Research-based design as translational research between the academy and practice

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ABSTRACT:Research-based design uses quantitative data collected from existing buildings, generated through rapid prototyping and testing, or simulated using parametric and genetic computer modeling to reduce resource consumption through improved design. This methodology has been validated in the widespread adoption of "evidence-based design" to improve patient outcomes in healthcare facilities. Outlining several models for aligning academic architectural research with the needs of practice, this paper focuses on the advantages and challenges in using graduate-level building science coursework as vehicle for translational research. The term translational research is borrowed from medicine and refers to taking current laboratory research and tools and applying them to practice. In 2012 and 2013, faculty members in the School of Architecture at Portland State University were awarded the largest NCARB grant at that time to generate translational building science research in collaboration with local architecture firms. This grant, along with the resources of an existing research lab focused on green buildings, transformed traditional lecture-based building science and technology courses into a series of on-going, graduate level seminars that revolve around two primary activities: (1) architecture and engineering students conduct building science research of relevance to a project currently under design in a firm and (2) students are embedded in project teams where they attend all interdisciplinary meetings for the course of a term to witness and document interdisciplinary collaboration. This paper highlights the lessons learned from these pilot seminars, including what types of research projects have been most fruitful for the students and practitioners, and how these courses could be a model for building science education elsewhere.

KEYWORDS: Research-Based Design, Translational Research

INTRODUCTION

The operation of buildings consumes 41 percent of the primary energy and is responsible for 40 percent of carbon dioxide emissions in the US (US DOE 2011). These numbers exclude the significant environmental impact of manufacturing, transporting, installing, maintaining and eventually demolishing materials used in building construction (Ramesh et al. 2010). While every other sector has been reducing energy use and carbon emissions over the last 30 years, commercial buildings have increased their energy intensity (energy use per square foot) by over 8%. Furthermore, the total square footage of these buildings has increased by almost 60% over the same time period. Only the recent recession temporarily blunted what had been the continual growth in energy use by the building sector (US DOE 2011). To meet ambitious and in some cases legislated goals to create net-zero energy buildings by 2030 or 2050 (Architecture 2030 2012, US Congress 2007), there is clearly a national need for future architecture professionals to be well-educated and skilled in building science.

Green building is defined by the EPA as "the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle" (US EPA 2013). Current green building practice relies heavily on rating systems to set goals and define strategies (Klotz et al. 2010). Unfortunately, a study of the energy intensity of 150 certified green buildings showed these buildings varied greatly compared to the average for the USA's existing commercial building stock; with some much higher, some the same and some lower (Turner & Frankel 2008, Newsham 2009, Scofield 2009). To improve this situation, this paper argues for a robust research-based STEM education for engineers and architects centered on building science, called building physics or building engineering physics in Europe. Decisions made early in the design process have the most significant impact on a building's resource use (Magent 2009). These decisions should be based on robust scientific and engineering knowledge and research rather than poorly constrained rating systems or rules of thumb. Research-based design allows for a more rapid integration of green building strategies, materials and systems by conducting university-led laboratory simulations or post-occupancy analysis of innovative buildings and applying this research to projects currently under design through collaboration with professional practitioners.

Interdisciplinary collaboration between engineers and architects during the design and construction of a building is also critical to the reduction of energy use and carbon emissions of green buildings (Griffin et al., 2010, Klotz et al., 2009, Kibert 2008). However, currently there is little, if any, interaction between architecture and engineering students during their education and a number of barriers to interdisciplinary courses and programs in academia (Simpson et al., 2009, Little 1999). Green building "charrettes," collaborative meetings of stakeholders early in the design process to discuss engineering and design strategies to reduce resource use, are common in professional practice. However, numerous barriers between participants of different disciplines, including disparate value systems and terminology, limit the efficacy of these charrettes (Hoffman and Henn 2008). As members of the building industry are highly influenced by their early training, one way to overcome these barriers is by offering opportunities for engineering and architecture students to take building science courses in other disciplines and have meaningful and substantive experiences together during their education. This will allow individuals to better understand the language, motivations and biases of each discipline in order to become more effective collaborators in the future. The Royal Academy of Engineering recently released a report (King 2010) arguing for the urgent transformation of engineering education to emphasize multi-disciplinary research in building design, engineering, energy and carbon efficiency and the need to recruit the best engineers of each generation to reduce the environmental impact of buildings. In 2002, Architect Ed Mazaria launched the 2030 Challenge with the mission "to rapidly transform the built environment from the major contributor of greenhouse gas (GHG) emissions to a central part of the solution to the climate and energy crises (Architecture 2030 2012)." This included the 2010 Imperative to transform architectural education toward designs that eliminate the need for fossil fuels and a renewed focus on building science.

1.0 EXISTING MODELS

1.1. Evidence-based design

> Evidence-based design is a process for the conscientious, explicit, and judicious use of current best evidence from research and practice in making critical decisions, together with an informed client, about the design of each individual and unique project (Hamilton and Watkins 2009, 9).

As Ulrich (2006) highlights, there have been over 700 studies published in medical journals linking the design of healthcare facilities to the health of patients and staff: "Much credible evidence now shows that good design of a hospital's physical environment promotes better clinical outcomes, increases safety, and reduces stress for both patients and staff." This data provides healthcare designers with the ability to improve future hospitals. There have been several recent books published on evidence-based design exploring the role research can play in improving the performance of buildings besides healthcare (Hamilton and Watkins 2009, Chong et al. 2010, Kopec et al. 2011). While the benefits of this approach are clear, the path to using more evidence-based design in practice is stymied by a lack of knowledge about research methods and requires educational reforms: "Hopefully, the profession will make clear to our educational system that we demand some level of research knowledge as part of basic design education, because it will be as important to our professional success as design and technical capability (Chong et al. 2010)."

There are two major, interdisciplinary university centers for evidence-based design focused on healthcare: the Center for Health Systems and Design at Texas A&M and the PhD Concentration in Evidence-Based Design in the School of Architecture at Georgia Tech. Although focused exclusively on healthcare design, Georgia Tech's SimTigrate Design Lab combines post-occupancy data and simulations to generate data in collaboration with professional practice to improve the design of buildings. In the case of the SimTigrate Design Lab, the improvements would include fewer falls in a hospital, whereas the translational research discussed in this paper will use similar tactics but focus on reducing the environmental impact of buildings.

1.2. Research-based design

As the term *evidence-based design* has been largely coopted by the healthcare researchers and focuses on human-centered outcomes (reducing patient recovery times, increasing staff well-being, lowering stress), this project prefers the term *research-based design* to refer to a similar data-driven design process that focuses on reducing the environmental impact of buildings. Two other groups that have pursued work comparable to the Research-based Design Initiative (RBDI) model discussed in this paper include the Vital Signs project at UC Berkeley, 1995-2000, (Benton and Kwok 1994, Kwok, et al. 1998) and the Agents of Change project at the University of Oregon, 2000-2005 (Kwok, et al. 2005). Both projects focused on incorporating quantitative, research-based exercises into building science coursework to train future architects "to create buildings that provide for human health and well-being while using energy responsibly" as well as providing training to architecture faculty across the US. These projects differ from the RBDI at the author's university in three ways: (1) the RBDI is interdisciplinary with students from engineering and architecture taking courses and collaborating on research together, (2) the RBDI engages professional practitioners to develop research questions and mentor students, and (3) Vital Signs and Agents of Change focused solely on understanding how existing buildings were working without applying the research to the design of new buildings and without the use of simulation software now available to supplement in-situ data collection.

1.3. University-housed research consortium

The West Coast of the US is fortunate to have several models for research-based design centers and laboratories at universities that focus on reducing the environmental impact of buildings. These centers have multiple funding sources, but the primary support comes from utilities wanting to promote energy efficiency. The Center for the Built Environment (CBE) at the University of California, Berkeley is “a place where prominent industry leaders and internationally recognized researchers cooperate to produce substantial, holistic, and far-sighted research on buildings.” The work of the CBE is driven by consortium of industry partners and focuses on longer term, non-project specific research into promising technologies for buildings as well as the largest database of post-occupancy evaluations for buildings in the US. While faculty members in the CBE teach building science courses, students in those courses do not have access to the equipment and resources of the CBE and do not work with the industry partners on research.

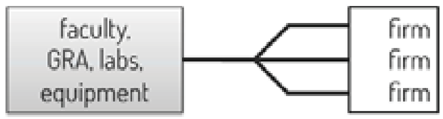

Figure 1: Building science research consortium organizational diagram. Source: Author

This model has advantages in generating longer-term, high quality research as the consortium pools funding to focus on a collective research goal. The professional partners have access to research and tools that have already been developed. One draw back to this model is that individual firms have less control over directing the research agenda. The consortium model cannot fulfill more immediate research needs that may be driven by a particular building under design.

1.4. University as consultant

Supported by BetterBricks – the commercial building initiative of the Northwest Energy Efficiency Alliance – and electric utilities throughout the Northwest, Integrated Design Labs (IDL) and the Energy Studies in Buildings Laboratories (ESBL) form a network of labs providing design assistance to architecture firms to reduce electricity use. As the utilities are focused on energy efficiency to reduce the need for building new electrical power plants, these labs typically focus on two topics – reducing electric lighting through the use of daylight and natural ventilation to reduce the size and need for mechanical ventilation – and act as building science consultant to architecture firms on specific projects under design. The equipment in these labs is centered on simulation. Like the CBE, the primary mission of BetterBricks is serving industry and not teaching building science. These labs are also housed in Schools of Architecture and not interdisciplinary. To varying degrees at the different labs in the network, students have limited access to the equipment in these labs and no part of the research conducted for architecture firms unless employed as graduate research assistants (GRAs) in the lab.

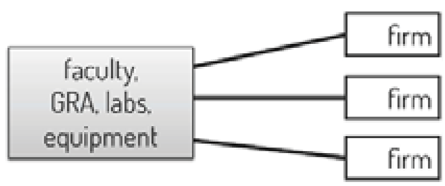

Figure 2: University as building science consultant organizational diagram. Source: Author

The advantages of this model include high quality research that is timed and directly applicable to improve buildings currently under design. Some shortcomings include having research topics and design assistance determined by the funding agency – typically a utility. Increasingly these funders require measurable results, which can be difficult to attain without further funding. The largest drawbacks of this model are that firms do not have access to previous research and the limited sharing of research between firms.

2.0 TRANSLATIONAL RESEARCH PRACTICUM

In short, there is no initiative or lab in existence at a university on the West Coast of the US that has the same aims as the RBDI to support the interdisciplinary teaching of building science through hands-on research in collaboration with industry. Donfrio (2013) has outlined the need for translational research as well as three models for collaboration between the academy and practice. The RBDI does not fit neatly in one of the categories defined by Donfrio and instead combines aspects of “the academy embedded in practice” and “collaboration” models as described below.

2.1. Overview

Even at universities with both architecture and engineering programs, there are limited opportunities in the academic setting for cross-listed, interdisciplinary courses where students would engage each other in meaningful ways to prepare them for practice. At the same time, there is a demand in practice for research-based design to optimize resource use and building performance. Unfortunately, most practices do not have the resources to conduct time-intensive research.

To address both of these issues, Assistant Professor Corey Griffin and Professor Sergio Palleroni transformed traditional building technology courses into a series of ongoing, graduate level seminars that revolve around two primary activities: (1) embed architecture students in project teams where they attend all interdisciplinary meetings for the course of a term to witness and document interdisciplinary collaboration and (2) have architecture students lead a multidisciplinary team of students in a sustainability research endeavor of relevance to the project team they are tracking. In this unique way, students become contributing members of a design team and building science experts on issues relevant to current practice. For the architecture firms involved, working with universities allows practicing architects the ability to utilize a deeper level of research expertise in the design process and access resources not typically available in practice. One of the most exciting outcomes of this collaboration have been the semi-annual research symposiums where students present their work to representatives from all of the participating firms, creating a dialog around pressing building science issues with students, faculty and practitioners.

Two graduate level building science and technology seminars were reoriented from lecture and case study based into practice and research oriented courses to ensure our students will be effective collaborators and leaders as part of multidisciplinary teams when they enter practice. The faculty instructors of these courses, continued to ensure students are given the content required to meet NAAB and departmental standards, the outcomes and deliverables of the course will shift to focus on multidisciplinary collaboration and original sustainability research relevant to practice. Advanced Building Structures, an elective seminar, was the first pilot for this new methodology in Winter 2012. Advanced Building Technology, a required course for entering M.Arch. students, and Advanced Building Structures expanded these efforts in Fall 2012 and Winter 2013.

To expose architecture students to various models for multidisciplinary collaboration, they were embedded in professional design teams in the midst of conceptual, schematic or early design development. A practitioner or group of practitioners at each firm identified one or more projects that align with one of our ten-week terms. They were responsible for meeting with the student(s) regularly and ensuring they are included in all multidisciplinary meetings and witness to other forms of interdisciplinary communication (e-mails, conference calls, etc.). Students documented this collaboration in the form of weekly memos that were shared with the rest of the seminar. These memos were used to construct a graphic timeline at the end of the course documenting when and how various disciplines interfaced over the course of ten weeks and the results of those collaborations in terms of design decisions made and issues resolved.

To provide architecture students with the opportunity to lead an interdisciplinary team of peers, students generated original sustainability research relevant to the firms and project team of which they are a part. The practitioners in consultation with faculty will select the research topics. As these seminars were promoted in both the mechanical and structural engineering departments, architecture students led teams of students from multiple disciplines in conducting the research.

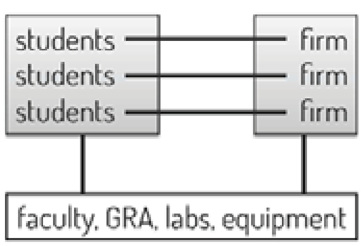

Figure 3: Building science research practicum organizational diagram. Source: Author

The advantages of this model is that all graduate students at Portland State University (PSU) are involved and trained with research skills relevant to professional practice – not just GRAs who happen to work in a lab. The research is conducted both at the university as well as in the firms, with students having the opportunity to have a space in their firm's office. The students have direct contact with practitioners with faculty, a GRA and labs supporting the research. Individual firms determine the research projects and topics that can be related to a project under design or not depending on the timing of the academic term and project schedules. The research is shared between firms through end of term symposiums and dissemination on the RBDI website. Three major drawbacks are that the project scope is determined by the length of an academic term, the quality of the research is dependent on the student(s) assigned to the project and coordination of over twenty graduate students and five firms – each with multiple research projects – can be challenging.

2.2. Research conducted
A total of 35 students took one of the three seminars sponsored by the NCARB grant and worked with over 20 practitioners from five architecture firms in Portland, Oregon. These firms included BOORA Architects, THA Architecture, SRG Partnership, YGH Architecture, and ZGF Architects, four of which were on the 2013 Architect magazine Top 50 list. Depending on the firms' interests and buildings under design during a given term, a wide range of research projects were conducted. The research projects can be categorized into five major categories: building envelopes, structural systems, daylighting/solar gain, ventilation (natural and displacement), and building retrofits. Some projects used tools from PSU's Green Building Research Laboratory to conduct post-occupancy assessments to measure the efficacy of replacement windows while others used simulation software to model daylight and natural ventilation for building under design. Students both wrote a research paper and create a research poster to disseminate their results.

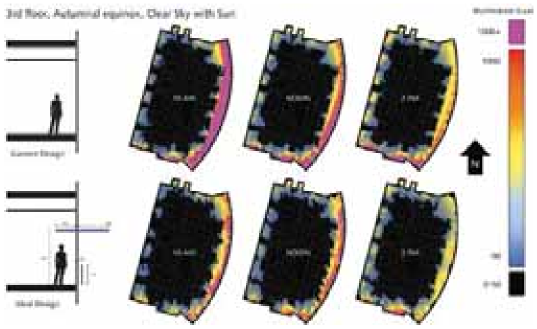

Figure 4: Image from student research poster focus on shading device design and illuminance. Source: Ben Deines

The greatest challenge faced was constructing research projects that could be accomplished in the ten-week terms at PSU. Many of the firms involved had little to no experience constructing building science research questions or experiments, and it required both meetings between faculty and practitioners as well as trial and error during the seminars to develop successful research projects. The most successful projects were one's that students could start in the required Fall course and continue in the Winter term elective. These students learned how to use new tools and simulations in the first class, often completing a proof of concept or single iteration, and then could deploy them to answer more complex questions in the second course.

2.3. Evaluation
The initial objects for the project are below, followed by an assessment of how they have been achieved to date. All of the student and non-faculty architect practitioners (including practitioners outside of the five main sponsors) who participated in at least one of the seminars sponsored by this grant were sent an evaluation survey (see appendix). Sixteen students and eleven practitioners responded to the survey, which included questions about how well each of the three goals for this project was met on a scale of one (not met) to five (very well met).

Goal One: Expose architecture students to various models for multidisciplinary collaboration by embedding them in professional design teams.

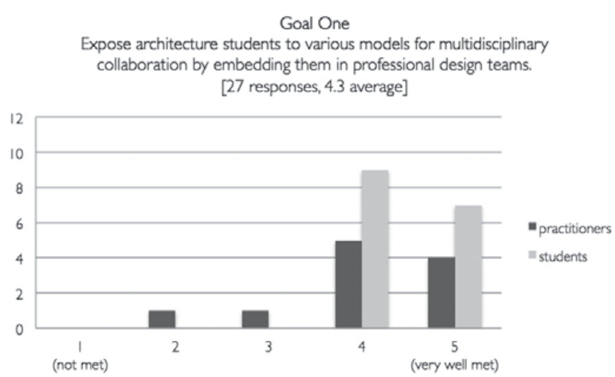

Figure 5: Student and practitioner evaluation responses to Goal One. Source: Author

Over the course of three pilot seminars, students worked on 12 research projects while embedded with professional design teams at five Portland firms. The students commented in their course evaluations that observing and participating on design teams was “enlightening” and one of the best parts of the course. This sentiment is reflected in the survey data above. During seminars students discussed the types of interaction they witnessed and documented between practitioners from different disciplines. Weekly collaboration memos and a final timeline were used to document this.

Goal Two: Provide architecture students with the opportunity to lead an interdisciplinary team of peers.

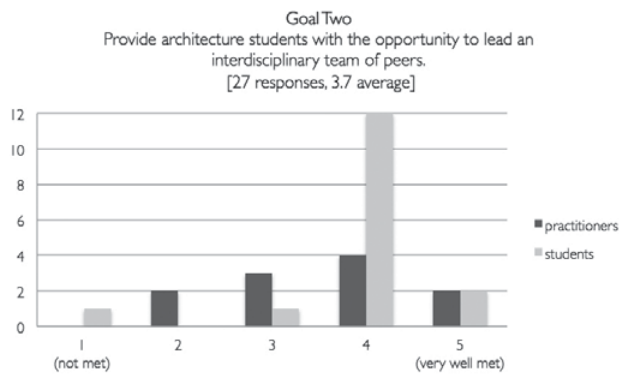

Figure 6: Student and practitioner evaluation responses to Goal Two. Source: Author

This goal was the least met of the three, but still achieved some measure of success as based on the survey results above. There was not enough time between the announcement of the grant (November 2011) and the beginning of Winter term (January 2012) to recruit students from other disciplines. While meetings were held with faculty from engineering departments to recruit engineering students and publicity materials were distributed to help with this recruiting, only one civil engineering student and two mechanical engineering student participated throughout the three seminars (with only one enrolled in the seminar), so only three teams were able to work with an engineering student. However, many of the students were able to interface with practicing engineers who were on the project teams they were tracking as well as work with engineering students who run laboratories. In many cases these engineers and lab assistants also assisted with the research projects. Two major barrier to including more engineering students in these seminars are that (1) students pay for each credit hour they take at PSU so there is a financial disincentive to take more elective courses or courses outside of your discipline and (2) faculty members in other disciplines, who advise students, need to know about these courses and the value they hold for engineering students.

Goal three: Generate original sustainability research to assist practice with pressing needs and improve the public health and welfare.

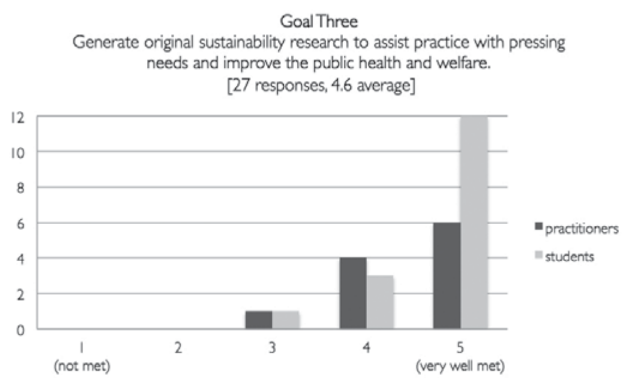

Figure 7: Student and practitioner evaluation responses to Goal Three. Source: Author

All three seminars were highly successful in meeting this goal. All of the non-faculty architect practitioners stated that the research the students presented at the end of the pilot course exceeded their expectations. Five students (or teams of students) have had their research papers from the pilot course accepted at an international conference in Portugal this summer. Equipment from the Green Building Research Laboratory is offering an opportunity for firms to engage in research that they otherwise might not have been able to do. It also provides training of students in these metrics and means of measuring environmental impact or performance.

CONCLUSION

The overall success in integrating practice and the academy to conduct translational sustainability research was excellent. Students in the courses worked closely with the practitioners, other architects in their office, and professional engineers on their research projects, meeting at least every other week outside of the seminar. All of the graduate research symposiums held at the end of each course were well attended by over a dozen practicing architects to hear and discuss the final results of the research. Most teams of students were invited to present their research findings to the entire firm that they were working with or to the design team in which they were embedded. The survey of students and practitioners at the end of the one-year grant showed that the goals of the project were "well met" and both groups thought the seminars were a "win-win" for all parties involved. This is best summarized by Miguel Hidalgo, project architect at BOORA Architects (and previously of THA and YGH), who wrote the following in his evaluation of the program:

> Throughout my involvement with the PSU Research-based Design Initiative I have been struck by the unique opportunities it offers to students to directly engage in active projects and offer actionable feedback that can impact the final project designs. For firms, the Research-based Design Initiative provides access to engaged and motivated students who can dig into issues that the design team may not have the personnel resources to fully explore. It also is an opportunity for firms that ask questions that may be tangential to project completion—new tools, new process—but can inform later work.

Due to the success of the pilot seminars, another grant for $100,000 from the Oregon Community Foundation's Van Evera and Janet M. Bailey Fund was secured which will continue to support these graduate seminars through 2018. These types of practicum courses that focus on translational research are a model for improving building science education and practice throughout the US.

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