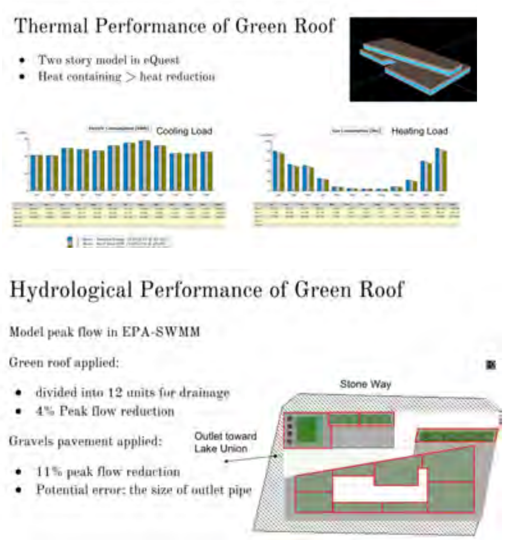


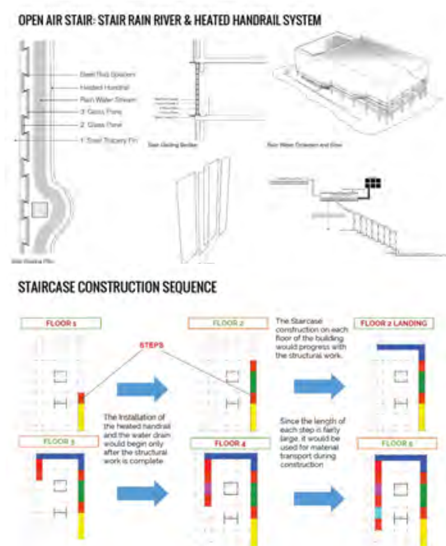


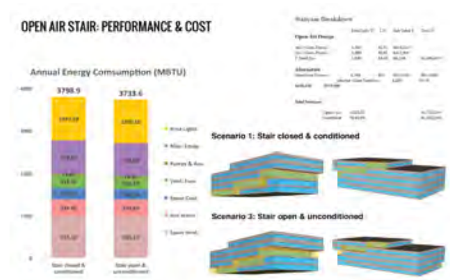
2016 Studio—Cycle 3: System Development











2016 Studio—Final Review

2016 Studio—Team A

ASCEND 3400 Stone Way N

Team A

Team Members

ARCHITECTS
SHANNEN
MELANIE
GEORGE
RILEY

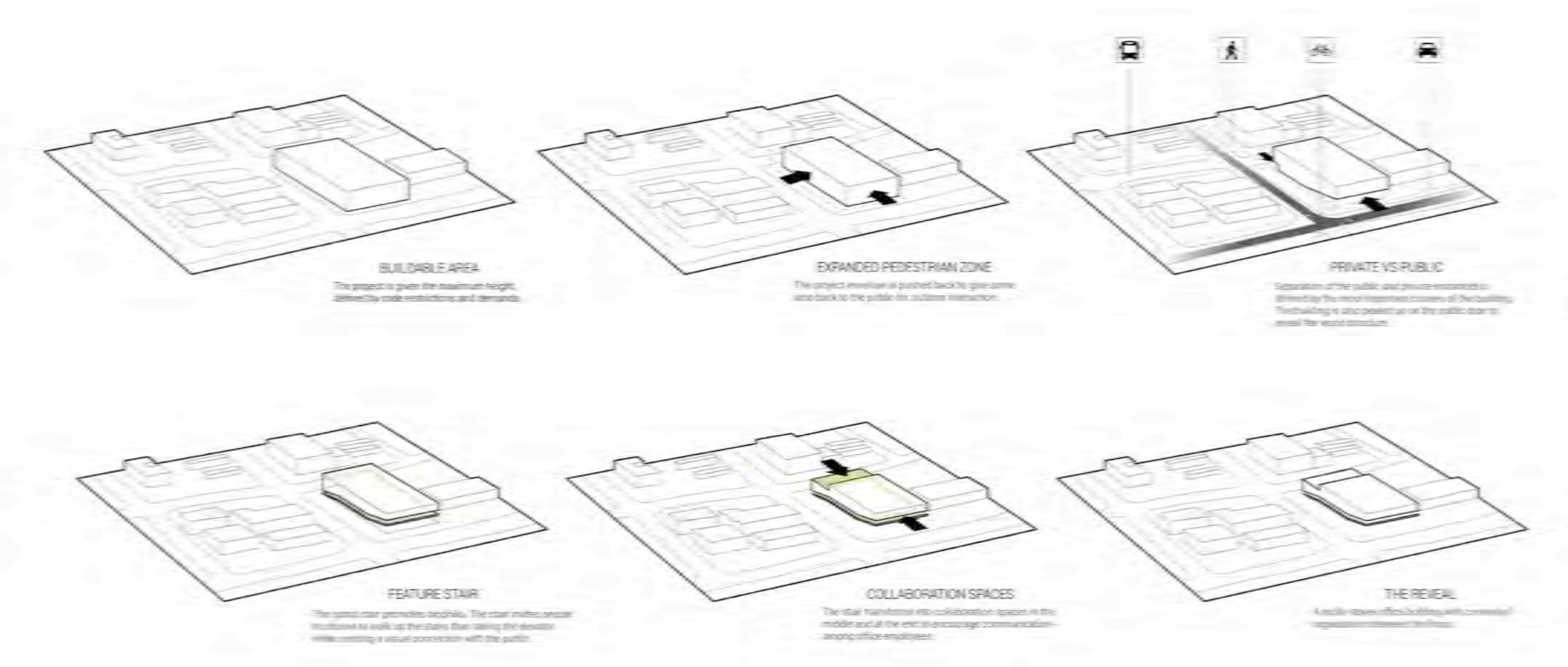
LOGISTICS
SIDDHARTH
CHRISTINA NHI

STRUCTURAL ENGINEERS
JEAN-LUC
MIRA

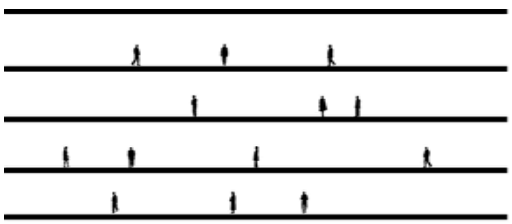
COST ESTIMATORS
ANTOINE
TING

SUSTAINABILITY ADVISORS
PEYTON
XIUQING

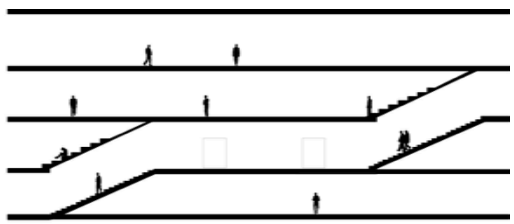
2016 Studio—Team A



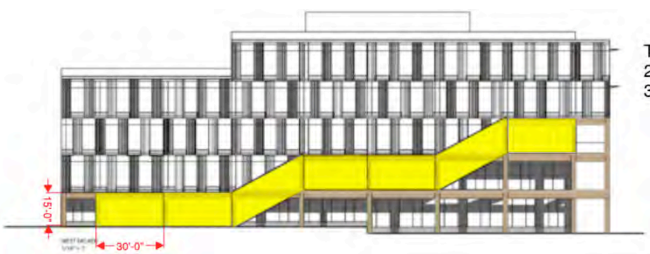
2016 Studio—Team A



TYPICAL MULTI-STOREY ORGANIZATION
In a typical midrise office, floors operate in isolation. Even when occupants work for the same organization, their interaction is minimal.

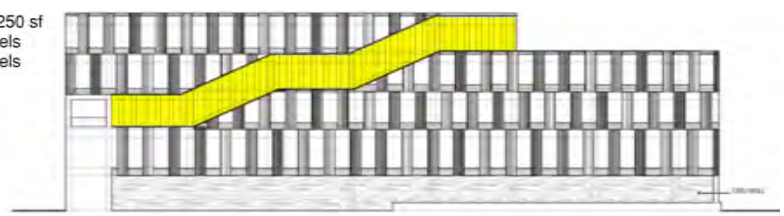


CONNECTED ORGANIZATION
The stair boasts a circulation space that links all the collaboration and interaction between occupants or



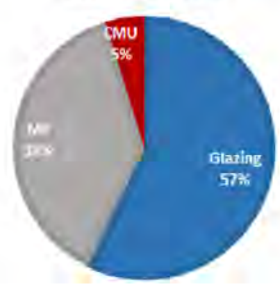
Total Area: 3150 sf
2x11: 42 Panels
3x11: 42 Panels

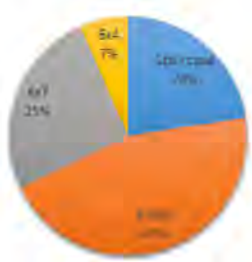
Total Area: 2250 sf
2x11: 30 Panels
3x11: 30 Panels



New 'Big Stiars' Design		SF/ct	U.P.	Cost
Glazing	Al Framed Storefront, Dark Mullion (**STAIRCASE**)	5,400	$ 75	$ 405,000
	Al Framed Storefront, Dark Mullion (Retail)	10,800	$ 75	$ 810,000
	6x7 Punch Windows (Upper), S&I	8,316	$ 55	$ 457,380
	6x4 Pop out Windows (Upper), S&I	198	$ 600	$ 118,800
	Glazing	**24,516**		**$ 1,791,180**
Metal Paneling	Metal Panel Framing	16,632	$ 31.50	$ 523,908
	Aluminum Paneling 4x15, Verticle	11,880	$ 40.00	$ 475,200
	Aluminum Paneling 4x6 , Horizontal	4,752	$ 40.00	$ 190,080
	Metal Paneling	**16,632**		**$ 1,189,188**
Masonry	CMU Panels @ Retails S&I + Water Repellents	3,150	$ 47.60	$ 149,940
	Masonry	**3,150**		**$ 149,940**
	Total Exterior Envelope	**49,050**	**$ 63.82**	**$ 3,130,308**

ENVELOPE BREAKDOWN

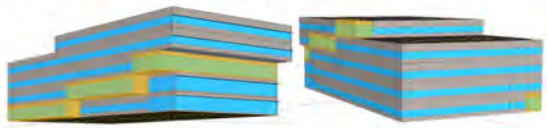




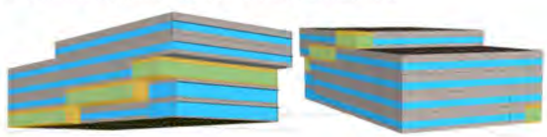
2016 Studio—Team A

Energy & Performance Analysis

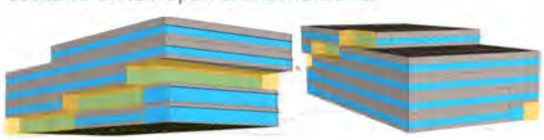
Scenario 1: Stair closed & conditioned

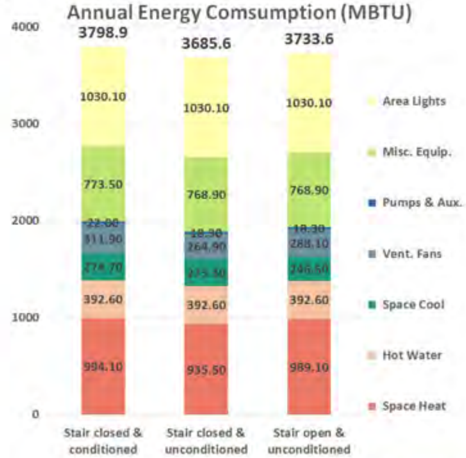


Scenario 2: Stair closed & unconditioned



Scenario 3:Stair open & unconditioned

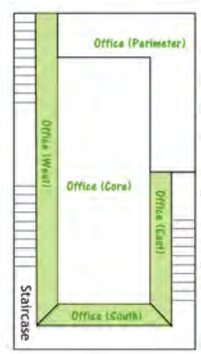


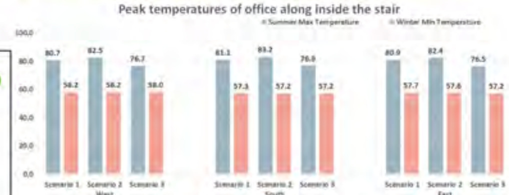


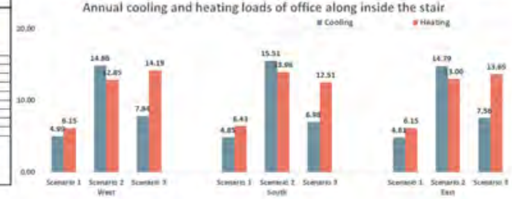
Comparing with scenario 1, scenario 2 consumes less energy for cooling and heating as the total conditioned space is reduced.

Comparing with scenario 2, some of the core office zones are turned to be perimeter zones after the stair became an open air space in the scenario 3. So in the scenario 3 the building consumes less energy for cooling, but more energy for heating. When comparing the total energy consumption, scenario 2 consumes the lowest.

Peak temperatures & total loads of office along inside the staircase





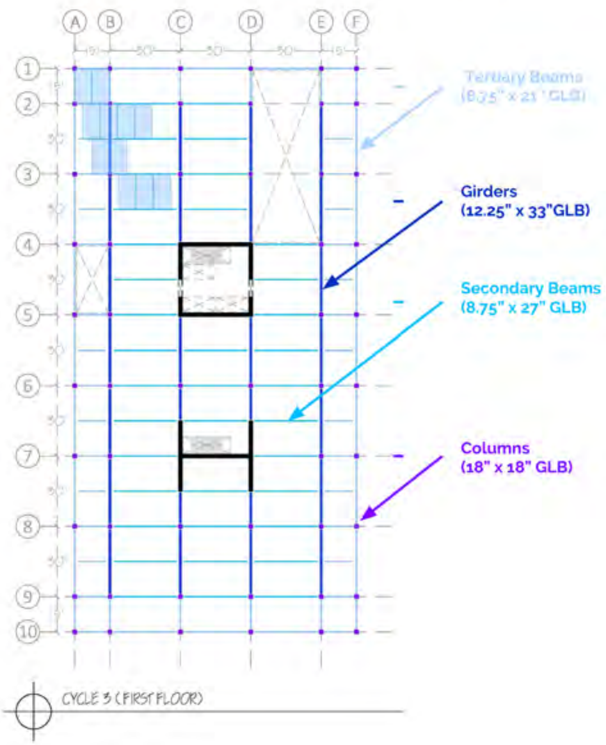


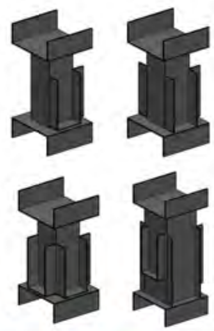
When the staircase is open, the maximum temperatures during summer are reduced by 7.0% in the West, by 7.6% in the South, and by 7.2% in the East compared to the scenario 2. This reduction is probably attributed to the effectiveness of natural ventilation as those three areas are turned into perimeter zones. Natural Ventilation helps a lot in moving away the cooling loads from the office space. While, during winter, the minimum temperatures are not decreased too much. And this can be explained with the high internal heat gain in the office space offsets part of the heating load.

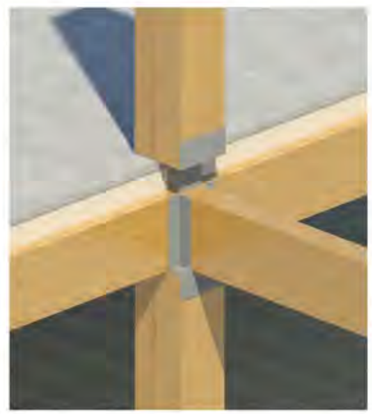
Considering both the energy consumption and the comfort condition, scenario 3 is the best design scenario.

2016 Studio—Team A

Framing, Columns, and Connections







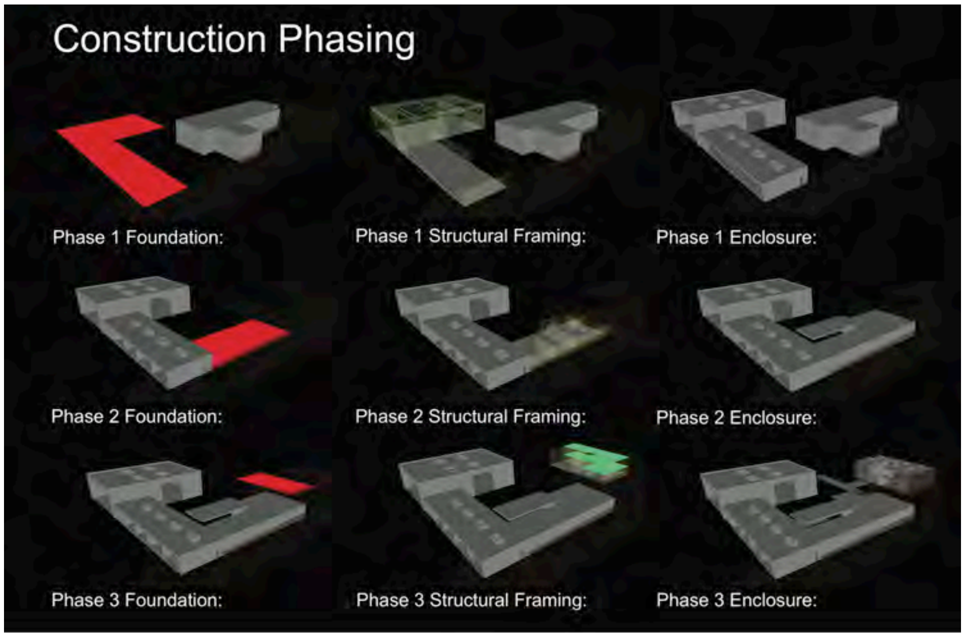
Structural Connections Cost Analysis

Description	Quantity	Cost	Total
Cycle 2 Structure			
Special Fabricated Fasteners	60	$ 500.00	$ 30,000.00
Girder Fasteners	200	$ 385.00	$ 77,000.00
One Level Cost			$ 107,000.00
Total Cost			**$ 535,000.00**
PT Beam Structure			
Special Fabricated Fasteners	54	$ 500.00	$ 27,000.00
One Level Cost			$ 27,000.00
Total Cost			**$ 135,000.00**

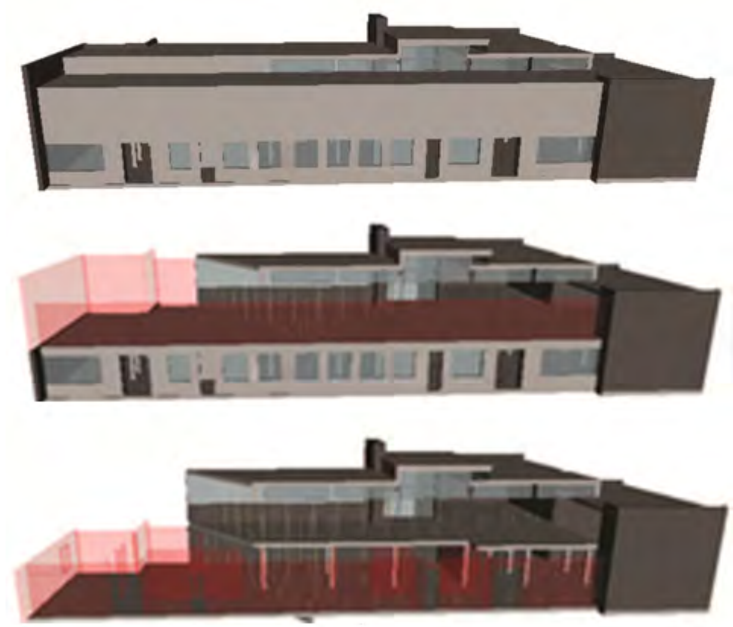
Post Tension Beam Cost Analysis

Description	Quantity	Length	Cost	Total
Beams				
8.75" x 21" x 30'	93	30	$ 35.78	$ 99,826.20
8.75" x 21" x 15'	210	15	$ 35.78	$ 112,707.00
12.25"x24"	189	30	$ 45.00	$ 255,150.00
PT Beams				
(2) 2.5" x 12"	224	30	$ 8.84	$ 59,404.80
10.75" x 12"	112	30	$ 29.82	$ 100,195.20
PT Cable	70	110.25	$ 2.50	$ 19,293.75
Columns				
18"x18"	252	10	$ 74.75	$ 188,370.00
CLT Slab				
5-Ply	5	28800	$ 15.00	$ 2,160,000.00
Concrete Topper				
2" Topper	5	178.13	$675.00	$ 601,200.00
Total Building Cost				**$ 3,596,146.95**

Insights: Cooperation vs Collaboration



Team B Cooperative 4D Model

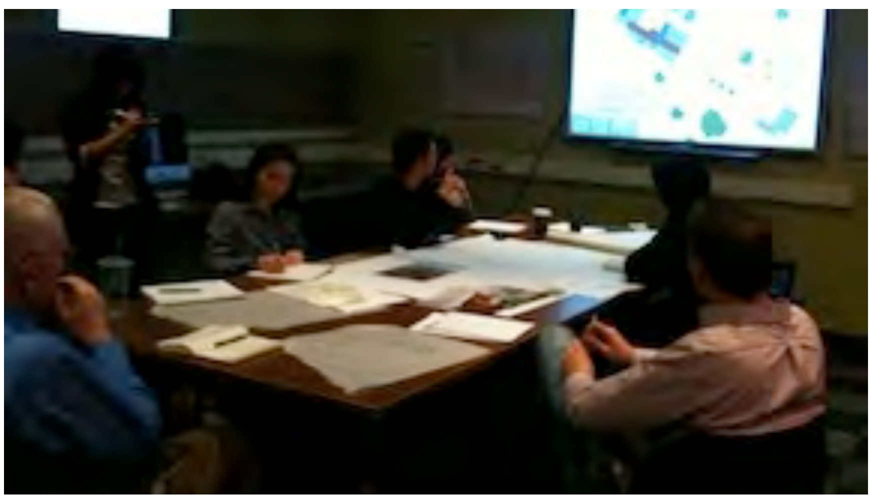


Team A Collaborative 4D Model

Insights: Spaces Reinforce Norms

- **Teams differed significantly**
- **Collaboration norms established early**
- **Co-ownership in design**
- **Strong relationship between space usage and interaction**

"It is not only a matter of appropriate hardware and software, but also one of appropriate digital studio layout to facilitate collaborative team work."
- Bob Holland



Examples: Communicating Analysis

Final Review Cost Analysis

SUPERSTRUCTURE	Total $	$/SF
1-Bedroom	$ 5,635,649	$ 151
Studio	$ 3,442,912	$ 143
Penthouse	$ 330,441	$ 105
Amenity	$ 313,584	
Roofing	$ 752,987	
Conveying	$ 397,575	
Exterior Finishes	$ 619,355	
Landscaping	$ 432,740	
Logistics	$ 912,400	
Subtotal	$ 12,837,643	
SUBSTRUCTURE		
Podium	$ 4,542,838	$ 210
Subtotal	$ 4,542,838	
Total	$ 17,380,481	
Overhead	$ 2,350,680	
Approx Total	**$ 19,731,161**	

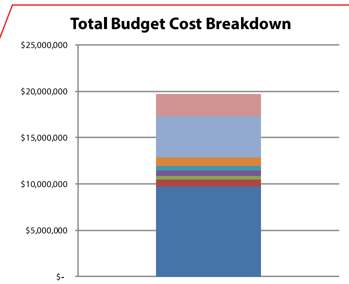


Figure 1. Total Cost Breakdown with Total Budget Bar Chart

Total Units		135
Total Modules		216
Residential Area		64572
Commercial Area		6100
Amenity Area		1771
Total Assignable		66704
Usable Area		107389
Assignable:Usable		62%
Modular Budget	$	9,722,586
Substructure Budget	$	4,542,838
Total Budget	$	14,265,424
Transportation Cost	$	556,000
Total $/ Usable SF	$	151
Modular Budget:Total Bud		68%
Total Annual Rent	$	2,416,982
Years to Return		8

Figure 2. Final Low Rise Data Table

1-Bedroom Cost Breakdown	Quantity	Unit	$ / SF	Total	Assumptions	Percentage
1 Bedroom	526	SF	$ 151	**$ 79,375**	Unit is made up of two modules.	100%
Structural	1	LS	$ 11	$ 5,950	See Breakdown Below	7%
Finishes	1	LS	$ 15	$ 7,910	See Breakdown Below	10%
Mechanical-HVAC	463.5	SF	$ 21	$ 9,683	See Breakdown Below	12%
Electrical	463.5	SF	$ 20	$ 10,491	See Breakdown Below	13%
Plumbing	1	LS	$ 27	$ 14,046	See Breakdown Below	18%
Exterior Enclosure	1	LS	$ 27	$ 14,179	See Breakdown Below	18%
Bathroom	1	EA	$ 21	$ 11,305	See Breakdown Below	14%
Kitchen	1	EA	$ 11	$ 5,812	$/SF is based on Kitchen total dependent on the SF of the entire 526 SF	7%

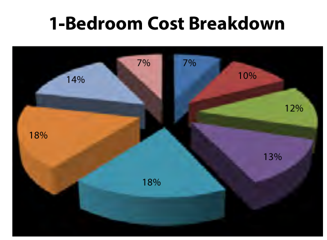


Figure 3. 1-Bedroom Cost Breakdown Table with Pie Chart

	SR85	SR125
CHARRETTE	$ 21	$21
CYCLE 1	$ 17	$25
CYCLE 2	$ 17	
CYCLE 3	$ 24	
FINAL REVIEW	$ 20	

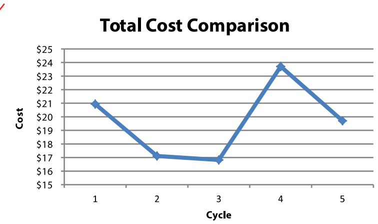


Figure 4. Total Cost Comparison Table with Line Graph

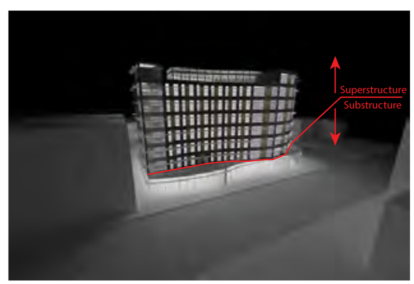
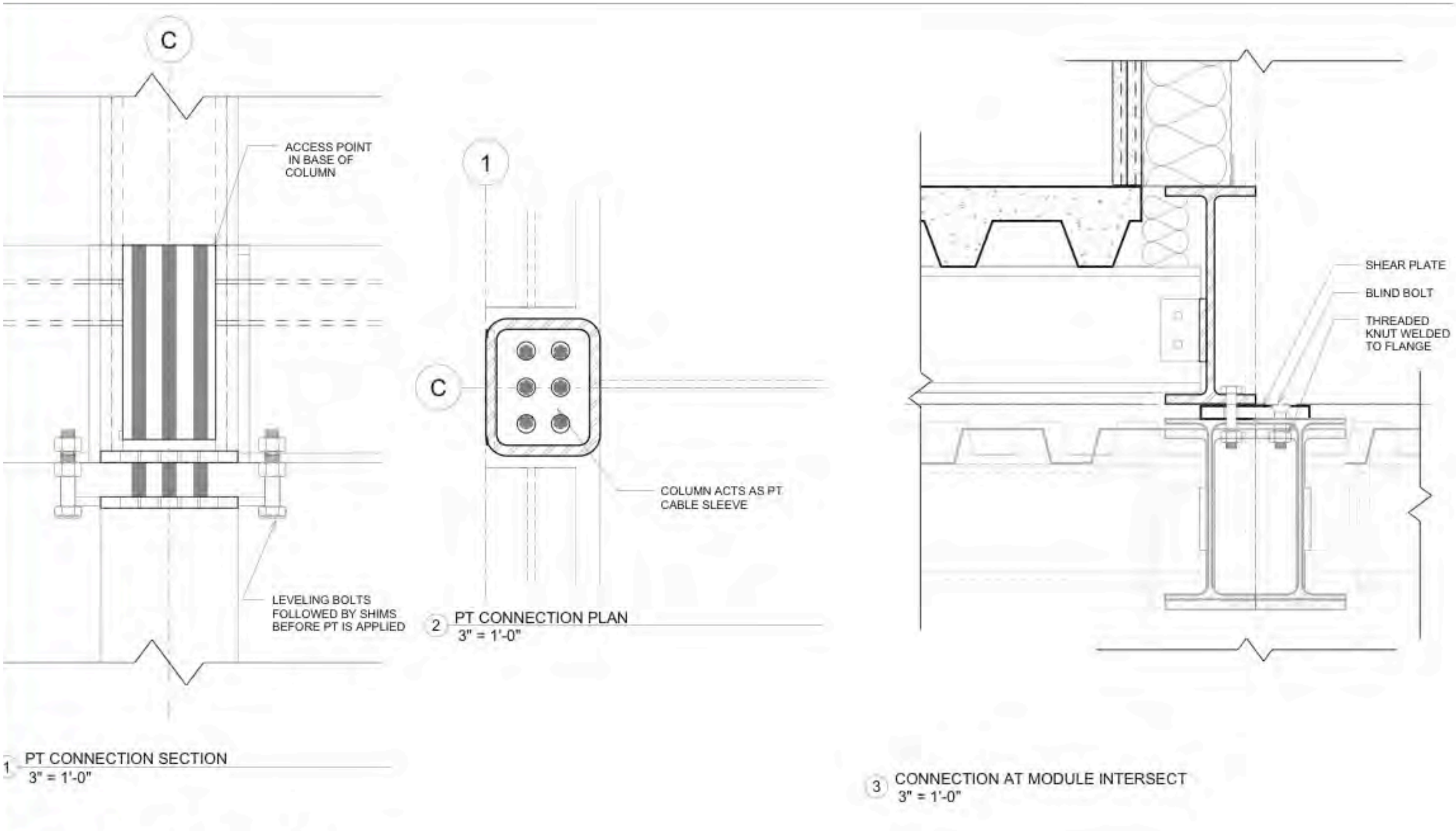


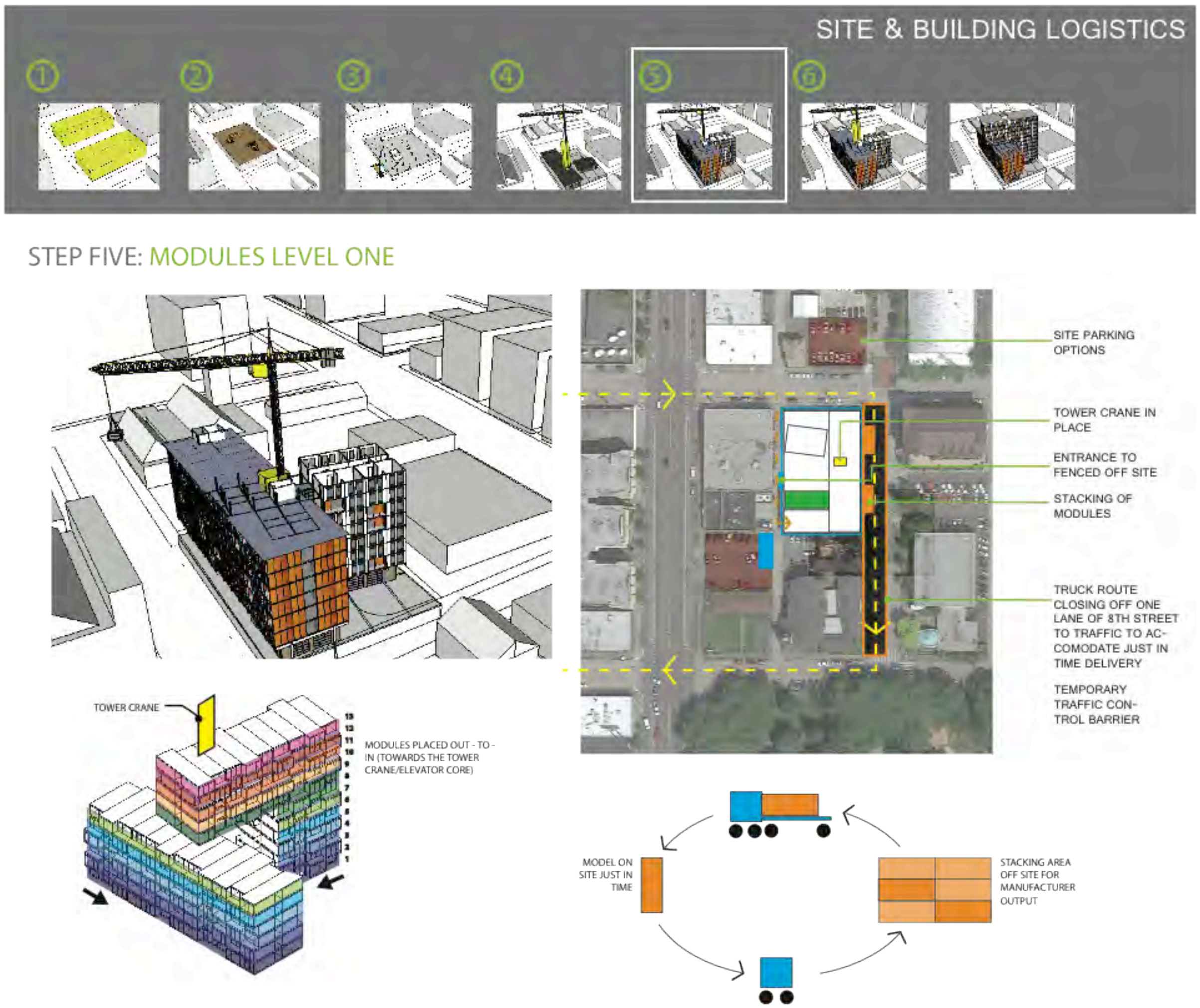
Figure 5. Superstructure and Substructure

Narrative:
Final Review Cost Analysis has taken all of the research done thus far and modified costs to match all assumptions, and re-designs. Assumptions include: 10% reduction for all factory/ modular offsite work (Figure 5), deduction of Walkable Skylight, corrections to structural costs to match agreed upon materials, corrections to exterior enclosure to match agreed upon materials (Figure 3), and corrections to Transportation to account for shape of modules and transportation of of two modules for 1-Bedroom, Penthouses, and two Amenity Spaces (Figure 2).
The changes mentioned above not only made our estimates more accurate, but reduced our costs significantly from $23.7 million to a total of $19.7 million with inclusion of Overhead (Figure 1).
Figure 2 also depicts that our total Assignable and Usable Areas have decreased due to more accurate design take-offs. Even though these areas have been lost we have gained costs in Landscaping costs (Figure 1) which include Green Roofs, Bio-Swales, Trees, and interior Atrium Green Mounts. What we have sacrificed in cost and usable and assignable area we have made up in designing a friendlier community space which exihibits a sense of welcome inside and out.
We have also gone back and took a look at our past cost estimates and came to find out that we have been on quite the adventure. As Figure 4 shows, we have abandoned the High Rise - SR 125 option and continued on with the Low Rise - SR 85. The biggest change in cost occured between Cycle 2 and Cycle 3 when our modular structural system, exterior enclosure system, and transportation took on high $/SF and miscalculations. Through this Cycle we have learned that there is always room for data, design, and assumptions to change and improve. At this stage in our studio project development we have achieved a reasonable cost for modular Low Rise construction, at $151/SF of total cost, with an amazingly low return rate of 8 years (Figure 2). The data presented here represents our best and final numbers for the project at hand, as well as our understanding of the entire project itself. This project has given us an interesting perspective of all components and key players that are involved in the Design-Build process. The amount we have learned as a team is exponential, and will be extremely useful in all of the different fields that we will be pursuing individually.

Examples: Communicating Details

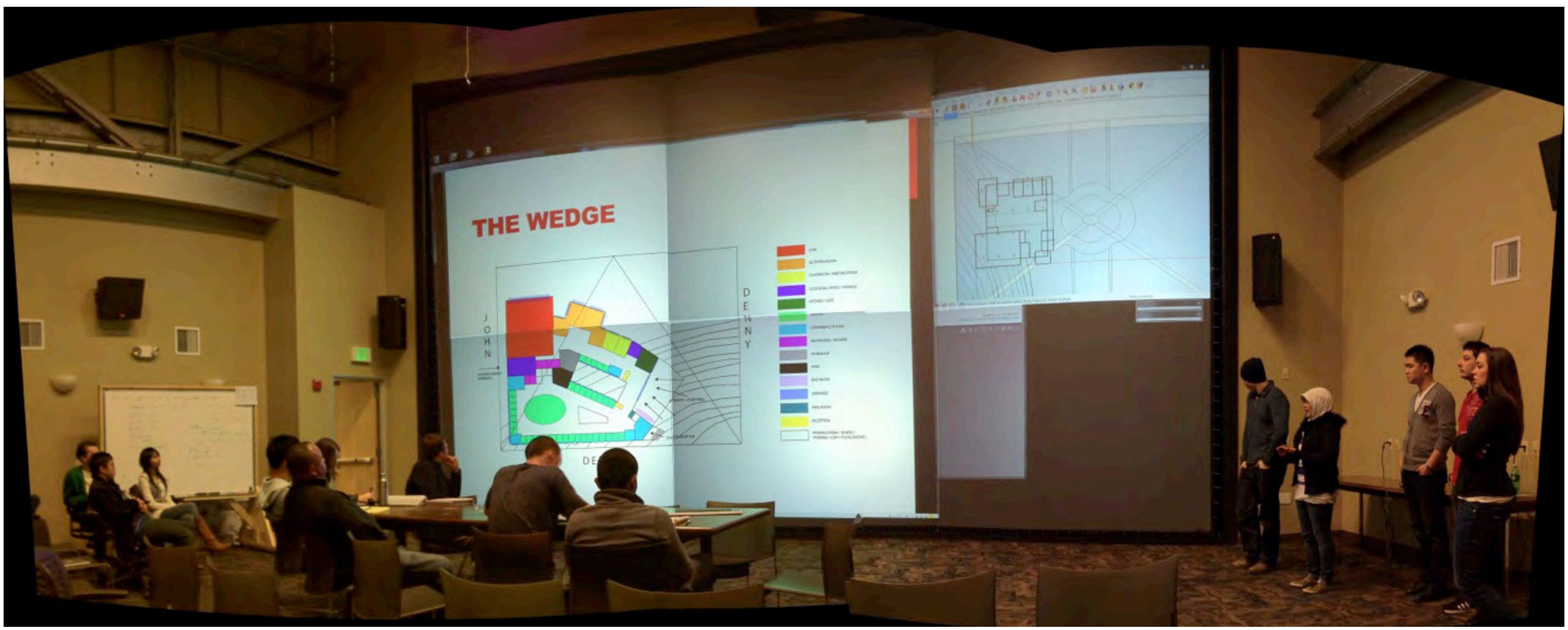


Examples: Communicating Constructability



Presenting to Industry and Instructors

CHARETTE CONCEPTS 1&2 | CYCLE 1 HORIZONTAL L | CYCLE 1 VERTICAL L | CYCLE 2 7D MODEL | CYCLE 2 NEW EXTERIOR MODEL | CYCLE 3 DEEP DIVE | FINAL CYCLE



The UW Integrated AEC Studio:
Pedagogy, course structure, and insights from 2009 - 2016

Ann Marie Borys (Architecture)
Kate Simonen (Architecture)
Carrie Sturts Dossick (Construction Management)
Chris Monson (BE Ph.D.)

COLLEGE OF BUILT ENVIRONMENTS

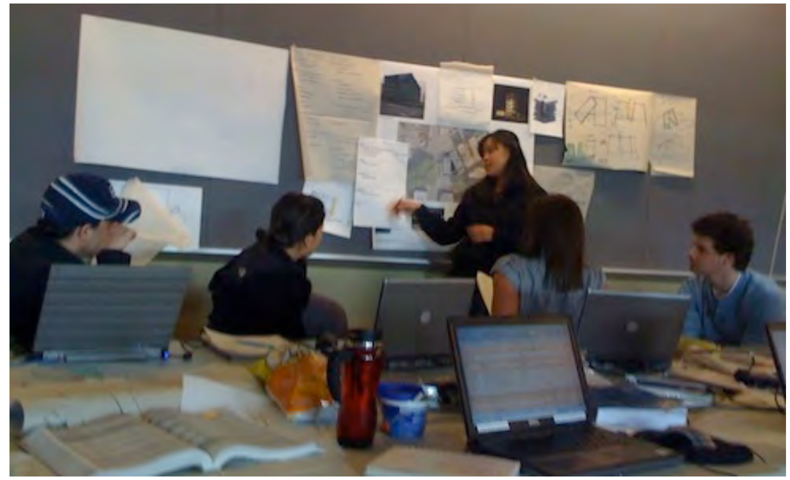
Complexity → Interdisciplinary Learning

More than one discipline

Methodology

Language

(Schaffer et al. 2008; Orr, 2006)



Interdisciplinary studio (lab) design courses

(McCuen & Fithian 2010; Dossick & Pena 2010; Holland et al. 2010; Dib & Koch 2010; Gardzelewski et al. 2010; Salazar et al. 2010)

Interdisciplinary Work

"design as a social process"
(Bucciarelli 1994)

develop shared mental models collaboratively
(Orr 2006)

A move away from cooperative approaches
- division of work into independent parts (Smith et al. 2005)

Collaborative interdisciplinary learning
- unstructured processes
- negotiate goals,
- define problems,
- develop procedures, and
- produce socially constructed knowledge

(Goldsmith & Johnson 1990, Dorsey et al. 1999)