

# PH01:BRK: Potentials of Teaching Building Science through Design-Build

**CHARLES MACBRIDE**

University of Texas at Arlington

**ROBERT ARLT**

South Dakota State University

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**The construction of a certified passive house in a rural, red state signals the successful completion of a case-study project that has had far-reaching effects beyond initial expectations. Instituting passive house principles into the curriculum of a newly established professional degree program was highlighted by the design, construction, certification, sale and monitoring of this single-family home. And while the house is the most visible manifestation, the ongoing influence of the larger initiative may prove to be its most important legacy. This includes a solidifying curriculum that teaches passive strategies, environmental stewardship and professional responsibility, and further establishes the department's role in community design, leading by example in an underserved region. The cycle of certified houses, established by PH01:BRK, now seeks to enter a self-sustaining mode of developing projects.**

**The PHIUS certified PH01:BRK serves as a model to successor projects that hone technical, budgetary and curricular constraints while continuing the momentum established by the first house. This paper describes the initiative within a pedagogical context, as a forerunner of sustainable building within the regional building industry, and as a political marker in a state that rejects regulation and often the notion of climate change altogether. This cultural condition has even created a difficult framework for the continuation of the initiative within the university itself.**

**This paper also summarizes and speculates on the initiative as a unique pedagogical model for design-build studio and supporting technical and professional coursework. Students were exposed to many of the design challenges that we have come to expect from a design-build studio in terms of process, outcomes, and challenges. This does not diminish the student's effort and embrace of the project. It does, however, bring attention to the positive effects that have been seen in the resulting curricular and service roles of the department and the recognition throughout the community. This is especially significant in a rural state with no residential energy**

**code and negligible building code enforcement, suggesting issues that go beyond pedagogy and are measured against the region's cultural and sociopolitical landscape.**

## INTRODUCTION

From the outset, the new Department of Architecture at South Dakota State University (SDSU DoArch) had identified a rural and regional tradition of making and self-reliance that had been mostly lost. The value of craft, materiality and assembly was rooted in the place but, like much of the post-industrial first world, had been replaced with an homogenous, throw-away culture. The vision of the first professional school of architecture in the state focused on a return to making. It shouldn't be exceptional for students to construct things, rather it should be a natural path of investigation toward broader architectural ideas.

DoArch, now an accredited four-plus-two professional degree program, during its initial years built a student body with studios and workshops that supported this vision. In addition, a community design and outreach program established a dual, mutually supporting agenda, and examples of student projects designed and constructed across the state became an annual highlight. The connection between community design and design-build is a critical component in the pedagogy, leading to grant funding, award winning projects, and connections to industry. As DoArch grew alongside its student enrollment, the foundational discovery of tools and techniques matured into a complex connection between faculty, students, the professional community, and the university itself. Recognition of the department's forward progress was easily identified and promoted in the rural Midwest. DoArch was building an architectural culture in a state with only a small collection of service firms and a university without a history of design curriculum. The design pedagogy and teaching methodology, along with the particulars of a professional degree program, however, reside in an uneasy and occasionally adversarial position within the university, all while many of the regional professional offices have thrown support at the new graduates.

The most visible and widely acknowledged effort in the short history of DoArch is the Passive House Initiative. An awarded grant by the Governor's Office of Economic Development established a broad and ambitious effort to introduce curriculum,



Figure 1. Exterior view of PH01:BRK. Image: VONDELINDE.

provide student and faculty training, and most notably, begin a self-sustaining design-build program of student-designed, single-family passive houses. The first design studio following the acceptance of the grant produced what is known as PH01:BRK, a PHIUS certified house sold to private owners located near campus (Figure 1). The entire project was a learning process for all involved and continues to provide lessons, both positive and negative, as the initiative moves ahead. The pedagogical approach to design-build has been sharpened as the successor projects and other non-passive house related DoArch coursework evolves. There are several factors for this, and, like many initiative's goals, outcomes and specific research points continue to find new techniques and pathways.

As the construction of PH01 ended, the next cycle of design began with a second graduate studio. This class produced two distinct projects including PH02, a single-family house designed immediately adjacent and north of the first, plus a multi-family proposal. The coordination with a general contractor experienced in high-performance residential building utilizing SIPs enabled the studio to research new envelope strategies, pre-fabrication, and to focus more critically on issues of affordability (Figure 2). The site-specific constraints and shading from PH01 provided its own set of issues with regard to daylighting and optimization of solar heat gain. A large window and shed dormer

serve as a lightwell and holds the stair. Solar shading analysis and energy modeling conducted using WUFI demonstrated a dramatic reduction in heating load, improving upon the performance of the first house.

The third cycle of this design studio was completed with fourth-year undergraduates. The brief built upon the overall scope of the initiative by focusing on retrofit projects. Students were introduced to high performance and passive house principles through a series of case studies, testing that knowledge through speculative, "generic" retrofits of suburban houses. Students implemented methods for numerous housing types, styles, and eras that are found throughout the community and the regional upper Midwest including historical Victorian, craftsman, bungalow, four-square and split-level styles. A split-level house with good southern exposure and a tuck-under garage was ultimately chosen for continued group study.

Unlike established and better known design-build programs such as Auburn's Rural Studio or Kansas' Studio 804, the DoArch passive house initiative was not designed purely as a design-build project and is unlikely to find university support as an autonomous program. The initiative does, however, consciously describe the significance of engaging a broader spectrum of the region's building and design industry sorely in need of innovation

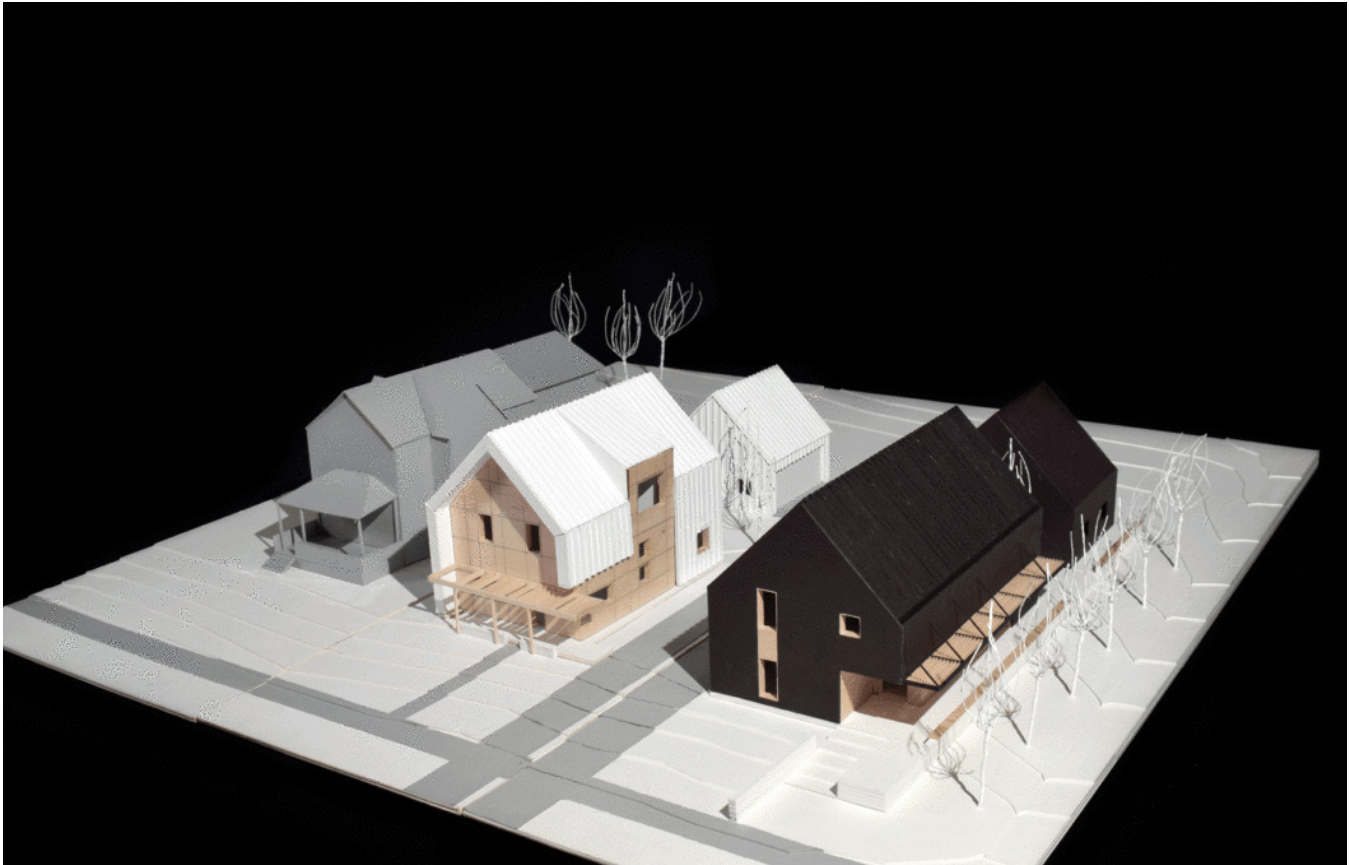


Figure 2. Urban Infill Models of PH02 (center) and PH01 (right). Image by author.

but without the “political will” to seek it out. The grant proposal describes faculty led studios that introduce passive house principles with local contractors completing the single-family house as a type of embedded workforce training. DoArch has supplemented these efforts with exhibitions, open houses, publications and workshops aimed to engage and educate the public.

### SYNERGIES AND EXPANDING CURRICULUM

At the start of the PH01 studio, the still developing DoArch program had completed just one full year in offering its complete six-year curriculum. The department continues to aggressively critique and alter the curriculum sequence; at the time, the passive house studio found synergy in the graduate level that brought both advantages and disadvantages. Offered in the sixth year, the biggest negative for students is that construction would not be completed by graduation. Due to the cold climate, “construction season” doesn’t even start until the spring semester is mostly completed. However, as written into the grant proposal, the “build” is intended for contractors and not students, an effort to expand the initiative into the workforce and local industry. This has had some success, at least in terms of awareness if not in increasing widespread adoption.

Internally, the pedagogy of the studio offered a counterpoint to a technology course and a professional practice course. Each

are positioned within larger sequences (typical for technology courses and less so for professional practice). The two-course technology sequence is divided into “Envelopes” and “Interiors” classes, the latter focusing on building science, interior environment, active and passive systems, and integrated systems. The four-course professional practice sequence, an unusual but highly effective pedagogy in itself, is based on the premise that practice and theory are inseparable. The four courses, each offered by different faculty, address fundamental “pro-practice” outcomes and are expanded as theory courses simultaneously. The sequence, Economy, Regulation, Stewardship and Management, has established a wider survey of environmental responses and ethical approaches that continue to evolve within the discipline. Passive House is one of many theoretical/technical approaches within the current condition of response to climate change, including professional certification, quantifiable metrics, and a design approach founded by five straightforward principles.<sup>1</sup> But neither the metric nor the singular building-as-precedent approach represent the only means for teaching. The Stewardship course teaches larger issues at urban and regional scales, alongside a critique of the multiple certification options and their resulting efficacy.

Another curricular sequence at DoArch is known simply as “workshop.” Initially, the workshop provided a complimentary

foil to the studio as a specifically focused semester of investigating a material property, assembly technique, representational strategy, technological process, or other condition especially related to a hands-on approach. Workshops often reinforced faculty research agendas, providing an outlet for experimentation while placing the students in the shop as a fundamental context for learning. The workshop supplements the studio but does not replace it. While the studio is the center of architectural education, assigning projects that address the broad range of cultural, technological, representational and professional criteria, the workshop is the sharply focused project in parallel, “digging deep” into one topic and delivered as a design investigation.

### VARIATIONS ON DESIGN-BUILD

DoArch initially identified a moment for design-build and community-based projects as part of the third-year undergraduate studio sequence. As a continuation of the community design projects introduced during year one, the third year has expanded the familiar site with outreach opportunities based around construction and installations. Quickly the success of this sequence connecting students and individual communities garnered recognition, both within the state and also as part of the academic personality of the department. Where the first year used community to teach basics of small town urbanism, studio fundamentals, documentation, and representation, the third year revisited the community with a design proposal in mind. A Precast Concrete Institute (PCI) grant funded design and construction of installations in three small cities across the state. Each, including unbuilt proposals, have been recognized and awarded widely. The recurring, site specific installations have settled into their respective communities as examples of student design and construction, with additional support and local industry partnerships.

The studio projects themselves developed the design and representational models at every scale. Drawings were produced for multiple audiences, including internal design reviews, public presentations, and shop-drawings and assembly details used by consultants and manufacturers. Studio was completed as group work. A single goal of the studio was to produce the models and documents necessary for construction. Similar to any typical design-build studio, these third-year students experienced a roller coaster of deadlines and presentations. Student led public review sessions with the community, planning boards, and other stakeholders is a powerful learning experience, defending and describing design work to an audience far different from a typical final jury. This underscores the heart of community design and design-build both, learning with your ears, releasing the ownership of projects, and negotiating compromise.

In addition, the lessons of design-build construction is an experience that introduces the humbling concerns of materiality with the cautionary rules of professional practice. The inefficiencies and mistakes from PH01 were certainly felt in this way, even as the “build” of the design-build model was left to the general contractor. The substitute for this became a third year follow up studio that produced a series of full-size construction mock-ups of PH01 alongside step-by-step fabrication drawing sets (Figure 3). The studio timing was perfect in that it occurred in the year after the PCI projects had been completed. The shift of focus toward passive house, still at an early date in the initiative, proved beneficial beyond expectations. Not only were the mock-ups a valuable learning outcome, but they became valuable to the contractors on the job site. Their inexperience with such tight construction detailing matched that of the students and faculty. The “cut-away” mock-up assemblies remain on display and were later recognized by the NAAB accreditation team for their value beyond just the studio that produced them.

The same third-year studio went on to design, construct and install significant pieces of PH01 (Figure 4). These include an exterior canopy covering the courtyard entry, the long upstairs guardrail balustrade, and the stair itself. The canopy combined a steel frame with a wood and polycarbonate roof, sheltering the outdoor space between the house and garage. The interior railing combined steel and basswood balusters that run the entire length of the upstairs landing. The steel supports were welded to an exposed wide flange beam that carries the upper floor framing. The stair itself is an L-shaped assembly of CLT treads suspended by oversized glulam stringers. Each of these three constructions were small group efforts within the design-build studio. The installation was delayed, allowing the actual house construction to catch up. The funding for this studio was supported by the passive house initiative, which continues to set an example of the potential synergy between studios in successive semesters, at different academic levels, working in concert on a larger project, and in coordination with faculty, contractors, consultants and community.

There is a strong argument to be made that this undergraduate design-build studio is actually the real design-build example when compared with the PH01 design studio that preceded it. There is also an argument for a better use of funding resources bolstering pedagogical goals when one compares the results. Certainly, PH01 is the project that provides a baseline example and case study that can thereby be improved upon in terms of budget, scope, schedule, program, performance, student involvement and outcomes. The design studio retains the responsibility for construction documents, energy modeling, site design, contractor and consultant negotiation. The design-build studio, by comparison, is the “utility” studio that provided the necessary construction phase follow through during the



Figure 3. Full size construction mock-ups for PH01:BRK. Image by author.

completion of PH01, simultaneously setting an example of design-build producing more with less. Of course, the latter studio was reliant on the initial project to exist at all, but as the self-sustaining cycle of houses continues, this supporting role offers a curricular example that teaches and mimics construction-phase issues without abandoning the studio setting.

As PH02 and PH03 began, each faced the difficult expectations of matching the success of the first, and each became the unsuspecting targets of additional constraints levied by the university and community. In addition, the changes in the scope and delivery of the successor houses has affected the continuity of the undergraduate design-build example described.

PH02 and PH03 were the second and third design studios in the initiative cycle. Each studio was successful in expanding the scope and potential of the initiative, and in engaging the students who have become increasingly interested in this now widely recognized DoArch project. Each of the houses have proceeded unfortunately with a decreasing level of support from the university with regard to construction. This is not a financial or budgetary issue, but a bureaucratic one as new administration

shifts autonomy away from the DoArch professional program. It is important to note that the university has in fact removed the ability of the research team to direct the design of these houses for fear of objectionable style or color choices, amongst other things. Additional burdens of forced collaborations and “spreading the wealth” have also effectively removed the resources needed for satisfactory research, construction or certifications.

### MERGING WITH BUILDING SCIENCE

The passive house project was introduced to DoArch faculty alongside other statewide initiatives that emphasized the teaching of building science and performance through the passive house principles. Other projects included a prototype income-qualified pre-manufactured home retrofitted to meet PHIUS certification. In addition, an incentive program for a multi-family passive house project that was designed and completed during the same time frame as PH01. The challenge to DoArch was to simply consider how passive house principles and teaching could be implemented within the curriculum, with a goal of introducing the next generation of young architects to better performing building and design strategies. The state and funding agency



Figure 4. Student design-build stair installation at PH01:BRK. Image by author.

were otherwise willing to let the pedagogical and teaching goals unfold as the grant initiative proceeded.

In the politically conservative upper Midwest, the mantra of passive house was presented in a way that favored long-life, low maintenance building practices over the “controversial” issue of climate change. Each approach immediately defaults to a belief in higher first-cost. The regional construction industry seems to consider their market too unsophisticated to pay for better performance or longevity and dismisses these new practices. This dilemma is presented as a topic to students as well. It frames an introduction to the socioeconomic condition of the design and construction industry and is a reminder that single family residential building falls outside the purview of architects.

Certification with PHIUS, monitoring, training and curricular development were all part of the grant proposal in addition to the student-led design of individual houses. The construction or “build” portion was seen less as a missed opportunity for students and more as a chance to involve local home builders and contractors. The PH01 construction was inefficient and expensive. Few to none of the contracting team had ever worked on high-efficiency houses, custom houses following architect’s drawings, or an infill site. Even an EnergyStar rating was a largely unknown metric, let alone full PHIUS certification. Internally, the small DoArch student enrollment and late construction season made a student-build option almost impossible. The undergraduate design-build studio offered an excellent supplement

and arguably accomplished equal or better results with respect to hands-on student learning.

The passive house initiative has settled into a multi-course building science curriculum. The graduate studio is the design moment that starts the cycle of new houses. PH01 was the learning moment for students and faculty alike. PH02 sharpened the model with outcomes aimed at affordability and increased difficulty with a narrow site and limited solar access. In addition, a larger student class size offered a second project in tandem that developed a multi-family proposal. The intent with PH02 was for a new general contractor with a background in SIP construction to build a house very similar to PH01 as a comparison. The potential for comparative research is at the heart of the grant initiative. Following the disappointing administrative failing surrounding PH02, the approach to PH03 shifted to individual speculations on the retrofitting of everyday suburban houses. It is now doubtful that any additional build opportunities will emerge despite the availability of all necessary interest, funding and resources.

The ongoing curricular success lies in the incorporation of building science teaching in supplemental, non-studio courses. The undergraduate design-build studio was unable to continue due to the construction stop of the successor houses. The third-year studio has now shifted back toward community design projects that remain successful but follow a different trajectory. The “Interiors” technology course and the “Stewardship” professional practice course expand on the passive house pedagogy,

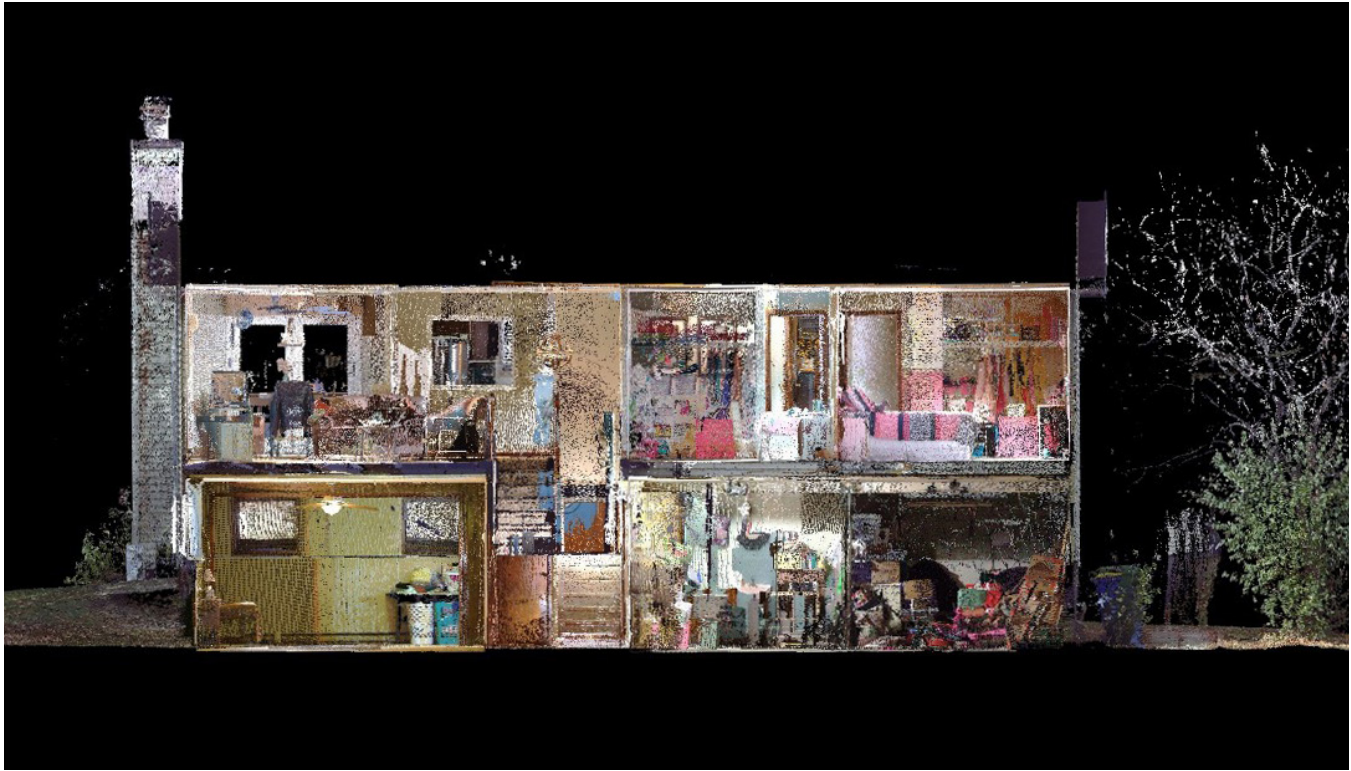


Figure 5. Digital laser scanned split-level prototype house for the PH03 studio. Image by author.

anchor their respective curricular tracks, and present building performance within a framework of practical examples and climate specific precedents.

### SPECULATION: THE FUTURE OF THE INITIATIVE

DoArch has had remarkable success implementing a range of building science and passive house teaching in a variety of formats, but its design-build future is not certain. The success of the paired graduate design studio and a follow-up undergraduate design-build semester was halted following PH01. These complimentary studios offered differing outcomes but each were framed using passive house principles. At the graduate level, the studio connects more closely with a recurring practice/theory pedagogy and sequence. The passive house studio specifically requires an understanding of basic building performance metrics, energy modeling software, construction documents, site design, project delivery, teamwork and collaboration. The design-build studio requires more directly a hands-on understanding of materials and assembly, re-introducing issues of documentation and community outreach.

Following the completion of PH01 the house was listed and sold to a local family enthusiastic about the house and its connection to the larger research initiative. Performance monitoring of indoor air quality, electrical usage, and PV generation has begun and data is being collected. This is supported in part by a grant obtained through PHIUS as it continues to revise its own climate-based certification standards. PH02 was intended to be a direct

research comparison to PH01, literally built next door. The design data will have to suffice as a comparison; these items include the energy model results, embodied carbon quantities, budget estimates, building size, and more. One interesting comparison is the certification metric which had shifted from the 2015 to the 2018 PHIUS standard, easing heating demand but increasing primary and site energy needs.

The results of the PH03 studio are an even more pointed response to the stalled “build” opportunity. By the start of this third cycle, DoArch students were anticipating the potential of the passive house studio and excited by the “real-world” possibilities. But while the outcomes of the original studio and house design may have dramatically changed, engaged students creatively rethought the necessity and urgency of implementing regenerative building practices and immediately sought to further broadcast the initiative’s achievements. These methods include leveraging previous undergraduate coursework, utilizing laser scanning technology (Figure 5), and building full digital walkthroughs with the Unreal Engine VR software which was introduced in the community design undergraduate studio. Students also rebooted the initiative’s website, adding and updating all of the previous design efforts and case studies. The adoption of additional software beyond just the requirements needed for certification show this generation at complete ease in utilizing tools for synthesized, creative practice rather than just collecting or reporting data.

DoArch has been recognized as a leader in teaching building science, passive building strategies, and its innovative professional practice sequence. These non-studio courses continue and evolve, presenting students with a host of the “new-essential” material that supports the discipline’s necessary response to climate change and the built environment. An inclusive recognition that this response can come from non-design roles and projects supports the wider responsibility of the schools beyond the design studio.

Beyond this specific example, the lesson of this effort has established the teaching of passive house principles and building science, each folded into studio, non-studio, and design-build coursework. Initiatives such as Architecture 2030 or the Living Building Challenge should be familiar to students and offices alike. More than simple recognition, an active curricular response is necessary to address climate change and the role architects take in the built environment. There exists a wide range of coursework for the student to understand both physical and sociopolitical means of response. Advocacy roles offer students an avenue alongside the more commonly taught technical or design response. Awareness of these potential roles combined with the ambitions of outside stakeholders has become a growing emphasis in both architectural theory and professional practice courses. Where previously the teaching of professional practice had focused on the traditional firm and means of project delivery, schools now are requiring the teaching of advocacy, social justice, diversity and equity, just as many of these same schools struggle internally with the issues themselves.

The delivery of this material poses the challenge of framing it within architectural discourse and academic curricula. It has, or at least should, elevate building science and related certification metrics to a status of providing both technical and social advances. Students are reminded that the equity of passive house and sustainable building practices in general offer a road map for housing justice and the equitable availability of natural resources.<sup>2</sup>

Building performance, certification programs, project delivery, and integrated systems coursework is not an optional curricular choice. While this is clearly recognized by NAAB, the ability for curriculum change within architecture schools varies significantly. This generation of students is expecting a direct engagement with issues of climate change, the social and ethical responsibilities of the profession, and how the discipline can provide leadership within the built environment.

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#### ENDNOTES

1. “Passive House Principles.” The Principles: Passive House Institute U.S. Accessed September 30, 2021. <https://www.phius.org/what-is-passive-building/passive-house-principles>.
2. PHIOUS 2020 Educators Hootenanny. YouTube. PHIOUS / Passive House Institute US, 2020. <https://www.youtube.com/watch?v=olr3V5inw6I>. Contributing discussion and concluding comments reinforcing the relationship between environmental, social, and economic equity.