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Energy Performance Within Integrative Design, Barriers in Academia

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Abstract

Whole building design is not a new design methodology. In practice, countless buildings achieved recognition and high performance ratings through the means of whole building design. Whole building design is simply a holistic design approach that does not overlook any of the design objectives, including energy performance. In the literature, it is also referred to as systems approach, comprehensive design, integrated design, and integrative design. A recent study by the AIA recommends more attention to be given to Integrative Design. In academia, Integrative Design is now one of the NAAB required student performance criteria. NAAB, in agreement with AIA, ACSA, and NCARB, is foreseeing a demand in the profession for the skills associated with integrative design. However, in academia it is still a work in progress. According to NAAB, Integrative Design is one of the most challenging criteria to achieve. This paper reports on the academic experience of the author in teaching integrative design, with emphasis on energy performance, at Oklahoma Stat University for the last sixteen years. In light of his experience, the paper presents a discussion of the curricular challenges in terms of the design studio's level, scope of design, educational goals, expectations, and available design-assisting tools; and faculty resources and expertise.

Keywords: *Energy performance, energy efficiency, integrative design, whole buiding design, comprehensive design, NAAB accreditation*

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1. Introduction

Indeed, if it has not already been, energy performance is increasingly becoming a premier architectural design goal. As a prerequisite for sustainability, it has been adopted by vast numbers of nonprofit and professional organizations across the globe. In the US, the American Institute of Architects (AIA) is actively advocating for the cause of making new buildings more energy efficient, more sustainable, and more innovative. Established in 1990, the AIA Committee on the Environment (COTE) is the building industry's oldest continuous program dedicated to sustainability (AIA, 2016). It organizes an annual national competition specifically focused on rewarding the top 10 projects that meet its rigorous criteria for sustainable design excellence (AIA, 2017). A recent study by COTE on the top ten projects 1997-2015 found that "advanced sustainable design practices can be applied to a wide range of projects of any scale, type, and budget" and concluded with a recommendation "to encourage more attention on key topics, including integrative design" (AIA, 2016). In 2005, the AIA adopted the 2030 Challenge, which seeks a series of successive targets toward carbon neutrality by the year 2030. Future generations of architects and architectural engineers should be prepared to help taking energy performance to new highs; maybe even reaching net-zero energy.

2. Integrative design in NAAB-accredited programs

In academia, students in NAAB-accredited programs follow a curriculum that is defined by the faculty partly in response to accreditation requirements. Comprehensive Design was one of NAAB's student performance criteria that was replaced in 2014 with Integrative Design. According to 2014 NAAB Conditions for Accreditation, Realm C: Integrated Architectural Solutions, students must be able to demonstrate that they have the ability to synthesize a wide range of variables into an integrated design solution. Under skill C.3: Integrative Design, students must demonstrate the ability to make design decisions within a complex architectural project while demonstrating broad integration and consideration of environmental stewardship, technical documentation, accessibility, site conditions, life safety, environmental systems, structural systems, and building envelope systems and assemblies (NAAB, 2017). Surely, different architecture programs respond differently in how to integrate Integrative Design into the curriculum. Taking the architecture curriculum at Oklahoma State University (OSU) as a case study, this paper dicusses the challenges faced in academia when integrating energy performance within integrative design.

3. Integrating integrative design into the curriculum

The architecture program at Oklahoma State University is a five-year B.Arch. program, which gives students enough time to acquire the skills required by NAAB by the time of their graduation. Similar to other programs, new students' first encounter with energy performance happens as part of the required lecture courses on architectural science, in which they gain the basic knowledge on all building systems including environmental control systems. In order to raise their skills to the level of "Ability" that is required by NAAB, after successfully passing architectural science courses, students must enroll in the follow-up Comprehensive Design Studio in their second semester of fourth year where they are expected to excell in integrative design including energy performance (OSU-SoA, 2017). Refer to Fig. 1. This is the studio co-taught by the author for the last 16 years where he is leading the energy and environmental performance design aspects. This studio proved to be successful and earned the NCARB Grand Prize for the integration between academia and the profession in 2004. The studio proved to be a perfect venue for introducing integrative design to students. Points 3.1 to 3.5 discuss the reasons made this studio such perfect venue, the challenges it faced, and the barriers to further enriching students' experience.

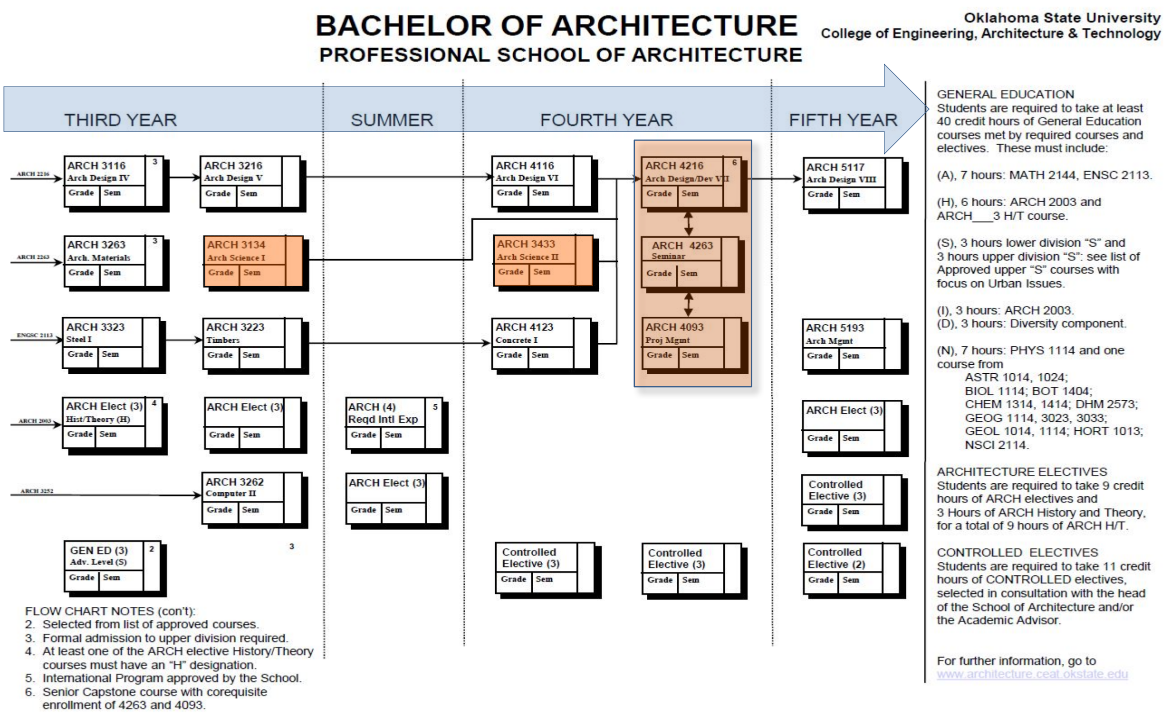

Fig. 1: Flow chart of the professional program at OSU

3.1. Students' level of maturity

Surely, integrative design is a challenging task to tackle and cannot reasonably be introduced to students in their early years in the curriculum. Compared to other building technology-related topics, it requires higher order thinking skills coupled with a good comprehensive knowledge of how buildings and building systems work. Historically speaking, the Comprehensive Design Studio at OSU used to be taught during the first semester of the fifth year. At that time, students performed better and were able to comfortably handle the complexity of studio requirements. For unrelated educational reasons, the studio had to be moved down one semester to the second semester of fourth year (Fig. 1). Based on faculty first-hand observations during the early years after that change, when the new cohort of students tackled integrative design with one less design studio experience, they became less prepared, needed much more help, and it became much harder for them to maintain focus on systems coordination and integration. Indeed, integrative design is best introduced to students towards the very end of the curriculum when the majority of students developed a good command of advanced design skills.

3.2. Studio's scope of design

Because of the in-depth study required for Integrative Design, it can only be addressed during the design development (DD) phase of design. Taking the design curriculum at OSU as a test case, shown in Fig. 2, studio sequence is composed of eight studios, the first five of which purely focus on schematic design. Students start their experience with DD in the first semester of fourth year (ARCH 4116). However, because it is their first time encountering DD, it would be overwhelming for them to address energy performance as well at this point. In the Comprehensive Design studio (ARCH 4216), it is the students second time to experience DD, which makes it a rational progression towards integrative design.

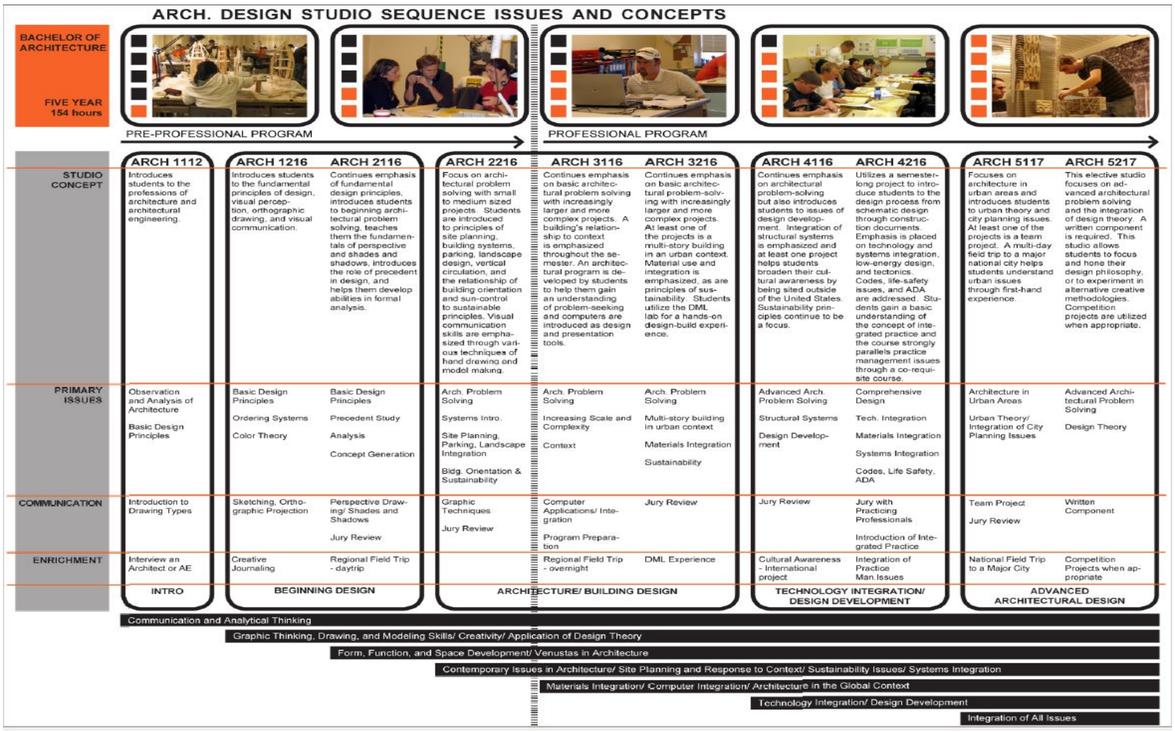

Fig 2: Studio sequence with eight required studios in five years

3.3. Studio's educational goals

In the curriculum, design studios are the vehicle for applying the knowledge students acquired in lecture courses as well as building upon design skills developed in prior studios. Follow-up studios gradually raise the bar for students, so they are not overwhelmed by a massive amount of new information at any point. Ideally, each studio would cover a reasonable number of the NAAB-required student performance criteria. However, practicaly, it is not always the case. Some studios cover few criteria while other studios cover too many. Since students must demonstrate a high level of understanding and ability by the time of their graduation (as required by NAAB), higher level studios are expected to cover more criteria. Fig.3 shows the matrix used for mapping NAAB's 26 student performance criteria on all required courses in the architecture curriculum. Black cells represent primary evidencs. Each criterion is covered by at least two required courses, where possible. Understandably, the Comprehensive Design studio and its required concurrent seminar (ARCH 4216/4263) cover 19 out of the 26 NAAB criteria, that is 73% of all criteria. In other words, students need to demonstrate their highest understanding and/or ability on 19 criteria in a 15-week studio. A primary challenge to faculty teaching this studio is time allocation. How long should students work on different educational goals? What is the reasonable time to spend on each studio asignment? What is a reasonable time to spend on energy performance? Given that energy performance considerations relate to eight different criteria, which are listed below. Six out of these eight criteria should be met at the level of ability. By NAAB definition, ability is: proficiency in using specific information to accomplish a task, correctly selecting the appropriate information, and accurately applying it to the solution of a specific problem, while also distiguishing the effects of its implementation. Understanding is defined as: the capacity to classify, compare, summarize, explain, and/or interpret information (NAAB, 2017).

- (A.3) Investigative Skills, ... Ability
- (A.6) Use of Precedents, ... Ability
- (B.3) Codes and Regulations, ... Ability
- (B.6) Environmental Systems, ... Ability
- (B.7) Building Envelope, ... Understanding
- (B.8) Building Materials and Assemblies, ... Understanding
- (C.2) Evaluation and Decision Making, and .... Ability
- (C.3) Integrative Design (all of the above). .... Ability

Given the imbalance between the limited time and the need to cover 19 criteria, strict allocation of time for different studio requirements is crucial. In ARCH 4216, time allocated for energy performance is around 15% of studio time (approximately two weeks total) spread out unevenly throughout the semester. The bulk of the related assignments is required during the DD phase, which should help students develop their projects based on a measurable assessment of energy performance.

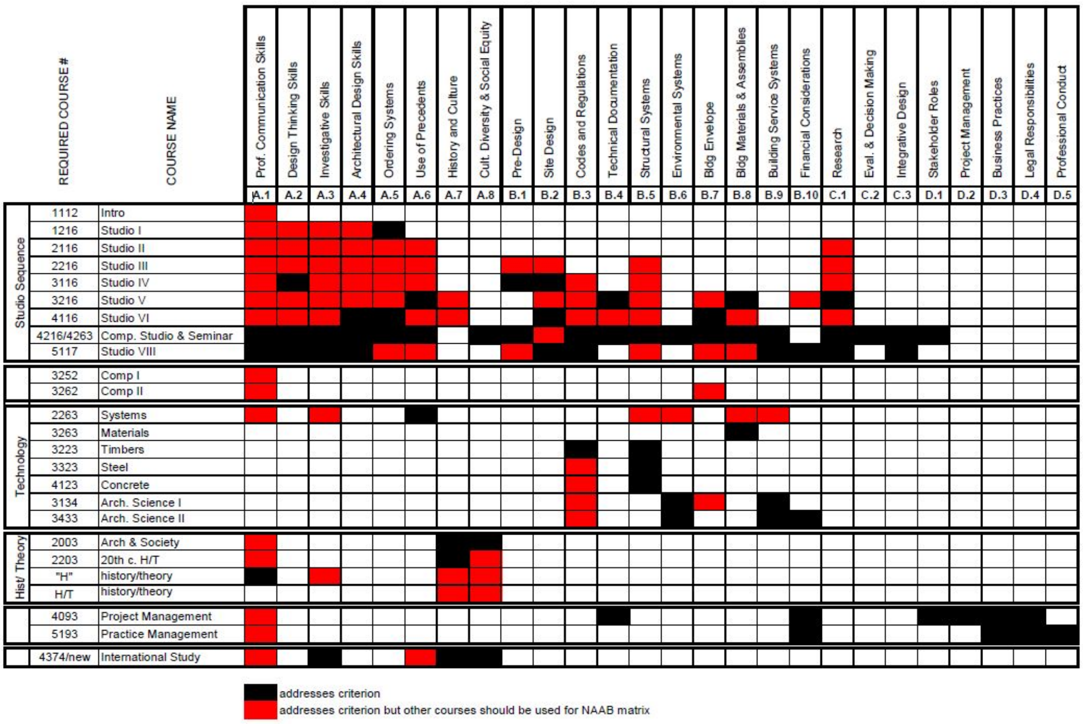

Fig. 3 Mapping NAAB's 26 criteria across required courses

3.4. Required tasks and design-assisting tools

Given the high level of accuracy required for energy performance in the Coprehensive Design Studio, students are allowed to use the rules-of-thumb only during the schematic design (SD) phase. Similar to all other studios, during SD, students use the simple daylighting rules-of-thum, such as the 2.5 rule, which is proven being not climte-dependant but still can be used with adjustment (Mansy, 2017). In sizing mechanical and electrical equipment and rooms, they use average numbers from the Architect's Studio Companion. After the building takes its priliminay shape in SD, students are prhibited from using rules-of-thumb. For the remainder of the design process, they only use accurate computational and experimental design-assisting tools to evaluate energy and environmental performance. Availability of accurate and user-friendly design-assisting tools makes it possible for the students to improve their understanding and to integrate energy and environmental performance into the architectural design process. A promenent required task is to utilize reliable and accurate feedback on performance to guide desision-making informing envelope design. Simply, students are asked to closely look at several performance-related issues:

a) Code-compliant building envelope, i.e., meets International Energy Conservation Code (IECC) envelope requirements as listed in Chapter 4 [CE], according to climate zone and type of construction. Envelope design must comply with code either following the prescriptive path, i.e., glass ratio, glass properties, and thermal properties of opaque envelope components (roof, walls, and slab-on-grade) or based on energy simulation to prove that building energy cost shall be equal to or less than 85% of the standard reference design building (ICC, 2015). For the prescriptive path, students perform simple manual calculations of R-values and U-factors and select glass types that satisfy code requirements. However, the vast majority of students design buildings with glass ratio exceeding the code maximum of 30% (40% with automated control of electric lighting systems), and prefer to comply based on 15% energy saving.
b) Cooling load reduction, i.e., in order to reach the minimum of 15% energy saving students must bring the actual cooling load of their envelope design 15% below the reference design as determined by the IECC code. Students perform hurly thermal loads calculations using an accurate energy modeling computer program that is approved by DOE for tax-credit submissions, that is eQuest (Fig.4). Typically, students are able to acheive the 15% energy saving by choosing an energy-efficient galss or using an external shading device.
c) Accurate design of daylighting systems, i.e., verifying that the acheieved illumination level in the focus space is within range to what is recommended illuminance for the visual task performed in the space. Students build scale models of a daylit space in their buildings and test them under the artificial sky dome (Fig.4). Typically, students who were able to achieve the minimum energy saving are also able to avoid excessive illumination levels and visual glare.
d) Size supply air ducts, mechanical equipment, and rooms in accordance with the calculated peak cooling loads. Also, select supply air diffusers based on their performance data (CFM, throw, and NC) that match the use of space.

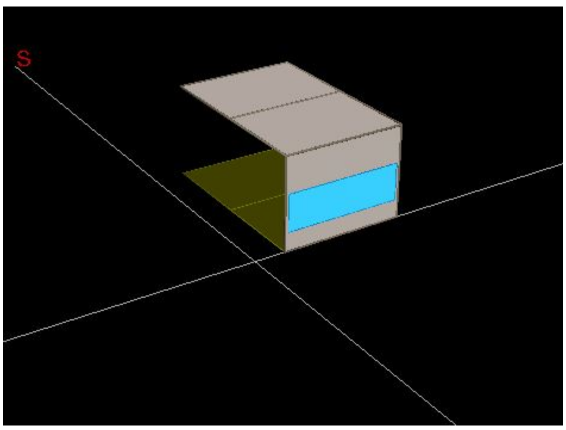
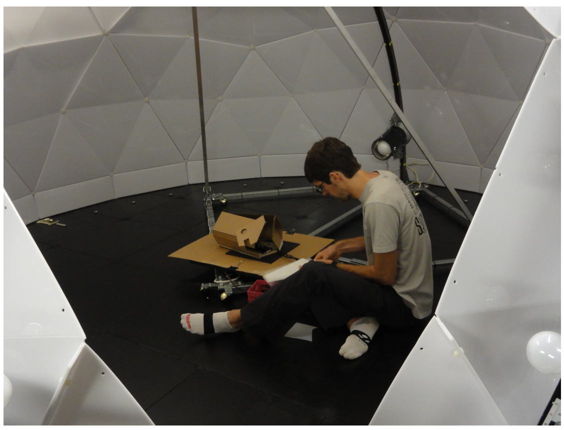

Fig. 4 Energy modeling (left) and testing daylight models (right)

Only accurate design-assisting tools qualify for the task of performance analysis that informs decision-making during the DD phase. At this level in the curriculum, studnets tend to accept the challenge and handle a variety of design-assisting tools at the same time. Hand calculations for code compliance. Computational method for cooling load calculations, and experimental testing for daylighting design. However, a challenging task remains to be that students need to move between different computer programs. They mainly use AutoCAD during SD, Revit during DD and Construction Documents (CD), and eQuest for thermal loads calculations. If one computer program qualifies for all phases of design and all tasks required for energy perfomance, it would save students valuable time that would be spent to further enhance their skills.

3.5. Faculty resources and expertise

Indeed, because of the wide variety of studio requirements and the need to check students work for accuracy in every assignment, the Comprehensive Design studio requires heavy involvement of faculty with competence covering diverse areas of expertise that relate to design and technical aspects, i.e., aesthetics and performance. In fact, in case of OSU, student-to-faculty ration is about ten-to-one on average.

4. Conclusions

Building on the experience at Oklahoma State University of integrating energy performance into the design studio, it can be cocluded that:

Energy performane must be taught to students within the context of integrative design since the chief purpose of energy perfoance is to inform the decision-making during advanced phases of design, which is possible during DD and typically out of scope of lower level studios that primarily focus on SD.

Since it requires advanced knowledge and skills in both of design and technical aspects, integartive design should be taught to students in their final years in the program when they become more prepared for the task. However, because higher-level studios carry the load of addressing many of the NAAB criteria, integrating energy performance broadens the scope of studio which requires very specific planning and coordination of required tasks and assignments that help students to reach the level of "Ability" in meeting related NAAB criteria. Faculty expertise should cover all design and performance aspects of design.

Prior to the integrative design studio (Comprehensive Design at OSU), thecurriculum must prepare students with all knowlege and skills, especially in terms of ability to use verified computaional and/or experimental methods to perform energy and environmental analysis in liu of relying of simplistic rules-of-thumb.

Because of the lack of one reliable computer program that can be utilized throughout the design process in drafting and performing technical analysis, students still need to switch between diferent computer programs.

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