

Developing building performance in the comprehensive design studio

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ABSTRACT: Building performance metrics such as those used to evaluate energy consumption, light levels and temperature are often used by architects and owners to assess environmental parameters that affect the function, comfort and economics of building designs. A majority of architects in practice rely on collaboration and recommendations from design professionals, in specialized technical fields, such as mechanical engineers, lighting designers and acousticians to help develop efficient and effective architectural solutions to meet the required technical demands. This collaboration and coordination positions the architect as a generalist who shepherds all of the disparate and broad-ranging aspects of the project towards a common design vision. To be effective at this task presumes the architect is knowledgeable and experienced enough in the project's quantitative and qualitative design parameters to balance the positives and negatives of the many factors and to not only lead the project towards a common goal but to help maximize its potential. It is this exact juncture between technical and artistic design which often is the crux of the comprehensive design studio in architectural education.

This paper examines pedagogical research in building performance analysis that supports qualitative design objectives. This paper proposes that one of the difficulties that students and designers have in technical integration stems from a lack of iterative design opportunities requiring relevant technical analysis in studio. To explore this proposition the author reviewed pertinent literature in the design of technical design curriculum and surveyed instructors and students in building technology courses and design studios. The results of this research suggest that when studio requirements in the comprehensive design studio are mapped closely with technical objectives initiated in the building technology courses, students have a greater likelihood of developing long-term skills and confidence in technical design integration.

KEYWORDS: building performance, comprehensive design studio, technical integration

INTRODUCTION

Building performance metrics such as those used to evaluate energy consumption, light levels and temperature are often used by architects and owners to assess environmental parameters that affect the function, comfort and economics of building designs. A majority of architects in practice rely on collaboration and recommendations from design professionals in specialized technical fields, such as mechanical engineers, lighting designers and acousticians to help develop efficient and effective architectural solutions to meet the required technical demands of the project (sometimes these are required by building codes; other times, to meet the functional needs/desires of the owner). This collaboration and coordination positions the architect as a generalist who shepherds all of the disparate and broad-ranging aspects of the project towards a common design vision. To be effective at this task presumes the architect is knowledgeable and experienced enough in the project's quantitative and qualitative design parameters to balance the positives and negatives of the many factors and to not only lead the project towards a common goal but to help maximize its potential. It is at this exact juncture between technical and artistic design which often is the crux of the comprehensive design studio in architectural education. Often the comprehensive studio is positioned in the 4th or 5th year of a 5-year undergraduate Bachelors of Architecture program. Thus, with only a few years of academic instruction, students are required to develop a complex, collaborative studio project with meaningful integration of technical, economic and artistic parameters.

This paper presents research and ongoing study of pedagogical methods to create curricula promoting the meaningful integration of building performance analysis and enhancing

qualitative design objectives in the comprehensive design studio in a NAAB accredited program. Building performance and analysis, although usually integrated into the overall architectural curriculum with classes specifically devoted to technical analysis (such as energy use, structures and thermal comfort), often are not well integrated into the process, deliverables and outcomes of the design studios. Critical thinking skills related to design implementation of building performance are often not fostered in the studio environment, limiting the future success of architects in coordinating and directing technical integration in their designs.

1.1. Analysis for support and generation of ideas

Building performance and analysis is often assumed to be merely a quantitative exercise related to the size and cost of equipment or materials. While economics and spatial impact are important factors in architectural design, these are often seen as limitations rather than supportive or generative elements in the design process. For building performance to become a more meaningful portion of the design process, the quantitative analysis must become more intricately linked to qualitative outcomes. That is to say that the analysis or numerical results should support and enhance qualitative architectural design objectives. In architectural design, an iterative design process is often expected, with back and forth input and participation with the client and design consultants. But even in the professional realm, analytical results are often only employed to vet or fix predetermined designs.

Rarely is quantitative analysis of building performance used iteratively to help generate or support qualitative design goals. For instance, most engineering consultants do not provide any quantitative analysis until the design development or construction documents phase of a project. Many conceptual and schematic design proposals have only loosely considered technical parameters and, as such, consultants are often not yet meaningfully integrated in to the design teams. This is largely due to a perception of technical parameters as constraints since the analysis and expertise is provided by an external party (the consultants). In addition, architectural design teams (much like architecture students) often wish to operate with greater flexibility in early design phases without the perceived burden of technical factors. What is unfortunate here is that many architects may have unconsciously shifted the responsibility of technical parameters so far outside of their ken that they no longer have the critical exposure to these parameters to include them into conceptual and schematic design iterations for meaningful support and generation of their design ideas.

Instead, imagine that designers are academically trained to directly integrate technical design parameters to exploit them towards positive design outcomes. For example, when considering structural layout and materials, the architect could anticipate (or even push to generate) how the repetition, orientation and depth of structural members could be utilized to increase the spatial or geometric reading of their designs much like how patterns and panelization greatly increase our ability to read volumes and contours of objects and spaces. When considering thermal comfort and HVAC systems, perhaps the architect could envision and direct the type of systems and thermal zones to decrease energy use while maintaining the thermal quality of main programmatic areas and utilize transition spaces such as corridors along the exterior as thermal buffers zones. By doing so, the size of the duct work and mechanical spaces along with their costs could also be decreased, thus shifting resources to other aspects of the project's design. Reaching a high level of conceptual architectural design integration with building systems and performance rarely happens as mere serendipity. Utilizing building performance and analysis as part of the process is important, but more importantly, designers must make the link between quantitative analysis and qualitative outcomes. To achieve high levels of successful integration, architects must develop a sense of how each technical parameter not only impacts the quality of the space but how it can be supportive and potentially generative in its design process.

1.2. Iteration and reflection

How can architects attempt to bring building technology and performance back into our design repertoire for greater beneficial design impact? Learning how to use building performance analysis can be similar to learning how to draw a wall section or construct a 3-dimensional drawing as analytical and revealing design tools. Practice, iteration, reflection and scale are

methods for developing and integrating design skills whether it be drawing, modeling or analyzing a building. Thus, for building technology and analysis to have the potential to play a meaningful role, architects must practice integrating and reflecting on building performance as part of their design process. This is no different than what designers expect when using 3-dimensional computer modeling, physical models and drawings. Perhaps factors that may be missing in the use of building performance analysis are the steps of iteration and reflection of analytical results within the design process.

Reflection can help designers target and shape future analytical attempts. Instead of merely solving a problem, such as the number of light fixtures needed or the size of a steel column, by reflecting on their potential impact, these technical parameters can become more supportive elements. For instance, the size and frequency of light fixtures may be mathematically related to recommended light levels in a space, but ultimately they can also become a field of objects that help define the reading of volume and intensify emotions within a space. The size and frequency of structural elements are mathematically related to the anticipated gravity and lateral loads, but as large visual elements they can also greatly affect our reading of scale, proportion and perspective within a space. Thus, by reflecting on the results of technical analysis in conjunction with design objectives, technical parameters can become supportive elements in the design process.

In an academic setting, architecture students should practice developing a critical understanding of building performance design and metrics not so that they will become performance specialists but rather to be better positioned to maximize design potential when collaborating with future technical consultants and to gain greater insight and understanding of the fundamental correlations between quantitative performance parameters and qualitative design outcomes. One of the difficulties that students and designers confront in technical integration stems from a lack of iterative design opportunities requiring relevant technical analysis and integration in studio. This paper will examine some of the obstacles common in technical integration and also propose methods for creating successful exercises for technical analysis in an iterative design process at conceptual and schematic design phases (phases during which technical iteration is typically absent in the studio design process).

1.3. Support courses and studio design

In most architecture programs, students and curricula place a large emphasis on the design skills practiced and developed in the design studios. The curricular structure of many programs thus is centered on design studios that become successively more complex, layered and sophisticated as students' abilities and methods develop (Banerjee 1996). Classes such as history, theory, structure, systems and modeling are often viewed as courses that provide context, skills and exposure to parameters that can contribute to and support design ideas in the studios. These support courses, although intended to feed into design studios, often are not successful in integrating themselves into the design outcomes of the students' studio-based work. There are three obstacles that reduce the effective transference of knowledge and skills from the support courses to the design studios. The first is a lack of critical understanding of the course material and its context within achieving improved designs. The second is lack of cross-course coordination of specific outcomes from the support courses into the design studios. The third is the lack of analysis as an iterative inclusion in the studio design process (Chung 2013). The first issue in the case of technical support courses often requires increased reflection and critical thinking activities in the technical course curriculum with a specific focus for students to link quantitative analysis with qualitative design goals. The second issue requires close coordination between support course and studio course faculty to arrange for the required documentation and deliverables in the design studio that specifically ask students to demonstrate reflection and integration of support course material as it directly applies to their studio designs. The third issue requires mapping the use and practice of analysis over multiple semesters in both the technical support courses and the design studios and working towards repeating analytical procedures in an iterative studio design environment. Each of these issues requires faculty to not only develop changes or modifications in the curriculum (in both the technology and studio courses) but to also develop assessment techniques that help gauge the development of critical thinking and confidence levels (related to technical integration) of students and to provide feedback to the instructors.

1.4. Student-centered activities

Technical material related to building systems taught to design students is often taught in a lecture format that relies on rote memorization of facts (Bower 2007). These courses frequently are designed to help students become familiar with a broad range of topics and pass the multiple choice questions anticipated on the Architectural Registration Exams. Thus, they may not be effectively designed to enable technically proficient outcomes in design studios. To achieve critical understanding of technical material requires students to not merely be exposed to topic areas, but requires them to integrate and apply the knowledge into their design experience through student-centered active learning methods (Schneps 1988). Problem-based learning methods utilized in science and medical educational fields are proposed as a way to facilitate critical thinking skills and abilities for architectural students regarding technical analysis for building performance (Roberts 2007). Most often this requires the students to be posed with a technical problem that they lack the skills to solve so that they can first analyze their own abilities and create a mental context for future information. Once this is accomplished, faculty help facilitate the implementation of established analytical methods for technical solutions (Hemlo-Silver 2004).

1.5. Structures as a precedent for building performance analysis

Most architects can agree on the importance of a solid education in structural analysis, having conceded that the structure and building frame are integral physical elements of their projects. Structural analysis education in architecture is required even though a majority of architects utilize structural engineers as design consultants. But when it comes to building performance such as energy, lighting and thermal comfort few architectural programs attempt to instruct students in the quantitative and analytical processes to measure the technical success of their projects. An education and early experience in building science analysis with strong correlations to design studio objectives allow for greater understanding and confidence for design students to meaningfully integrate these technical elements into their design process. By primarily using methods of hands-on analysis and evaluation (not via prepackaged software), students can develop meaningful correlations between technical parameters and design outcomes.

Architects routinely attempt to calibrate the size and shape of building spaces based on their programmatic analysis, attempting to fine tune and tailor a building to relate to the function and experience of users of their buildings. Now imagine if the size and shape of the structural elements were conceptually integrated into the design process to be linked as not only an economic factor but one exploited to enhance spatial readings and intensify the legibility of design concepts. This type of integration is actually not that rare, and examples are readily available when looking at larger scale buildings such as stadiums and large office towers where structure plays a pivotal role in the creation of building forms. Examples such as the Hancock Building in Chicago, the Seattle Public Library and CCTV are just a few examples of buildings that are fundamentally linked to their structural designs and display large lateral framing and structural elements on the skin of the buildings. The architectural payoff in each of these examples, with their strong structural strategies, is that each has a unifying façade language that has effectively increased the reading of the formal building massing as well as having improved the interior spaces by reducing the size, frequency and location of internal lateral framing systems, thus allowing for larger and more unconstrained interior spaces.

1.6. Goals and relevance

Ultimately the instruction of technical analysis for architects is an attempt to enhance their understanding of technical material so they are better able to make design decisions related to technical parameters (Chung 2013). So that building performance parameters (such as the type of structure or thermal systems used) that are often blindly relegated to technical consultants become integrated more fluidly into the design process, thus increasing the opportunity for those parameters to be supportive rather than a hindrance to the overall design vision of the project. By practicing and experiencing technical analysis, designers are given the opportunity to develop an understanding of the relative leverage that individual parameters have in determining spatial outcomes that impact design goals. This does not mean that

architects would not utilize technical consultants, but that they would be better able to lead consultants in accomplishing project goals and design ambitions.

1.7. Seven technical topics for building performance in the comprehensive studio

To explore the proposed effectiveness of implementing iterative analysis as part of a studio design process as a means for more meaningful integration of building performance in design (and in particular in the comprehensive design studio), I investigated over a three-year period the instruction of technical support courses and their cross-course, cross-semester outcomes in related design studios. The research started in 2010 and has continued through 2013, with the author participating in the instruction and/or coordination of the structures, environmental systems and design studio curricula for architecture students in a 5-year B.Arch program. The following seven technical areas were analyzed in both the technical support courses (in the third year) and the comprehensive design studio (in the fourth year).

- 1) Lighting levels and energy use (USEIA 2001),
- 2) Acoustical reverberation time, reflection and absorption,
- 3) Structural member sizing for beams, slabs and columns,
- 4) Solar energy production and sizing of PV arrays,
- 5) Thermal balance points, heating & cooling loads, and thermal system sizing,
- 6) Project capital costs,
- 7) Project operational costs.

The technical analyses were practiced at least three times (in class, labs and assignments) during the technical support courses by the students for each of the seven areas and at least twice during the comprehensive design studio (directly applied to student design projects). During the comprehensive design studio, students were asked to utilize technical analysis first to establish a baseline for building performance given their designs and then to improve the design over the course of the semester. Thus, many elements were redesigned by students in direct response to technical analysis. By integrating the analysis into student-created Excel spreadsheets that were directly related to their 3-D models, students were able to quickly update their analyses and use them as iterative design tools. The seven technical areas can be shuffled, reorganized, edited and tailored to aid in the design of studio projects in the comprehensive design studio so long as the size and scale are substantial enough that project budgets become a limiting factor. By providing capital and operational cost constraints related to regional or national averages (USEIA 2001), students begin to see the cost-benefit correlations to design decisions.

1.8. Surveys to track implementation

I conducted surveys of both students and faculty at my institution as well as faculty members from other institutions that coordinate building technology and studio courses in NAAB accredited architecture programs. In addition, I researched pedagogical teaching methods through surveys, assessment techniques and literature reviews in how technical material can be more meaningfully integrated into studio courses (Chung 2013).

As part of the literature review on teaching methods of technical material to non-technical students, a well-documented correlation (demonstrated by pedagogical researchers in chemistry and medicine) showed that student confidence levels in discussing the relevance of technical material outside of class and relating the material to their other courses were significant indicators of long-term knowledge transference into other contexts (Bower 2007). Thus, student surveys in both the technical courses and design studios utilized questions to gauge their confidence related to technical material rather than only testing them on specific technical ability or content.

Student surveys were performed in both technical support courses such as the environmental systems course (taken in the third year) and design studios such as the comprehensive design studio (taken in the fourth year). The website salgsite.org was utilized for the surveys to provide a method for anonymous participation for students within the classes while also providing quick access to quantified survey data. Figures 1-4 are included to provide examples of the questions used in the surveys (implemented via salgsite.org) completed by students in

both the technical support courses and the comprehensive design studios at the beginning, middle and end of each course. This is one of the assessment tools used to track confidence levels and the likelihood of technical integration into students' future design processes.

Understanding

1. Presently, I understand...	1: not applicable	2: not at all	3: just a little	4: somewhat	5: a lot	6: a great deal	Mean	N
1.1 The following concepts that will be explored in this class							Mean	N
1.1.1 How climatic conditions impact building design form and organization	0%	0%	0%	25%	58%	17%	4.9	12
1.1.2 How structural systems are organized and impact building design concepts.	0%	0%	25%	50%	17%	8%	4.1	12
1.1.3 How building systems and the building envelope are responses to cultural, contextual and climatic conditions.	0%	0%	8%	42%	17%	33%	4.8	12
1.1.4 How building science and performance metrics can be used to evaluate designs.	0%	0%	8%	58%	17%	17%	4.4	12
1.2 The relationships between those main concepts	0%	0%	0%	50%	33%	17%	4.7	12
1.3 How ideas we will explore in this class relate to ideas I have encountered in other classes within this subject area, such as Tech 1, 2, 3, 4 and Structures 1 and 2	0%	0%	0%	25%	50%	25%	5.0	12
1.4 How studying this subject helps people address real world architectural design issues.	0%	0%	0%	33%	50%	17%	4.8	12

Figure 1: Survey questions completed by students gauging their perceived understanding of course material (2013)

Skills

2. Presently, I can...	1: not applicable	2: not at all	3: just a little	4: somewhat	5: a lot	6: a great deal	Mean	N
2.1 Effectively diagram and incorporate schematic structural systems into my studio design process.	0%	0%	8%	17%	67%	8%	4.8	12
2.2 Effectively incorporate and diagram building systems meaningfully into my studio design process.	0%	8%	8%	42%	33%	8%	4.2	12
2.3 Effectively analyze and draw material assemblies related to the building envelope in regards to structure, climate and constructability	0%	0%	8%	50%	33%	8%	4.4	12
2.4 Effectively determine and discuss the intent and character of my studio project.	0%	0%	0%	17%	58%	25%	5.1	12
2.5 Develop logical arguments in regards to design decisions and concepts	0%	0%	0%	25%	58%	17%	4.9	12
2.6 Write documents in discipline-appropriate style and format	0%	0%	8%	33%	42%	17%	4.7	12
2.7 Work effectively with others	0%	0%	8%	17%	42%	33%	5.0	12
2.8 Prepare and give oral presentations	0%	0%	8%	17%	58%	17%	4.8	12

Figure 2: Survey questions completed by students gauging their perceived skills related to course material (2013)

Attitudes

3. Presently, I am...	1: not applicable	2: not at all	3: just a little	4: somewhat	5: a lot	6: a great deal	Mean	N
3.1 Enthusiastic about the subject of comprehensive design studio.	0%	0%	0%	8%	33%	58%	5.5	12
3.2 Interested in discussing the subject area with friends or family	0%	0%	8%	17%	50%	25%	4.9	12
3.3 Confident that I understand the subject matter.	0%	0%	0%	17%	67%	17%	5.0	12
3.4 Confident that I can effectively design in a comprehensive manner.	0%	0%	0%	42%	50%	8%	4.7	12
3.5 Comfortable working with complex ideas	0%	0%	17%	17%	50%	17%	4.7	12
3.6 Willing to seek help from others (teacher, peers, TA) when working on academic problems	0%	0%	8%	8%	50%	33%	5.1	12

Figure 3: Survey questions completed by students gauging their perceived attitudes related to course material (2013)

Integration of learning

4. Presently, I am in the habit of...	1: not applicable	2: not at all	3: just a little	4: somewhat	5: a lot	6: a great deal	Mean	N
4.1 Connecting key ideas I learn in my classes with other knowledge. For instance creating meaningful links between technical, theoretical and design classes.	0%	0%	0%	25%	42%	33%	5.1	12
4.2 Applying what I learn in classes to other situations. Such as using Tech or Structures class material in studio design.	0%	0%	8%	25%	42%	25%	4.8	12
4.3 Using systematic reasoning in my approach to problems	0%	0%	8%	33%	50%	8%	4.6	12
4.4 Using a critical approach to analyzing data and arguments in my daily life	0%	0%	17%	8%	58%	17%	4.8	12

Figure 4: Survey questions completed by students gauging their perceived integration of course material outside of the course (2013)

Figures 1-4 show the surveys questions that are focused on assessing students' perception of their understanding, skills, attitudes and integration of course material, goals and objectives.

1.9. Results from surveys

The results of this research suggest that when studio curriculum and assignments in the comprehensive design studio are mapped closely with technical objectives initiated in the building technology courses, students have a greater likelihood of developing long-term skills and confidence in technical design integration. Surveys showed that confidence levels sharply increased after the second time an analysis was performed, and each time the analysis was performed within a studio setting all four survey subsections results increased in a positive direction.

The results of the three-year curricular study have shown a significant increase in the integration of analytical tools in the students' design process leading to more thoughtfully considered designs and economically viable attempts at higher performance-building designs. Perhaps more importantly, surveys have indicated that student confidence in the use of technical analysis is high enough that they expect to integrate it into their future design work outside of the requirements of the design courses and that many students believe that the design profession can and should be capable of utilizing analytical tools within the day-to-day design process to achieve high-performance buildings.

CONCLUSION

This paper presents some of the perceived and real difficulties of incorporating building performance analysis into an iterative architectural design process and offers an implementation method for education programs to provide students with the means to build technical skills so that they can meaningfully utilize building performance analysis toward high-performance designs. It is the early educational application of fundamental building science analysis through basic building science calculations on a student's own studio design project is a highly effective method of creating a curriculum where students are empowered to use building performance analysis as a meaningful design tool.

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