

# Passive Aggressive Education: Infusing Passive House Principles into the Curriculum

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**ABSTRACT:** In 2006, recognizing the impact of buildings on global climate, the American Institute of Architects adopted the 2030 Challenge<sup>1</sup>— an initiative to reduce the building sector's dependence on fossil fuels and mitigate greenhouse gas emissions. Recent professional training in the building methods of the Passive House concept in the U.S. promises to reduce space-conditioning energy use by 90% compared with conventional buildings. The Passive House method sets target performance criteria that must be met during construction. Education and training for design professionals involve intensive classes on building science principles of envelope construction, thermal comfort, heat gain/loss, ventilation, shading, orientation, and calculations of total primary energy use. Implementing Passive House principles into the curriculum suggests a variety of educational opportunities for enhanced student involvement, engagement and understanding of ways to address the 2030 Challenge. The intent of this paper is not to describe software platforms or passive cooling/heating concepts. This paper describes and explores the workings of courses and examples of faculty-student discourse at 3 institutions (Miami University, North Dakota State University and the University of Oregon) to infuse the curriculum through seminars and design-build studios for a real-world community project. The delivery process of curricular innovation reveals several barriers to embedding concepts into the curriculum, but greater dialogue on concepts and principles, construction techniques, energy targets, and the need for collaboration among building professionals (designers, contractors, engineers, and consultants).

**KEYWORDS:** education, primary energy, curriculum, ventilation, passive house

## INTRODUCTION

In 2006, recognizing the impact of buildings on global climate, the American Institute of Architects adopted the 2030 Challenge — an initiative to reduce the building sector's dependence on fossil fuels and mitigate greenhouse gas emissions. In 2010, a quarter of a million people from 47 countries participated in a Global Emergency Teach-in<sup>2</sup> conducted by Architecture 2030 calling for the community to make changes to the curriculum by adding a requirement to all design studio problems: "*the design shall engage the environment in a way that dramatically reduces or eliminates the need for fossil fuel.*" All courses should achieve ecological literacy in design education. The recent partnership between the DOE Challenge Home program and the Passive House Institute US promotes a common goal of reducing energy consumption in the residential sector by the Year 2020<sup>3</sup>. Educators are beginning to train students in Passive House principles.

In the past 6 years, professional training in the building methods of the passive house concept in the U.S. promises to reduce space-conditioning energy use by 90% compared with conventional buildings. The passive house method sets target performance criteria that must be met during construction. Performance can be calculated using software to predict moisture transfer within the building envelope (WUFI-ORNL/IB); potential thermal bridging (THERM/LBNL); and, validation (or invalidation) of building performance targets (Passive House Planning Package (PHPP) spreadsheet). The passive house method is a design concept, which uses superinsulation as a means of reducing the mechanical system to an absolute minimum (it is an "active system" which uses a heat recovery ventilator to operate); whereas a passive solar heating system, "consists of south-facing glass ...for solar collection and thermal mass for heat absorption, storage and distribution. (Mazria, 1979).

This paper describes efforts at 3 institutions (Miami University, North Dakota State University and the University of Oregon) to infuse PH methods into the curriculum via seminars and design-build studios. Albeit anecdotal, the intention is to show how such electives fill a perceived gap in education where students are not getting an in-depth understanding of analyzing complex building science topics such as vapor diffusion

and thermal bridging. Each institution's course description will include class organization, student outcomes, course format, required materials, and indicate where it is offered in the curriculum. Most importantly, faculty and student perspectives to the barriers to implementing the course, innovative teaching methodologies, impacts of new software tools, and examples of faculty-student discourse will give background stories to implementation and future offerings.

## **1.0 MIAMI UNIVERSITY - SEMINAR**

### **1.1 Class Organization and Outcomes**

The Department of Architecture and Interior Design at Miami University offers two course options for students to engage in the study of Passive House: a Passive and Low Energy seminar and a Passive House Malta Summer workshop. Both elective courses are offered to graduate and undergraduate students; predominately third and fourth year architecture students and several graduate students. The courses are now run in succession with the intent that students who enroll in the Passive and Low Energy Seminar will follow up the experience with the Malta workshop. Both courses are new offerings in the department and are entering their second year of instruction.

The Passive and Low Energy course meets 3 days a week for 50 min each session. The focus of the course is Passive House design as a means for achieving Net Zero construction. Students are instructed in the importance of airtight construction, super-insulation, thermal bridge-free design, solar heat gain, ventilation, and hot water systems to achieve Low and Net Zero results. Students also explore PH energy modeling software (PHPP or WUFI Passive)

The Passive House Malta Summer workshop is conducted every other summer. Our initial offering was in the summer of 2011. Seventeen students traveled to the 15<sup>th</sup> International Passive House Conference in Innsbruck, Austria for one week, and then to the island of Malta for three weeks. In Innsbruck, students attended an introductory full-day seminar, held by Dr. Wolfgang Feist, one of the founders of the Passive House Institute in Germany. Students were expected to attend all general sessions of the conference, workshops held during the conference, attend the building trade show, and participate in an all day building tour of various PH projects under development in the area. Following the conference, we proceeded to the island of Malta, where we studied traditional Maltese stone construction and current concrete construction methodologies. Students were introduced to heat transfer analysis software (HEAT2 & THERM) and were required to analyze the thermal qualities of current Maltese construction and offer alternative solutions to improve the thermal performance of the construction.

### **1.2 Barriers to Implementation**

A working knowledge of Passive House concepts and techniques, and familiarity with the PHPP energy modeling software is difficult to accomplish in a 16-week semester course that meets just 2-1/2 hours per week. A companion studio that runs parallel with the course would be beneficial so students could apply PH concepts to their studio design projects and test them using the PHPP. Some students who took the seminar course followed up the next semester with an Independent study design studio and were successful at achieving PH designs. Although it was an independent study, increased faculty involvement was necessary to help the students complete the PHPP analysis

One of the biggest barriers to the implementation of Passive House in our department is the "bias/influence" that LEED has in the minds of some the faculty and many of the students. Energy standards obtained through branded certification processes hold great allure to students and many feel that a LEED accreditation will ensure chances for employment upon graduation. To that end, the PH organization is actively working on a student level Certified Passive House Consultant (CPHC) designation. The difference is that the PH is based on building performance rather than point acquisition and the students gain more useful knowledge in the testing and training required to be a CHPC.

Passive House construction techniques of super insulation, triple glazed windows, minimal heating systems (depending on climate), ventilation and extreme air tightness challenges the way that building envelopes have been traditionally designed. In architecture departments, where the aesthetic appeal of the design is the predominate focus of a studio's criteria, getting faculty and students to embrace the strategies that will ensure higher building performance is often a challenge. There is a lot of material to cover in a short amount of time.

### 1.3 Innovative Teaching Strategies and Impacts of Tools

The Passive and Low Energy seminar course has a focused research project that has been effective at making students aware of the energy implications of their design and construction strategies. Students are assigned a multi-phased research project of construction details and work in teams of three. This research includes three parts: 1) Investigation & Familiarity, 2) Analysis, and 3) Full-Scale Mockup. The assignment is detailed as follows:

#### Part 1: Investigation & Familiarity

Identify a light wood (2x4, 2x6) framing construction connection detail that you will study in depth. You may pick from the following list or you may find another detail.

- Exterior wall to roof (flat roof with parapet)
- Exterior wall to roof (sloped roof with exterior overhang)
- Exterior wall to roof (vaulted ceiling)
- Exterior wall to intermediate floor
- Exterior wall to floor slab
- Exterior wall to crawl space
- Exterior wall to slab (shallow foundation)
- Exterior wall to interior wall
- Exterior wall at corner

Each team member identifies a different source for the detail. Students may consult the library or Internet for sources. Once a detail is identified, students are to hand draw the detail @ 1"=1'-0" and note the materials and indicate the total R-value of the wall. Any media is acceptable. The objective is to become familiar with the components of the detail and to practice detailing. A 3D file using Sketchup or Bonzai3D is also required to reveal the various layers of the construction.

#### Part 2: Analysis

The selected construction detail is then put through a thermal analysis using the free version of HEAT2 (a PC-program for two-dimensional transient and steady state heat transfer). Students are to revise the original detail to eliminate any thermal bridging and re-evaluate using HEAT2 (PC-based program examining heat transfer). After elimination of the thermal bridge, the new construction detail is redrawn at 1"=1'-0" making note of all necessary air sealing to achieve air tightness. Students then construct a new Sketchup or Bonzai3D model of the revised thermal bridge free detail.

#### Part 3: Full-Scale Mockup

Teams construct a **full-scale** model (1"=1") of the revised thermal bridge-free construction detail. The model should be built with impeccable details and should be easily portable (maybe on wheels), exploring different exterior wall siding systems or roofing systems that could be used, and providing manufacturers' information/literature on all products used in the model. In some cases, students might have to contact manufacturers to request small sample materials. A final presentation includes the model, all documentation, analysis, and 3D models.

The most successful part of the research project was the analysis. Students are able to visualize the impact of various construction details in a way that they were not able to do before. Through the analysis exercise, they can visually verify the energy performance of a design solution. Least successful was the full-scale construction mockup. This was probably due to several factors: a) inadequate time to complete the mockup; b) students had little or no experience with actual building construction, and limitation to accessing material resources -- resulting in a lot of vinyl siding and rigid insulation solutions.

### 1.4 Interdisciplinary Collaboration

The course involved several guest speakers from the profession, but since it was the first course offered in the department on PH concepts and techniques, we relied on the expertise of the instructor as a Certified Passive House Consultant and building professional.

### 1.5 Examples of Faculty/Student Discourse

Students have several opportunities to engage with various faculty in conjunction with both PH courses. At the end of the semester, the Passive and Low Energy seminar students held an open house to display their semester work. Faculty were invited to a poster session in which the students engage in discussions about their analysis results and mock-up. The first session was challenging for the students, as they had to defend

a design approach that is radical to how most architects practice. The mockup remained on display for several weeks in the architecture building.

The students from the Malta workshop exhibited their work at a university-sponsored venue, the Cage Gallery, featuring travel photographs, high performance building manufacturer samples, drawings and large-scale thermal analysis print outs of researched details. The exhibition was on display for two weeks and was well attended by students and faculty.

As a result of the mock-ups and student exhibition, several faculty have referenced the materials produced into their course instruction.

## 2.0 NORTH DAKOTA STATE UNIVERSITY – PASSIVE HOUSE DESIGN/BUILD

### 2.1 Class Organization and Outcomes

In 2011, a 3-semester Design/Build course was offered at NDSU with a goal of designing, constructing, exhibiting, certifying and occupying a Passive House (PH) structure. Students engaged several clients, consultants, governing authorities, manufacturers and researchers. They provided design and energy solutions for four different sites to prospective clients using Passive House Planning Package (PHPP) and full-scale construction as primary modes of investigation through various stages of design and implementation. One of these projects moved forward to pre-certification and construction.

**DESIGN SEMESTER SUMMARY & OUTCOMES** (Spring 2011 – 1 studio of 6 credits with 22 students): Students researched, analyzed and designed through scaled and full scale investigations, completing typical phases of a design project such as schematic design, design development, construction documentation and specifications. Experts and studio faculty introduced building science and PH principles during visits to certified structures in the region. In addition to PHPP, Athena and USGBC LEED for Homes provided a comprehensive approach to measuring environmental impacts. Studio instructor used WUFI and THERM to further the energy analysis by the students. Students constructed full-scale modules of various construction systems such as Structural Insulated Panels (SIP), double wall stick frame, solid wood construction to analyze super-insulated PH performance for a cold climate. Emphasis on developing careful craft with construction techniques and strictly following safety protocols prepared students for the construction semester. Students experienced fundraising, marketing, budgeting, client – contractor – consultant – collaborations.

- a. End of semester exhibit, Fargo ND: Full scale PH super-insulated walls, roofs and floor connections and educational materials for PH concepts (250+ visitors).
- b. Completed construction drawing set and specifications in preparation for construction semester.
- c. Marketing and fund-raising to raise \$20,000 in cash funding and \$80,000 in-kind product donations.
- d. Faculty and Design/Build studio partnered to apply for energy education grant: Granted \$46,000.

**CONSTRUCTION SEMESTER SUMMARY & OUTCOMES** (Summer 2011 – 2 seminars of 3 credits each with 15 students): Students and studio faculty completed pre-certification of the cabin with Passive House Institute US (PHIUS) after which students constructed a 650 nsf PH cabin in St. Paul, MN at the Eco-experience exhibit. Exhibit lasted ten days after which the students dismantled the various modules and created installation instructions and a labelling system for re-installation at the permanent site. The modules were transported to the permanent location.

- a. Eco-Experience Exhibit: Invited by the Minnesota Pollution Control Agency, Design/Build studio exhibited a full scale PH cabin. 300,000+ visitors over a period of 10 days.
- b. 45-minute presentations: teams of two (student and faculty) gave on their research focus at the Eco-experience;
- c. PH educational materials: students developed, made, installed and distributed materials to engage various age levels. Materials ranged from interactive games for children to understand PH concepts to sophisticated numerically verified models for the knowledgeable visitor.
- d. Published construction video: two construction cameras photographed construction progress every 2 minutes.
- e. Published a website: dedicated to Design/Build NDSU ([www.ndsudesignbuild.com](http://www.ndsudesignbuild.com)) where students published personal blogs as a course requirement.
- f. Radio and television interviews: articles and blogs published by media about NDSU Design/Build, (including Minnesota Public Radio).

**DOCUMENTATION SEMESTER SUMMARY & OUTCOMES** (Fall 2011 – 1 studio of 6 credits with 14 students): Based on the work of the Design & Construction semesters, the students translated months of documentation (photos, writings, models, drawings, full scale modules and document sets) into two books.

- a. Studio published *Voices & Chronology*. *Voices* contains four one-page articles written by each student. *Chronology* documents the process of 2011 Design Build in essays and photographs. Introductory essays by faculty are included in both books.
- b. Faculty published a conference paper in the proceedings of the Passive House National Conference 2012 titled, PH as a University Design/Build Start-Up
- c. Faculty published a conference poster at the Passive House National Conference, 2011.

## 2.2 Barriers to Implementation

- a. PH Design/Build projects are multi-semester efforts that produce better than code-compliant completed structures. This entails finding the right clients, projects, donors and funding resources that can support a multi-semester applied-research effort.
- b. Quality and reliability of donated products designed to meet a very stringent performance can create logistics and performance problems.
- c. Full-scale construction studio strained limited resources. As an investigative and generative tool, it meant that the studio required more space, tools and workshop time than the average studio
- d. Intensity of time required to meet learning goals would have been more successful if all the classes students were taking were related to Design/Build over the course of three semesters. However, this results in a high concentration of Design/Build credits. Subsequently, classes worth fewer credits were offered but the workload involved created incredible time pressures on faculty and students involved which resulted in a severe workload and credits earned mismatch;
- e. Students had inconsistent preparation in building science fundamentals;
- f. Dearth of locally manufactured PH certified building products at a reasonable cost;
- g. Even though Design/Build can be greatly beneficial in creating a deep understanding of energy and performance issues, there are very few legal frameworks that allow such projects to be covered under practice laws such as general and professional liability insurance.

## 2.3 Innovative Teaching Strategies and Impacts of Tools

- a. Design/Build and PH taught together allowed for in-depth understanding of an integrated design process. PH principles, concepts and computations created a framework of stringent performance requirements which impacted architectural form, orientation, detail and craft, requiring students to understand every part of the building system, form and detail and comprehend its interdependencies.
- b. Full scale building from day one of the semester was the primary analytical, investigative and generative tool and allowed students to understand and translate PH concepts into a built construct.
- c. On the first day of the semester, students were required to build a section of the typical stick-frames code-compliant wall. This set the tone for the semester requiring students to be resourceful about finding and assembling materials at short notice with limited financial resources, understanding building science principles, building code compliant structures and paying detailed attention to craft, care and quality.
- d. Multiple project types (new construction, existing renovation, single family and multi-family homes) allowed students to understand PH concepts and use PHPP to enter data and interpret results.

## 2.4 Interdisciplinary Collaboration

Several professionals, experts, authorities, manufacturers donated time, experience and expertise.

- a. **Primary collaborations** allowed the students to engage with people as they would in a typical architectural practice: Engineers, product vendors, experts such as co-director Katrin Klingenberg from PHIUS, clients, governing authorities such as the Building Code authority, State Historical Society and Department of Natural Resources and building inspectors.
- b. **Secondary collaborations** allowed the students to experience what it means to be an entrepreneur and find funding for opportunities. Students engaged in pricing, bidding, budgeting, marketing and fundraising and logistics planning.
- c. **Tertiary collaborations** with construction supervisors, licensed trades, contractors & builders allowed students to experience the construction side of the building industry. They became familiar with safety protocols, OSHA rules, hands-on experience with construction methods, logistics and liability issues.

## 2.5 Examples of Faculty/Student Discourse

The discourse in the Design/Build studio was captured by the students in the Documentation semester in a publication called *Voices*. The topics chosen by students do not comprehensively address the various areas of interest but do reveal the pre-occupations of the group and those issues that the students found were unique to the studio. Following are some samples of the student articles:

**Collaboration and authorship (or lack thereof):** Questions of authorship do not emerge in the typical design studio since students primarily work on individual projects. In the Design/Build PH studio several authors created one work. Projects and roles were constantly traded such that labels such as designer, manager, specification writer etc. were not assigned to people. Only the work received labels and almost everyone in the studio made a contribution to the development of almost every component. This collaboration model left deep impressions on several students who wrote about this approach in *Voices*.

**Do-It-Yourself:** The lack of reasonably priced, locally available certified PH building components created a culture of Do-It-Yourself innovators. This resulted in various components that were designed and manufactured by students. It also created an “us versus them” culture where the students measured their innovations against the purchased and donated products that were incorporated into the constructions. Ultimately it created a “your waste is my treasure” discourse.

**En-LARGE-d scale:** Typically students make scaled artifacts while in this studio they were asked to make full scale investigations. Typically students present their end of semester work over a very short duration from a few minutes to few hours. At the Eco-experience exhibit students presented the PH cabin for twelve days, twelve hours a day for over 300,000 visitors from all walks of life. Typically, the student budgets for finishing and presenting a studio project might take an investment of a few hundred dollars at the most. Here the fundraising demands were to the order of \$100,000. This enlarged scale on several fronts allowed the students to experience the decision-making involved in professional projects. The studio discussion often focused on the differences in scale between the typical studio project and the Design/Build PH studio.

### 3.0 UNIVERSITY OF OREGON - SEMINAR

#### 3.1 Class Organization and Outcomes

The Department of Architecture at the University of Oregon offered a four-credit seminar course in the Spring Term of 2012 called Passive House Design and Detailing. This course fulfilled an advanced technical elective requirement and was offered to undergraduate and graduate architecture students. There were two prerequisites for the course: Building Construction and Environmental Control Systems I, since the students needed a basic understanding of wood framed construction, passive strategies, thermal comfort, and heating and cooling systems to adequately engage the material. The course met twice a week on Tuesday and Thursday for 1 hour 50 minutes over the ten-week term. Typically, a lecture on a specific aspect of the Passive House concept was given on Tuesday; on Thursday, the students were assigned an in-class activity that complemented Tuesday’s lecture material. At the end of class on Thursday, a take-home exercise, which the students completed in pairs, was assigned and due the following week. The last four weeks of the term, the students worked in pairs to develop the design of a small passive house for a hypothetical site in Eugene, Oregon. In lieu of in-class activities during the final four weeks, we held in-class checkpoints for the final project to keep the students on track. Faculty and local professionals attended a poster review session on the last day of class to provide feedback to the students on their final projects.

Throughout the term, we collaborated with the Center for the Advancement of Sustainable Living (CASL), a student-initiated program at the University of Oregon. CASL is renovating a small single-family house – the CASL house – near the University of Oregon campus using Passive House principles. Many of the activities and exercises during the term asked students to investigate aspects of the CASL design, including the assemblies, connections, and mechanical system. Several of the students enrolled in the course were also involved with the construction of this project. During one course period, the students had the opportunity to visit the CASL house and see Passive House strategies implemented firsthand, including advanced framing, types and applications of insulation, and the heat recovery ventilation system. During this visit to the CASL house, we also conducted a blower door test and showed the students how to interpret the results.

We received a small grant (\$5,000) for the course and used this funding to invite guest speakers during the term. The guest speakers were given a lecture topic to cover during the first hour of the course, and were asked to share examples of their own work during the second hour. In some cases, they led the week’s in-class activity. Guest speakers were selected based on their experience/expertise with PH and related software tools. We were fortunate in that there were many professionals involved with Passive House in our region of the country. All of our guest speakers were located on the west coast; most were located in Oregon or Washington and within driving distance of Eugene. For this reason, we were able to make our relatively small grant go a long way.

We were also fortunate to have several students in the department who were Certified Passive House Consultants and provided instructor support throughout the term. These students had a strong understanding of PH principles and the associated software and were able to provide support to the students during activities and exercises, as well as assist in the development of course materials.

### **3.2 Barriers to Implementation**

Because of the high level of knowledge and software expertise required to design PH buildings, we found the guest speakers to be a critical component of the course's success. The speakers had first hand experience with PH projects and brought a unique perspective regarding their particular discipline and expertise. Had we not received the grant that allowed us to pay the guest speakers for their travel expenses, we would likely not have been able to invite them. The grant also allowed us to hire teaching assistants, who played a key role in providing instructor support as mentioned above. For these reasons, a lack of funding would significantly hinder the ability of the course to be offered in the future. However, since the course materials are now in place, it is more likely that this course could be offered again without relying as heavily on guest speakers and teaching assistants to supplement the instructor's lectures, activities, and materials.

Though the guest speakers generally stayed on topic when asked to cover a particular aspect of PH, it would be beneficial to provide them with an outline of the material to be covered ahead of time so they can properly incorporate the material into their lecture. Our approach was to have a brief conversation with the guest speaker about the lecture topic and the material to be covered, though a written outline would likely be more effective in preventing course material from being inadvertently omitted.

The availability and/or expense of software tools used in the course created some challenges. THERM and WUFI, which analyze thermal bridges and moisture transport, respectively, are available for free download. However, the free version of WUFI is limited in its functionality, and the full version is prohibitively expensive for students. The lack of availability of an I-P version of the Passive House Planning Package (PHPP) during the time this course was offered also presented challenges. If we had easier access to the necessary software, we would have likely dedicated more class time to learning it. Ultimately, we did not dive into the software as much as we would have liked.

Depending on their level in the program, some students had not yet taken their required Building Enclosures course when they enrolled in this seminar. While these students were at a slight disadvantage with some of the course material, including envelope detailing and moisture management, they will likely be more prepared to tackle Building Enclosures after having completed this elective course.

As mentioned previously, the CASL house offered a unique opportunity for students to engage a real world project in their coursework. However, there were some challenges in collaborating with CASL due to scheduling. Our course schedule and the schedule of the CASL house design and construction did not always seamlessly align. In the future, the instructor would need to engage CASL (or a similar project) well before the start of the course to find where there might be opportunities for collaboration.

### **3.3 Innovative Teaching Strategies and Impacts of Tools**

Throughout the term, we always introduced concepts and calculations before introducing related software. For instance, the students completed an annual heating demand calculation by hand before being introduced to the PHPP. Additionally, the students plotted the thermal gradient across a wall assembly and located the dew point before being introduced to WUFI. This emphasis on understanding the concepts and calculations behind the software before being introduced to the software itself was very effective; the students were able to engage the software in a more thoughtful way when they had an understanding of some of its underlying principles.

We found that the students responded better to class activities when they were asked to use the software tools for design rather than verification only. The exercises were most effective when the students had to analyze a condition, interpret the results, and then respond to the results with a change in design. For example, the students were asked to model an assembly in WUFI, interpret the results, and then make design changes to the assembly to improve its performance. The emphasis on using the software as a design tool rather than simply a tool for verification was a major theme in the course.

### **3.4 Interdisciplinary Collaboration**

While we did not collaborate with other disciplines or departments outside of architecture in this particular course, we see opportunities for this type of collaboration in the future. We did however engage a variety of professionals from other disciplines as guest speakers. Students in engineering and construction programs would be interested in the material, as the topics include HVAC design, plumbing design, renewable energy systems, and construction means and methods. It is worthwhile to note that our guest speakers included contractors, architects, and engineers. Each brought a unique perspective due to their education, background, and experience. We feel that this diversity in discipline contributed to a rich learning environment.

### 3.5 Examples of Faculty/Student Discourse

Throughout the term, we set aside time for class discussion and question/answer sessions, particularly when guest speakers were present. During one course period, we divided the students into groups and provided them with a list of questions intended to generate a critical discussion of the PH approach, its applicability to various climates, and alternate approaches to low energy construction. We feel this open dialogue is an important aspect of any college level course, even when the topic is a technical one.

The conversations around PH topics seemed to spark curiosity, inspire the desire to delve more deeply into topics, and created stir demanding that the department offer more courses on the topic. This year, two adjuncts taught a class at the CASL house that was about implementing, testing, and installing components in the CASL house on campus.

Further, graduate students were required to submit a one-page research prospectus on a PH topic. This assignment was intended to help graduate students generate ideas for further research in PH topics. Ultimately, our hope is that some students will engage faculty for guidance in carrying out their proposed research project as an independent study or master's thesis.

### CONCLUSION

The authors have proposed the PH curriculum as a means of exposing students to analysis tools like WUFI and THERM, but also our intention was to collaborate and to begin a dialogue on ways to infuse the curriculum with new courses that address the 2030 Challenge. Clearly, our focus was on academic courses, rather than mimicking professional training. The courses provide tangible methods and tools for students to learn at multiple scales, and linking technology/science to design integration is difficult administratively, but with efforts at several levels it can be resolved successfully. Three different models shown in this paper (see Table 1) include raising awareness and increasing understanding of traditional building science concepts/principles, including envelope construction, thermal comfort, heat gain/loss, ventilation, shading, orientation, and calculations of total primary energy use. All involve real-world examples, thinking and doing exercises, applying principles/concepts in a real, hands-on activity. Lessons from the faculty and student discourse are valuable as the authors hope to help other institutions do the same.

TABLE 1. Matrix of curricular structure for 3 passive house courses at 3 universities

Institution	Class Type	Students	Level	Duration	Credits
Miami University	elective seminar	20-25	UG: 3 <sup>rd</sup> year+ G: 1 <sup>st</sup> year+	16-week semester	3
	summer workshop	17	UG: 3 <sup>rd</sup> year+ G: 1 <sup>st</sup> year+	4 weeks	6
North Dakota State University	Design/build studios (Spring & Fall)	22	G: 4 <sup>th</sup> year + G: 5 <sup>th</sup> year	15-week semester	6 (per studio)
	Design/build seminar (Summer)	14	G: 4 <sup>th</sup> year + G: 5 <sup>th</sup> year	8-week semester	3+3 (summer)
University of Oregon	elective seminar	30	UG: 3 <sup>rd</sup> year+ G: 1 <sup>st</sup> year+	10-week quarter	4

### ACKNOWLEDGEMENTS

Many people and organizations have contributed knowledge, materials, ideas, and opinions to the passive house movement. We acknowledge the co-directors, Katrin Klinengberg and Mike Kernagis of PHIUS, the many Certified Passive House Consultants (now 400+), and the administration (and faculty) at the three institutions that have taken the steps to start up a new course. The authors are deeply passionate about the passive house method, but have reflected on the experience to hopefully offer it again.

### REFERENCES

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## ENDNOTES

<sup>1</sup> <http://www.architecture2030.org/> Established in response to the climate change crisis with a goal to achieve a dramatic reduction in the climate-change-causing greenhouse gas (GHG) emissions of the Building Sector by changing the way buildings and developments are planned, designed and constructed.

<sup>2</sup> [http://architecture2030.org/action/2010\\_imperative\\_global\\_emergency\\_teach\\_in](http://architecture2030.org/action/2010_imperative_global_emergency_teach_in)

<sup>3</sup> DOE Challenge Home and PHIUS+ Passive Home Certification - A New Partnership to Promote Zero and Plus Energy Homes, Katrin Klingenberg, Proceedings of the 7th Annual North American Passive House Conference, September 28-29, 2012, Denver CO. DOE has targeted 70% energy savings by the Year 2020. The PHIUS + program integrated with the Challenge Home Requirements provides a way to meet the 2020 goals right now.