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Reflections on the Adoption of Building Performance Simulation in Architectural Education

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Abstract

This paper contributes to the discussion about the place of Building Performance Simulation (BPS) in architectural education. First, the paper introduces three new perspectives grounded in established theory from social science relating to 1) taste, 2) the agency of technical objects such as BPS software, and 3) the divergence between architecture and adjacent fields. The perspectives offered by these theories can be useful for understanding and acting upon some of the long-standing obstacles to the broader adoption of BPS in architectural education. Second, the paper suggests three heuristic goals to guide initiatives to increase the adoption of BPS in architectural education and beyond: familiarity, confidence, and trust. The paper is informed by previous literature on BPS education and the author's experience as a tenure-track faculty member teaching in a five-year professional undergraduate degree program in the United States.

Introduction and Intent

Calls to integrate building performance simulation in architectural education are regularly framed in terms of a knowledge gap. For example, a recent DOE-sponsored report noted that "few have formal training in BEM [building energy modeling] since only a handful of architecture and mechanical engineering programs include BEM as part of the curriculum" (Roth and Reyna 2020, p. 75). The report goes on to identify barriers to BEM education, including the small number of faculty with specialized knowledge, the lack of ready-to-go support materials such as sample exercises or lab assignments, and the need to support students interested in BEM, for example with design competition prize money, graduate fellowships or internships, and support for faculty interested in the development of BEM materials.

These are regularly recurring themes in the BEM and BPS literature. The way this problem is framed—as both a lack of appropriately trained teachers and as a lack of knowledge in the form of educational resources—succinctly answers the question of *what* is missing from architecture education. Yet the framing of this question, precisely because it puts the focus on the content, rather than the form of knowledge, obscures a question of arguably equal or greater import: *how* can building performance simulation be integrated into existing architectural education curricula? This paper is written from the perspective of teaching in the US context, where relatively few programs deliver a deep understanding of building physics and where past surveys have shown that faculty question whether their own programs' graduates are equipped with the skills needed to deliver net-zero energy buildings (Kwok, Tepfer, and Grondzik 2014). However, recent research from Spain suggests this also may be true in other countries and educational systems (Fernandez-Antolin et al 2021). While it is important to acknowledge differences in culture, curriculum, accreditation, and professional requirements, this paper introduces a set of theoretical and conceptual tools useful for integrating BPS into architectural education across cultural and educational contexts.

Accounting for the place of Building Performance Simulation in Architectural Education: elements from three theoretical perspectives

Three elements drawn from theories of social science shed light on the limited uptake of building performance education software.

Taste

The first element is the Fits-Like-a-Glove Framework, which was developed by consumer researcher Douglas Allen (2002). Working in the context of higher education, Allen accounts for why some working-class students gravitate to for-profit educational institutions offering two-year secretarial degrees: because the familiar and familial atmosphere of the for-profit institution feels more like home than the unfamiliar and egalitarian atmosphere of the four-year campus. The theory is notable for its divergence from dominant models of choice, which frame decisions as a matter of maximizing economic and other benefits. These theories cannot explain why generations of working-class students would repeatedly choose *more* expensive for-profit two-year institutions with a history of delivering degrees that limit lifetime earning over their four-year counterparts. One of the most significant contributions of this theory is how it highlights the role of taste. In the context that Allen studied, taste is expressed as "an affinity for applied, hands-on training and an aversion to formal subjects composing a traditional academic curriculum" (p. 523). Shifting to the context of architectural education, when I ask why a student has chosen to study architecture, one of the most common responses I hear is "because it's like engineering, but I heard there's less math." In slightly different terms, architecture is widely perceived by undergraduate students as an applied, hands-on field. It is similar to engineering in focus and professional outcome. It just requires less math. This distaste for the rigors of calculation, which can be reinforced by implicit and explicit aspects of architectural curricula, is a profound barrier to the adoption of BPS.

The Agency of Technical Objects

The second element is the concept of *scripting the user*, which comes out of Actor-Network Theory, or ANT, most often associated with the work of the prolific scholar Bruno Latour. While ANT is too large of a topic to summarize here, it is part of a broader turn in the social sciences to call attention, in part, to the ways that material objects mediate social relationships. As such, ANT has been of broad interest to researchers across disciplines and within architecture. *Scripting the user* is an idea from a foundational essay by Latour's collaborator Madeline Akrich. The fundamental move is to differentiate between the intent of the creator of a technical object and how that object is used. A blunt (if somewhat unappetizing) example is the divergence between the intention of the designer of a spaghetti spoon, whose ostensible intention was to create an implement for wrangling slippery noodles out of boiling water, and the legions of people who have been moved to trumpet online the utility of this humble kitchen implement as a back scratcher. In Akrich's terminology, the designer *inscribed* one use (for extricating pasta), while its users *described* another (for alleviating itch.) Moving back to the worlds of architecture and building performance simulation, this theory highlights the assumptions built into the *inscription* of building performance simulation. Central is that the use of building performance simulation as a design tool will necessarily result in better buildings. But evidence shows this is not the case. Though they did not engage Akrich's theory, Sara Alsaadani and Clarice Bleil De Souza's quantitative work on the relationship between architects and BPS consultants can be seen through this lens. They found that there is room for improvement in the trust dynamic:

> In light of... the use of BPS for compliance, and architects' attitudes toward BPS... architects' lack of understanding about the purpose and potential of BPS, and their misperceptions that the primary purpose of BPS is to guarantee compliance, coupled with pre-existing negative attitudes toward the software, may be affecting trust dynamics to a lessening degree. (p. 405, Alsaadani and Bleil De Souza 2018)

As discussed later, Alsaadani and Bleil De Souza's data and analysis highlight the *description* of building performance simulation, not as a tool for improving design, but rather as one for measuring compliance. The diminishment of trust results from the attachment of a different set of meanings and practices: simulation is used to demonstrate compliance *after* design was completed, and their research suggests that architects often do not understand or necessarily trust the results of simulation.

Legitimation Code Theory

The third element, which shares some common threads with the first two, is from the field of Legitimation Code Theory. A concept at the core of the theory is *knowledge blindness*, which indicates the tendency for knowledge to be a common subject of conversation or object of study, yet one that remains significantly under-determined. What constitutes knowledge in one field—say, the sense of whether dough is sticky enough to make good bread—is completely different from another, such as how to determine the right price to buy or sell a stock. What's more, the ways that knowledge is generated, shared, experienced, and validated (that is, legitimated), varies broadly between fields. In the field of architecture, it's important to know about the latest buildings by important architects such as Jeanne Gang and David Adjaye, but it's also important to exhibit knowledge through one's image, for example by wearing black clothes. In other fields, such as engineering, a person is a legitimate knower when they can follow established procedures and arrive at the right answer; style is much less important.

In the terms of Legitimation Code Theory, when there is a difference in what knowledge is valued between fields, or when there is a difference between how knowers are considered to be legitimate in different fields, then there is a *code clash*. Going beyond the stereotypes of architects as black-clad and image-obsessed and engineers as, well, a little nerdy, considering the differing nature of both knowledge *and* knowers has profound implications for the adoption of BPS.

Familiarity, Confidence, and Trust: A Heuristic to Increase Adoption of BPS

Familiarity

Taking a step back from the articulated theories articulated in the previous three sections, familiarity is a foundational component of psychology. In the guise of the "mere-familiarity effect," the principle holds that the more times a person is exposed to a particular stimulus, the more the person will come to regard that stimulus positively. This is why Coca-Cola is ubiquitous and political advertising unavoidable around elections. However, in the context of BPS, the literature makes clear that in most architectural education programs, BPS is far from familiar.

So far, two strategies to increase familiarity are apparent. One is to find ways to overcome the (sadly!) typical and continuing artificial divide between technical and non-technical courses (Oakley and Smith 2007). This approach often takes the approach of a course taught in collaboration between an architect and an engineer or performance consultant (Charles and Thomas 2009; Laboy and Onnis-Hayden 2019). Another variation of this approach is to expose students to a wide variety of BPS packages within a single elective course: for example, see He and Passe 2015. The other is to restructure entire architectural curricula around BPS (e.g. Berger and Mahdavi 2019).

From the perspective of Legitimation Code Theory, these approaches exhibit a form of knowledge blindness. The assumption is that what is missing is students knowing how to operate (to some degree) BPS software packages, interpret the results, and integrate them into outputs, in particular the output of high-status studio classes used to benchmark the success of individual students and entire architectural education program. Of course, this is undeniably true. Students and faculty are lacking in BPS-related knowledge (Fernandez-Antolin 2020). But thinking more broadly about familiarity exposes another part of the problem: students and faculty are unfamiliar with *people* who use BPS tools. The survey research conducted by Soebarto and colleagues found that about 1 in 5 respondents did not know anyone who uses BPS tools and another half of respondents knew five or fewer people (2015).

This suggests the need not only to introduce BPS tools and techniques but also to introduce students to people who use (or depend upon the outcomes of) BPS across the broader context of the building industry. In contrast to the logistical and organizational challenges of revising curricula, this can be done relatively easily by working within the structures of existing courses. One way of doing this would be to bring guest lecturers or critics who use BPS into the first and second year of undergraduate education when in many schools courses focus on fundamental form and technique to the exclusion of "technical" concepts. Familiarity can be built by connecting the use of BPS to the development of innovative architectural forms or the care and craft of details. For example, SAANA's Grace Farms project, widely recognized for its design excellence, required extensive energy modeling to meet performance objectives and clever detailing to reduce thermal bridging. While explaining tools and techniques in the early years of architectural education, or teaching them in subsequent years is needed to bridge the knowledge gap, familiarity with the people behind BPS is needed to spark curiosity and increase motivation to learn and apply concepts in different contexts.

Trust

Previous work has exposed the rift in trust between architects and building performance consultants working in a professional setting. Evaluated using Hartman's model of trust (Hartman 1999), these relationships have been found to be deficient in all three dimensions of integrity, competency, and intuitive trust (Alsaadani and Bleil de Souza 2016). Given the presence of practicing architects as instructors and faculty in American schools of architecture, it is likely that the kind of trust modeled by the collaborative approach to teaching exhibited in the work of Charles and Thomas (2010) is the exception, rather than the rule. However promising a collaborative teaching method may be, the difficulty in finding a teaching team that can authentically model trust to a classroom of students constitutes a considerable barrier to the teaching of BPS in architectural education. Even when there is general agreement on the need to teach BPS in a given curriculum, changes to curriculum and teaching assignments can require the commitment and expenditure of tremendous amounts of trust and other social capital.

Taste is another elephant in the room that has a direct bearing on trust. In my own experience, I have seen it manifest in at least two ways that correspond to the same division between applied, practical skills and abstract knowledge that Allen saw in his research context. In the context of a design-build course with a limited budget for construction where I was brought in as an expert consultant (a situation that shared many characteristics with what Charles and Thomas (2009) describe as the outside expert model), a senior colleague with primary responsibility for the studio (and construction budget!) lamented that she was "following me around and telling the students to un-do almost everything" I had suggested they change. In this case, two primary and necessary goals of the studio, practicality, and affordability, were perceived by the studio instructor, and to some degree the students, as being in opposition to the goals of BPS, in this case, to improve comfort and reduce energy use. While one promise of BPS in the integrated design process is to enable the cost-effective incorporation of high-performance details, it is important to recognize that the incrementalist incorporation of BPS into existing structures can implicitly frame these details as *costly* upgrades, *extra* work, or *unnecessary* encumbrances to a "pure" design process.

This overlaps with another, and seemingly opposed, expression of taste in architecture, which is a largely unquestioned belief in the pure beauty of unadorned materials, such as cast-in-place concrete and steel. This, combined with the modernist impulse to blur the line between interior and exterior, runs headlong into a principle of building physics that is understood as a fundamental truth by most in the BPS community: the integrity and sanctity of the building envelope. I watched a particularly skilled architect walk the line while presenting a home she had designed and certified to the US passive house standard with what appeared to be a concrete wall that flowed seamlessly between an exterior courtyard and the home's entry. "I've learned how to lie," she said, explaining how the door frame concealed a discontinuity and, therefore, a thermal break in the visually continuous wall. In studio projects, however, students are rarely taught to make these kinds of performance-enhancing lies, nor how BPS tools can be used to account for the cost of thermodynamic extravagance. Instead, I often see students rewarded for making design and material decisions that celebrate the modernist taste for truth and honesty. For example, a recent student project designed for a site in the high desert was awarded by jurors associated with a major professional association. The project was designed with an envelope that was entirely poured-in-place concrete, with no insulation to be found. Here, the inconvenient truths delivered by even the most rudimentary BPS model are suspect because it is a mechanism to undermine trust in the aesthetic system that continues to be the basis for distinction in the profession.

Scholars of taste have shown that across contexts, such as music, food, and fashion, that taste is a central mechanism of group identification. A corollary is that demonstrated distaste is equally, if not more important: it's not enough to like jazz, but you also need to hate disco. This is where Ackrich's concept of scripting the user comes into play. Using BPS tools is not a neutral act or a simple addition or substitution to an existing design process. "Describing" BPS tools in this specialized sense of the term requires the user to acknowledge, engage with, and aspects of architecture that many consider outside the field and that, crucially, are defined *in opposition to* tacit ideas of what constitutes "good architecture," such as dishonest wall sections, the banalities of material selection, or the acknowledgment that some kind of mechanical system is often needed to keep a building operating in alignment with contemporary expectations for comfort and air quality. Demanding students pay attention to these details threatens to undermine what has been a tightly bounded, carefully guarded group identity.

In response, advocates of BPS need to acknowledge in internal communications and in discussions with colleagues and students that the integration of BPS in architectural education is not simply augmenting or substituting elements of a different design process, but is likely to be interpreted as an attempt to overhaul, if not hijack, the very identity of a profession.

In parallel with this, advocates of BPS need to do much more work to demonstrate the reliability of predictive simulation and to counter negative examples (such as the often-repeated sentiment that building energy simulation isn't worth doing because it's not accurate anyway.) This is doubly important in a post-trust culture, where expert judgment is regularly questioned and torn down in favor of "alternative facts." The BPS community could look to the success and failure of social movements, such as the expansion of anti-vaccine efforts, to develop proactive strategies for enhancing trust in the predictive nature of BPS tools. Increasing trust in BPS will be especially important as codes continue to transition from prescriptive to performance-based metrics.

Confidence

Arguably the most important learning goal of any BPS educational effort is to increase student confidence with the tool or tools in question. He and Passe's surveys of students show that students are generally satisfied with a range of BPS tools introduced in an elective class (2015). Other work has focused on whether students have access to BPS tools, or, as discussed earlier, how these tools can be integrated into a curriculum. But big questions remain to be asked: does learning BPS tools increase a student's sense of agency? For different BPS tools, what are the minimum levels needed to attain competency? What constitutes mastery? One set of answers to these questions can be arrived at by applying Alsaadani and Bleil De Souza's (2019) classification of three different paradigms of BPS education: 1) training an expert, 2) training a consumer, or 3) training a performer.

Adding Ackrich's idea of inscription and description to these three paradigms could add nuance to future applications of these paradigms. In addition to differences in depth and breadth of knowledge, one thing that appears to distinguish the categories of student-expert, student-consumer, or student-performer is the degree of transformation applied to BPS-derived knowledge in the act of description. The consumer is expected to apply knowledge derived from others' use of BPS; the performer, to use BPS systems directly; the expert, to question and manipulate the data—in effect, de-scripting and reinscripting it. Alsaadani and Bleil De Souza add a further distinction between the expert, whose training moves outside of the realm of design and into a new realm with boundaries defined by expertise in BPS tools, and the consumer and performer, who remain bounded by expertise in the domain of design. As the authors explain, this highlights a conflict within the BPS community over the rightful place of BPS in the design process.

In combination with Alsaadani and Bleil De Souza's work, Legitimation Code Theory suggests that the BPS community pay more attention to the ways students are encouraged to build confidence as a designer in the context of specific architectural education curricula and programs. For example, many programs still require students to learn hand drawing. This is one of many ways that embodied learning is privileged in design education.

One parallel theme in the literature on BPS and architectural education is the importance of representing BPS outputs in visual form. This call takes several forms, from the simple reflection that architects are visual people who prefer visual tools to elaborate and thoughtfully produced tool prototypes such as the Design Performance Viewer developed by Schuleter and Thessling (2009). Returning to the context of embodied learning, one example would be for BPS education to connect exercises that emphasize the embodied experience of comfort with the use of BPS tools. This would build on a structure of knowledge that is already familiar to the student and that is socially valorized within the culture of architecture, helping to counter the message that it is ancillary or non-essential knowledge. Furthermore, embodied knowledge can help build confidence precisely because it is felt and experienced. Put another way, BPS education needs to get off the screen, out of the head, and into the body.

Conclusion

Taken together, the theoretical perspectives of taste, the agency of technical objects, and concepts from Legitimation Code Theory, along with paying closer attention to the mechanisms through which BPS education efforts produce or erode familiarity, trust, and confidence, suggest that efforts to increase the adoption of BPS would benefit from a closer examination of identity. In addition to optimizing, rearranging, or gamifying the design process, BPS advocates need to focus on the motivations of people who use (or could use!) BPS. Modeling the different types of BPS users—and how these users fit into or require the reworking of existing structures within architectural education—can no longer be overlooked. Future work should explore how teaching BPS tools can build familiarity, trust, and confidence, both in students and among faculty and instructors, and should take into account the social mechanisms that govern access to contested fields.

References

Akrich, M. "The De-Scription of Technical Objects." 1992. In *Shaping Technology/Building Society*, edited by W. E. Bijker and J. Law.

Allen, D. E. 2002. "Toward a Theory of Consumer Choice as Sociohistorically Shaped Practical Experience: The Fits-Like-a-Glove (FLAG) Framework." *Journal of Consumer Research* 28(4). https://doi.org/10.1086/jcr.2002.28.issue-4.

Alsaadani, S., and Bleil De Souza, C. 2016. "Of Collaboration or Condemnation? Exploring the Promise and Pitfalls of Architect-Consultant Collaborations for Building Performance Simulation." *Energy Research & Social Science* 19. https://doi.org/10.1016/j.erss.2016.04.016.

———. "Performer, Consumer or Expert? A Critical Review of Building Performance Simulation Training Paradigms for Building Design Decision-Making." 2019. *Journal of Building Performance Simulation* 12 (3). https://doi.org/10.1080/19401493.2018.1447602.

Berger, C., and Mahdavi, A. 2019. "Integrating Building Physics And Performance Simulation In Architectural Curricula: A Collaborative Effort." In *16th IBPSA Conference Proceedings.* https://doi.org/10.26868/25222708.2019.210117.

Charles, P., and Thomas, C.R. 2009. "Four Approaches to Teaching with Building Performance Simulation Tools in Undergraduate Architecture and Engineering Education." *Journal of Building Performance Simulation* 2 (2). https://doi.org/10.1080/19401490802592798.

Charles, P., and Thomas, C.R. 2010. "Integrating Building Performance Simulation in Studio Teaching: A Multidisciplinary Consultancy-Based Model." In *Rebuilding: 98th ACSA Annual Meeting Proceedings.*

Fernandez-Antolin, M., del Río, J. M., and Gonzalez-Lezcano, R. 2021. “Building Performance Simulation Tools as Part of Architectural Design: Breaking the Gap through Software Simulation.” *International Journal of Technology and Design Education*. https://doi.org/10.1007/s10798-020-09641-7.

Fernandez-Antolin, M., del-Río, J.M., del Ama Gonzalo, F., and Gonzalez-Lezcano, R. 2020. “The Relationship between the Use of Building Performance Simulation Tools by Recent Graduate Architects and the Deficiencies in Architectural Education.” *Energies* 13 (5). https://doi.org/10.3390/en13051134.

Kwok, A.G., Tepfer, S., and Grondzik, W.T. 2014. “Zero Net Energy Education: Mind the Gap.” In *ARCC Conference Proceedings*.

He, S., and Passe, U. 2015. “Architectural Student’s Attitude towards Building Energy Modeling: A Pilot Study to Improve Integrated Design Education,” in *Proceedings of BS2015: 14th Conference of International Building Performance Simulation Association*, Hyderabad, India

Hartman, F. T. 1999. “The role of trust in project management.” In *Proceedings of Nordnet ‘99’ International Project Management Conference*, Helsinki, Finland

Laboy, M. and Onnis-Hayden, O. 2019. “Bridging the Gap between Architecture and Engineering: A Transdisciplinary Model for a Resilient Built Environment.” In *BTES 2019 Conference Proceedings.* https://doi.org/10.7275/MR5P-8X02

Oakley, D., Smith, R. 2007. “Bridging the Gap: Reviving Pedagogical Discourse in Architectural Technology Education,” In Proceedings of the 2007 ACSA Annual Meeting.

Roth, A., Reyna, J. 2020. “Innovations in Building Energy Modeling: Research and Development Opportunities for Emerging Technologies,” US DOE EERE Report. https://doi.org/10.2172/1710155

Soebarto, V., Hopfe, C.J., Crawley, D., Rawal, R. 2015. “Capturing the Views of Architects About Building Performance Simulation to Be Used During Design Processes.” *IBPSA Conference Proceedings*.