From Integration to Embodiment: An Evolving Approach to Teaching Design and Building Technology

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ABSTRACT: *This paper explores how an expanded notion of 'embodiment' can provide a conceptual and pedagogical framework for teaching the integration of building technology and design, particularly in the context of comprehensive studios in professional architectural programs. Drawing on the rich discourse around the term embodiment in the humanities, architectural theory, and contemporary sustainable design, we argue that our understanding of embodiment can be expanded to include notions of embodied practice, aesthetics, and knowledge. After outlining this conceptual framework, we go on to discuss specific pedagogical goals and share examples of assignments and student responses from recent iterations of the comprehensive studio at our university. We identify four areas of focus that support a more embodied approach to architectural education: 1) generative models, 2) the problem of the section, 3) assemblies of exchange, and 4) deep specifications. Reviewing each of these areas in terms of their potential to foster embodied forms of design, we outline a set of frameworks for future development of comprehensive building design sequences, and for architecture curriculum in general.*

KEYWORDS: Design, pedagogy, embodiment, building technology

1. INTRODUCTION

The hiring of two new tenure track faculty members in the area of design and building technology in our department has become a catalyst for redesigning the comprehensive studio sequence and rethinking the relationship between design and building technology more generally. At the same time, the sudden transition to remote teaching in response to COVID continues to reverberate through the academy, spurring us to reconsider what was gained and what was lost during these disruptive years. Furthermore, the multiple crises facing the discipline – climate change, architecture's role in perpetuating inequality both within the profession and through its output, and the ongoing disruptions of the digital age – demand new and more engaged frameworks for the conceptualization and practice of architecture and architectural education. These challenges become even more important in the context of building technology, where architecture makes its final affirmative transformation from ideas to materials. In response, our evolving approach to teaching design and building technology, most notable in the comprehensive studio sequence, embraces the reciprocal idea that technical considerations and constraints can be generative opportunities for design and that the technology of building can be understood as rich territory for creativity, expression, and meaning. To capture this, we propose adopting an expanded notion of 'embodiment' as the conceptual framework to understand architecture as a dynamic process situated within the nexus of material, energy, labor, capital, and culture.

There is a rich discourse related to the term embodiment in the humanities and social sciences. Broadly speaking, it refers to a shift in perspective from overly abstract, rational frameworks to more unmitigated, felt engagement with the material world in all its vibrancy and insistent material properties (Bennett 2010, Ingold 2007). In contemporary architectural discourse, this term has become most closely associated with the concepts of embodied energy and embodied carbon, concepts that refer to an accounting of the environmental impact that accrues in the processes of making a given building material or product. (Benjamin 2017, Moe 2021). While the idea of embodied energy and carbon is an important emerging framework, we argue that there is more to mined from the notion of embodiment in the context of teaching building technology and design.

Just as embodied energy opens the possibility of comprehending the multiplicity of energy expenditures contained within a building, an expanded notion of embodiment opens the possibility of comprehending the multiplicity of other relationships endemic to an architectural work. This includes understanding embodiment within the framework of aesthetics and knowledge, as well as an expanded understanding of embodied labor, embodied culture, and embodied building and form. It also offers a framework for thinking about the making of architecture through notions of embodied practice. Crucially, viewing architecture through the lens of embodiment compels us to see buildings not as static objects, but rather as conditioned artifacts situated in a complex set of relationships with history, culture, technology, materials, and processes of making. With respect to building technology and design, this compels us to see technical details and technical resolution of architecture as opportunities for further engagement with this embodied nature, rather than merely functional solutions.

2. EMBODIMENT IN CONTEMPORARY ARCHITECTURAL DISCOURSE

Writing nearly forty years ago, Alberto Perez-Gomez diagnosed what he saw as the shortcomings of then contemporary architectural education and practice as a problem of embodiment; namely a failure to recognize and appreciate the extent to which architecture is, fundamentally, a form of embodied knowledge and therefore, an embodied practice (Perez-Gomez 1987). For Perez-Gomez, architecture is necessarily an interdisciplinary endeavor that derives value and meaning in the contemporary era by adopting a critical stance towards culture, thereby generating knowledge. Knowledge (as opposed to mere data or information) is something that grows out of an active interaction with the material world. Architecture's engagement with knowledge is two-fold: first, it generates knowledge through its function as a creative practice, and second, it materializes this knowledge, embodies it within itself, within its material form. Through architecture, material is given meaning, and that meaning is in turn embodied in the physical form of the building. The technology the architect chooses becomes a critical hinge in this double articulation. Writing at the cusp of the digital revolution, Perez-Gomez pushed back against the premise that technological systems that seek to

> "functionalize, control and manipulate variables in order to attain greater efficiency and economy…can easily be put to work in the name of humanist values…[rather] the self-referential values of the system (efficiency and economy) invariably dominate production" (ibid., 57).

Instead, Perez-Gomez implores:

> "The architect's work confronts technology with desire and thus explores the true potential of new materials. It is by definition new because it is not preconceived; it is a discovery occurring at the intersection of the potential abstraction inherent in modern consciousness with the ground of figuration inherent in the human body itself" (ibid., 58).

Writing three decades after Perez-Gomez, Stephen Kieran similarly diagnosed what he saw as the shortcomings of so-called sustainable architecture as the lack of a robust environmental *aesthetic*. An environmental aesthetic is derived from direct engagement with the natural world, forging relationships that are essential, integrative, and not overly abstracted. Opposing this, Kieran identifies an "additive culture of innovation" (Kieran 2008, 244) where technical solutions, each responding to the problems created by the previous solution, accumulate within the built environment as an ever-expanding technical edifice, taking us, for instance, from the air conditioner to the hermetically sealed glass building to the high-performance envelope, and so on. While the resulting architecture might be "constructive, functional, and ethical" (ibid., 244) it lacks, in Kieran's mind, an *aesthetic* dimension. This results in an architecture that, despite our best intentions, is increasingly alienated from nature and natural systems, and perhaps more critically, undermines architecture's capacity to function as an aesthetic form and thus to "attract." This is to say, it undermines the capacity of architecture to inspire, to express our collective stories and aspirations, and to render visible the potential and consequences of our actions, activities, and interventions in the material world. The role of architecture to communicate through an aesthetic means is for Kieran "always more potent than force" (ibid., 246), outstripping the benefits from any incremental innovation.

In relation to sustainable design principles, the term embodiment has become most closely associated with the concepts of embodied energy and embodied carbon. Embodied energy, along with operational energy, provide a framework for quantifying the total energy (and by proxy carbon impact) of a building over its lifespan. Embodied energy has gained focus as buildings and mechanical systems become increasingly efficient and as we become more attuned to the carbon impact of the global supply chain of building materials (McDade, 2018). While the conceptualization and implementation of approaches to quantifying embodied energy and carbon is of unquestionable importance, in recent years several architects and scholars have argued that notions of embodied energy should be expanded beyond the mere numerical calculation of energy and carbon to be a critical lens to understand the ways a building, and the material components of which it is made, are situated in the world through their making, use, and ultimate disposal (Andraos 2017, Benjamin 2017, Moe 2021). As Amale Andraos puts it,

> "embodied energy renews architecture's commitment to an engaged worldliness – an engagement without which architecture loses its chance for reinvention, relevance, and even existence" (2017, 8).

To understand the embodied energy of a building compels an understanding of the building not as a singular object, but rather as a participant in an expanded, dynamic process. As Andraos further elaborates,

> "embodied energy connects the smallest part of a building to territories of extraction, transformation, and transportation, rendering once and for all mute the possibility of architecture as an autonomous object. Instead, embodied energy reveals architecture's potential as a frame for registering multiple and overlapping scales of environment at once" (ibid., 9).

Taken together, the critical lens of embodied energy alongside an appreciation of embodied forms of knowledge and aesthetics, provide an expanded notion of embodiment within architecture; one that resituates architecture within an extended field and opens new readings of architecture and new opportunities for intervention. The existential crisis of climate change and broader recognition of human's planetary impact,

along with the recent, acute disruptions of COVID, have presented the opportunity to reformulate our relationship to the world. This entails a fundamental recalibration of our relationship to technology, one that engages technology not just as a sequential set of solutions (which it undoubtably is) but also in its social and poetic dimension, and as a historically contingent framework that guides how we, as humans, situate ourselves in the world. This is to suggest that for architecture, perhaps the most important point of creative and expressive exploration is at the intersection of technology and design, for that is where perhaps most effectively, we can reconstitute our relationship to the natural world and to ourselves.

3. EMBODIMENT AND ARCHITECTURAL EDUCATION

This expanded notion of embodiment has become a critical and catalytic tool for examining the ways in which we teach the integration of building technology and design. Building on the work of educators who have developed pedagogy aimed at integrating building technology into the design process in a vital way (Armpriest 2017; Albright et al. 2019), our approach grows out of an ambition to foster a more sophisticated approach to sustainable design that incorporates the cultural and poetic dimensions while better accounting for the complex interrelationship between the built environment and the planet.

A key point of focus for this curricular development has been our comprehensive building design studio, which comprises of a two-course sequence over two semesters. The first, Graduate Design IV, engages students in the design of spatially and programmatically complex public building. The second, Integration Studio, engages students in further design development and technical resolution of the studio project and seeks to enable students to think through a fully integrated building solution from site to detail. Building on the theoretical framework provided in the previous section, we have identified four areas of focus in the continuing development of our comprehensive building design sequence: 1) generative models, 2) the problem of the section, 3) assemblies of exchange, and 4) deep specifications. Each of these categories articulate a set of goals, challenges, and problematizations that organize and motivate our pedagogy in relation to the comprehensive building design studio and in the teaching of building technology in general. They are outlined below, with student work provided to better illustrate our approach and goals.

3.1 Generative Modeling

At the core of an embodied practice is an emphasis on the development of generative models. A generative model is not a thing but an iterative process, an approach to making that draws out conceptual ideas, while imprinting material forms with meaning. It provides a framework for “thinking with our hands and our gestures” (Perez 1987, 58). As Mark Lee and Sharon Johnston recently observed, generative modeling should be iterative and engage “in-between conditions – between idea and building, material and immaterial, problem and solution” (2022, 57). As they further outline:

> “A model is not simply a model. It never stands alone but is always part of a larger iterative set, whether the others are present or not. A collection of models is always greater than the single model because it is through the collection that *the model as an idea is measured against the model as a physical form*.” (ibid., 61, emphasis added).

Generative models grow out of a reciprocal process of material experimentation and critical evaluation, building an embodied knowledge progressively through the process. The advantage of founding a design process on generative models is two-fold: first, it foregrounds material practice at the outset, framing the design process in material articulation; and second, it fosters a mentality and a set of design frameworks that are assertively open-ended, and thus can adapt as the myriad constraints (structure, mechanical, code, constructability considerations, cost, user-requirements, etc.) are brought into the process. In other words, the goal of the studio is not to produce a form or idea, but rather a process. This notion of generative modeling represents an embodied form of practice, where architectural ideas emerge through the experimentation with actual, physical material forms, and thus these ideas are constructed as intrinsic to these forms (and vice-versa).

A useful point of reference for introducing students to the practice of generative modeling as an embodied practice is the artist Richard Serra and his Verb List (1967). Consisting of a handwritten list of actions (“to lift”, “to spatter”, etc.), the Verb List conceptualized an open-ended, but highly specific and deeply embodied form of practice that underpinned Serra’s formative early work. By applying a kind of creative combinatorics, Serra engaged a given material with a specific action of his body: lifting rubber, splattering lead, and so on. For Serra, the verbs are “actions to relate to oneself, material, place, and process” (MOMA, 2022); they are way to locate one’s creative process in relation to the physical world of action.

Figure 1. Graduate Design IV Student Work: Generative Models – from Concept to Façade Studies. Image by Erica DeWitt + Lincoln Nemetz-Carlson (2022)

In a recent iteration of the Graduate IV design studio, we used the Verb List as a point of departure for the design of a new building for the United States Mission to the United Nations in Geneva Switzerland. A particularly successful example of this approach can be found in a student project that took the action “to join” as a framework for thinking through their approach for integrating the diverse programmatic requirements. Starting with a simple idea of stacking different programmatic strata, their project evolved and grew more sophisticated as they embraced the idea of wood joinery as a conceptual and material framework to think through the complex requirements and ambitions of the project. Rather than static objects, these generative models operated as a set of material configurations that could be tested and explored to achieve different effects. At the same time, the students’ proposal began to take shape as a critical response to the US embassy building in Athens designed by Walter Gropius. The generative model became a tool for critically assessing the closed, introverted nature of the courtyard typology of the Athens’ building by enabling the students to unlock the courtyard with more nuanced, permeable boundaries. This idea extends from building massing to the details of a system of modular façade screening elements. The physical boundary of the building and the threshold between the exterior and the interior of the courtyard begins to function like a filter that integrates rather than an envelope that “systemically segregates” (Kieran 2008, 245). The proposal goes beyond the “functional fact of integration” (ibid., 245) and suggests an architecture that embodies a critical stance towards material, culture, history, and technical constraints. Understood within the broader pedagogical goals, this project illustrates an approach that engages material properties in the design at the outset while engaging these material systems as a set of possible configurations that help negotiate the space between architectural ideas and architectural form (Lee 2022).

3.2 The Problem of the Section

Writing at the cusp of the digital revolution in architecture, Perez-Gomez could be considered uniquely prescient in anticipating many of the challenges we face as a discipline and in design education. Chief among this is the tendency to conflate information with knowledge and to let fluency with information occlude the creation of true knowledge.

> “Computers may indeed allow the architect to have at his or her fingertips all the information one needs […] but the fundamental problem of meaningless will still prevail” (Perez-Gomez 1987, 57).

One place where we see this play out in contemporary design education (and practice) is in the section, particularly the conceptual discrepancy between a section that is constructed and a section that is derivative. The section is a unique, critical tool for creating architecture. More than any other analytical drawing type, it is the section that most provocatively engages the core functions of architecture.

> "The architectural section is the key to architectural innovation […] the section is the site where space, form, and material intersect with human experience, establishing most clearly the relationship of the body to the building" (Lewis, Tsuramaki, and Lewis 2016, 6).

The section is the tool that enables architects to think through these essential relationships, both conceptually and technically. As such, it is the critical framework where there is the greatest opportunity for the integration of the various functions, both practical and poetic, required of contemporary architecture. This is particularly true of sustainable architecture. There is a way of understanding the problem of sustainable architecture as a problem of the section: the section reveals materials and the relationships between them and, most critically, defines the relationship between the interior and exterior, the threshold between the building and the environment. This can be a practical question about the way a wall assembly manages environmental factors like heat, water, and light, but it can also be a conceptual question that directly targets the essential relationships between humans and their environment. It's also the site that is most apt to respond to Kieran's injunction to think about filters rather than envelopes. For Kieran, an environmental aesthetic depends on an embodied relationship with context and environment. This requires interrogating the separation between interior and exterior as a filter that "selectively integrates rather than systematically segregates" (Kieran, 245). The rich potential of the section is often lost when section drawings are merely derived from other sources (e.g. BIM models). It's the difference between something found and something created, between information and knowledge. With this in mind, we have introduced a number of exercises to interrogate this discrepancy and help student develop an understanding of the constructed section as a critical, and potentially revelatory tool for architectural design both at the scale of details and the scale of buildings.

The first assignment in Graduate Design IV was an in-depth precedent analysis focused on section and exterior facade details. Instead of an outside-in approach to precedent analysis, this was an inside-out approach that privileged the façade as the critical lens for understanding a building as a whole. The goal was to ground students understanding of a precedent building through the section and set the stage for seeing technical details as a site for architectural meaning. In a precedent analysis assigned in Design IV studio, students were tasked with building three-dimensional, "bas relief" style section models. Starting with an existing section of their precedent, students had to build the section up from the two-dimensional space of the paper. The translation from drawing to model and the purposeful pace of physical modelling compelled a different level of engagement and understanding of the section. As before, it grounds students' understanding of the building through the section and prioritizes the relationships embodied in the section as the critical architectural relationships.

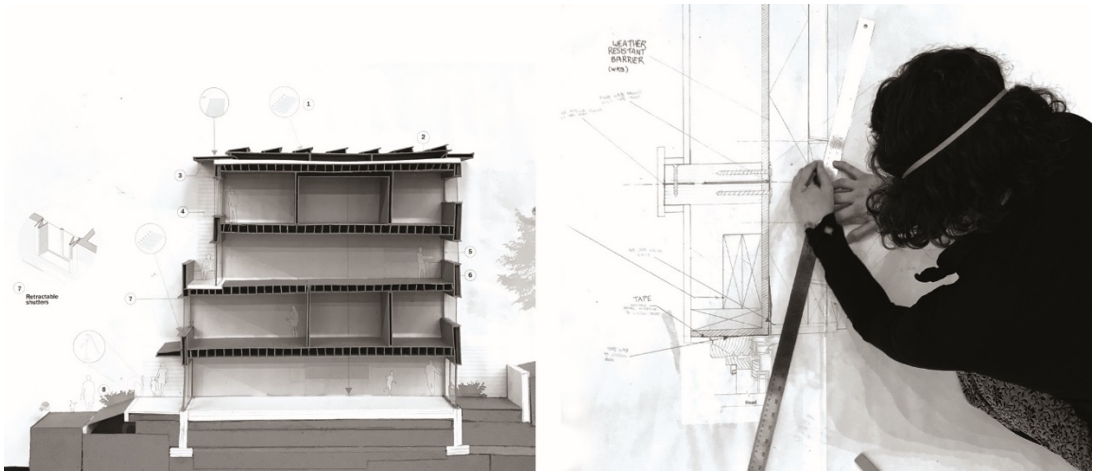

Figure 2. Design IV Student Work: "bas relief" section models. Astudent literallyembodied in full scale sections

Continuing this trend at the scale of details, in an assignment titled "Section Forensics" in the Integration Studio, students were challenged to draw a full-scale section of an assigned building on campus. This required students to visit, observe, document, and finally deduce the composition of the wall section. The explicit goal was not for students to get it exactly "right", but rather to construct a drawing that could be right. The assignment sought to build relationships between the physical, embodied world and the space of drawings, and to encourage the understanding of the section as a critical tool for investigation. In another course, this

assignment was inverted such that students hand drafted full-scale wall sections of proposed designs. As see in Figure 2, the students were literally embodied within the space of the drawing. Taken together, this constellation of assignments is intended to engender an understanding of the section as a generative tool for the production of architectural meaning and embodied knowledge, rather than merely as a single, derivative artifact.

3.3 Assemblies of Exchange

Extending the exploration of the potential of the section to engage the threshold between the building and the environment, our approach to teaching building envelope design emphasizes the role of the building envelope not as a separator, but rather as a territory of exchange that negotiates the thermodynamic, atmospheric, biotic, and cultural environments inside and outside of the building (Kieran). Furthermore, the building envelope represents a site of technical and aesthetic intensification. When handled right, the conceptual and performative ambitions of a project can be fully embodied and an *aesthetic* – in Kieran's sense of the word – can emerge; if not, these will inevitably be drowned out in a myriad of conflicting solutions and functionally expedient decisions. This becomes particularly evident in the context of high-performance building envelope systems, where the performative and technical criteria exponentiate and often overshadow the expressive opportunities of the envelope.

An engagement with building envelope design is incorporated throughout the comprehensive building design studio sequence – including an initial façade precedent analysis and a series of conceptual façade modeling exercises in the Graduate Design IV studio, as well as the development of a series of detailed envelope drawings in the Integration studio. A key part of this exploration, particularly in the later design development exercises include the use of multiple/hybrid drawings that combine orthographic views and/or 2d and 3d detail drawings. The intent of these drawings is to help the students interrogate the assemblies they are developing from multiple points of view and frames of reference and to understand these assemblies as robust systems of three-dimensional elements that must be assembled in a coherent way. We have found that these hybrid drawings, particularly the 3d "chunk" drawings done at the detail scale, help the students overcome the inherently abstract nature of detail drawings, and begin to engage the underlying material and geometric characteristics of the elements in their proposed assemblies.

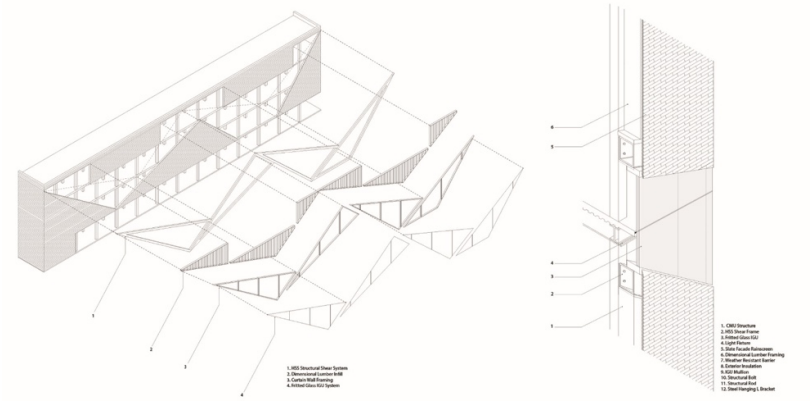

Figure 3. Integration Studio Student Work. Aerogel Façade Panels Image by Kamil Quinteros (2021)

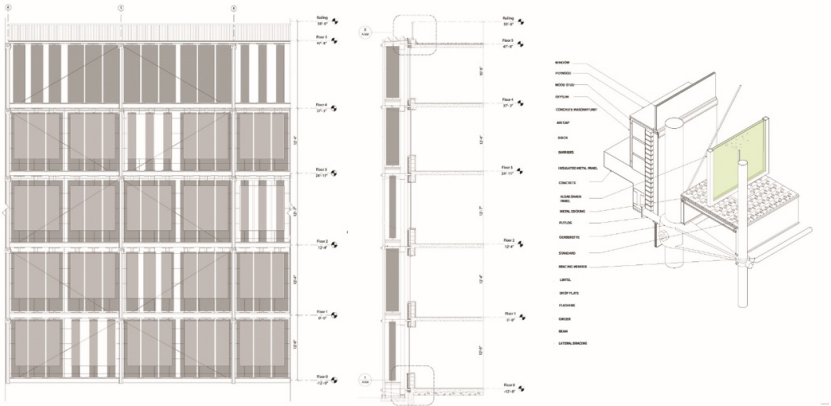

Figure 4. Integration Studio Student Work. Dynamic Algae Fin Façade System. Image by Carly Regalado (2021).

A recent iteration of the Integration Studio focused on the adaptive reuse of an existing academic building on campus. The existing building, constructed in the 1970's, was characterized by a monolithic, underperforming masonry façade with limited apertures. Responding to this existing façade, students developed proposals for the integration of high-performance façade systems as a key part of their overall design. Proposals included large-scale aerogel window inserts (Figure 3) and a system of movable fins that held algae growing containers (Figure 4). As the students developed their designs later in the comprehensive studio sequence, they were challenged to consider the limitations and potentials of the existing masonry façade. Rather than strip the building down to the structure, several students explored the potential to make more surgical interventions into this façade, opening questions about how to improve its thermal performance and introduce more apertures while respecting the constructive logic of the existing masonry system. The constraints and material realities of the existing building forced the students to address the building in a direct way, and the drawings became a framework to interrogate the conditions of the existing building, and to develop a set of strategies for integrating their proposed interventions into the façade. For the algae fin proposal, the student developed a scaffolding approach that created a steel superstructure that tied into the existing concrete structure that both supported the fins and provided lateral support lost through a series of window openings in the existing CMU walls. For the aerogel proposal, the student envisioned a system of steel frames that bridged across the large window penetrations. This student developed a large-scale axonometric drawing to determine which sections of CMU could be saved and used a set of 2d and 3d detail drawings to understand how the existing and new assemblies came together. This approach allowed students to gain a tangible, embodied understanding of the material systems at play, and to begin to manipulate them to achieve the effects they sought out in their designs.

3.4 Deep Specifications

Alongside these exercises, we are also exploring pedagogy to empower students to make informed choices about the materials and products they incorporate in a building. This involves an engagement with an expanded conception of specifications to think about both the performance of materials and systems on a building, as well the broader impact of these choices on the larger ecology of extraction, labor, and energy that is involved in its creation and ultimate disposal. Embodied energy provides a starting point for quantifying the environmental impact of different material choices, however, as Stephanie Carlisle has observed, these numbers, taken on face value, do not tell the full story. As she points out: "Embodied energy is a proxy, like transportation distance or recycled content – a stand-in for a host of relationships and end-point measures that are much more complex and meaningful. Clearly, all megajoules are *not* created equal" (Carlisle 2017, 166).

Life Cycle Assessment (LCA) provides a much broader analytical framework to track the processes and flows of material and energy in the production of a given product, pushing beyond information to generate knowledge about these materials and their history, supporting "deep thinking about materials and places" (Carlisle 2017, 174). And while the complexity of buildings makes LCA a challenging enterprise for architects, its deeper potential is made evident when we shift from an emphasis on determining an absolute quantification of environmental impact of a given set of materials or products, and instead employ LCA as a "means and method to explore a richer narrative about the full history of materials" (Carlisle 2017, 174), and as a "provocation rather than a solution" (Benjamin 2017, 15). Ultimately, as Carlisle reminds us: "A closer examination of materials does not limit design: it empowers and grounds creative practice" (Carlisle 2017, 174).

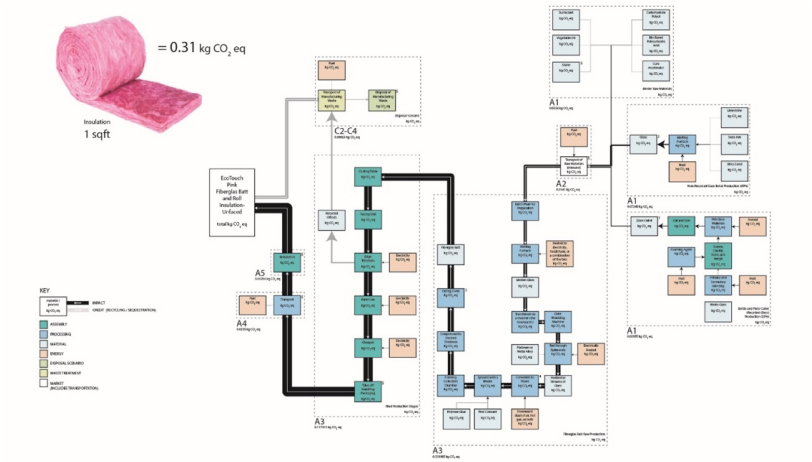

Figure 5. Carbon Mapping: Fiberglass Insulation. Image by Amanda Ferrante (Based on a diagram by Stephanie Carslile)

Our approach to introducing students to specifications was informed by this approach to LCA and a diagram created by Stephanie Carlisle. Building on Carlisle's graphic language, students employed the analytical methodologies of LCA to develop and understand the ways the global warming potential (GWP) accrues in each product. Students were tasked to take one material in their building envelope assemblies and create a carbon map of its production, from raw materials to delivery on site. Using Environmental Product Declarations (EPD) for each product, students broke the production process into a series of life cycle phases, and then further broke these phases down into specific extraction, manufacturing, and transportation processes. Using GWP data gleaned from the EPD and further refined through additional research and educated guesses about the energy requirements of various processes, students were able to develop quite robust maps of their products and a strong intuitive understanding of the relative GWP contributions in the history of the products production (as illustrated by the line weights of the energy flow lines). This in turn, provided the students with a framework to think about ways in which they can intervene in these processes and expand the scope of design from building in isolation to a deeper understanding of how that building and its material systems operate in the world, and to extend their understand their building designs as fully embodied forms in the world.

4. CONCLUSION

The four approaches outlined in this article represent a set of principles and frameworks for a pedagogy of embodiment that is still very much a work in progress. They have grown out of intuitive responses to a variety of challenges in the contemporary academy including broad disciplinary shifts in response to the ongoing digital revolution, mounting social, political and environmental crises. We view these approaches as tactics to help students engage in the increasing and unavoidable overlapping of technology, aesthetics, culture and nature, emboldening architecture in its historic role to give meaning to our material world. Ultimately, we view the turn towards embodiment and embodied forms of knowledge in an expanded sphere as a shift that engages architecture with the specific constraints and forces that face the discipline, but also with a much broader set of discourses, from the humanities to the sciences, that will ensure architecture's relevance in a rapidly changing, increasingly complex world.

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