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Hand to Mouse: Integrated Technology Laboratory in Undergraduate Architectural Education

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Abstract
The undergraduate building technology sequence (uBTS) seeks to impart a broad understanding of environmental systems through a variety of research and simulation techniques including direct observation, traditional calculations and scientific method, and advanced modeling and evaluation software. The integration of the uBTS sequence with studio project work and engagement with the larger inter-institutional research efforts encourages strong student engagement and early mastery of advanced skills. This paper will discuss the above general themes through specific laboratory case studies which are tied to key points in the three year uBTS.

Keywords
digital analysis, design integration, engagement, building performance simulation, building technology education

Disciplines
Architectural Technology | Art Education

Comments
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ABSTRACT: The undergraduate building technology sequence (uBTS) seeks to impart a broad understanding of environmental systems through a variety of research and simulation techniques including direct observation, traditional calculations and scientific method, and advanced modeling and evaluation software. The integration of the uBTS sequence with studio project work and engagement with the larger inter-institutional research efforts encourages strong student engagement and early mastery of advanced skills. This paper will discuss the above general themes through specific laboratory case studies which are tied to key points in the three year uBTS.

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INTRODUCTION

The undergraduate building technology sequence (uBTS) seeks to impart a broad understanding of environmental systems through a variety of research and simulation techniques including direct observation, traditional hand calculations and scientific method, and increasingly through advanced modeling and evaluation software. The integration of the uBTS sequence with studio project work and engagement with larger inter-institutional research efforts encourages strong student engagement and early mastery of advanced skills. This paper will discuss the above general themes through specific laboratory case studies which are tied to key points in the three year uBTS.

1.0 CASE 1: MULTI-INSTITUTIONAL RESEARCH WITH BEGINNING DESIGN STUDENTS

The building systems faculty members were invited to participate in LORAX, a multi-institution research project, to improve the DIVA plug-in to the Rhinoceros modeling program (Reinhart, 2012). Participation in the project involved several stages, some of which were specifically targeted towards beginning design students. The student participation for this project was completed during a one hour laboratory section when the students were in their first five weeks of a Bachelors of Architecture program. The course was the students' first exposure to quantitative research, and the tools used in architectural building science.

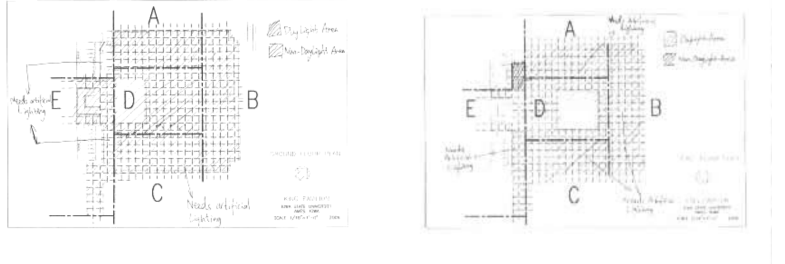


Figure 1: Student assessment of daylit areas for ground floor and first floor. Source: (Liu, 2012)

Students' initial tasks required them to make qualitative observations of daylight for a large, open classroom building and record those in a hand drawn plan drawing. These observations were followed by the gathering of quantitative measurements with light meters. Measurements were taken in foot candles at 30" above the floor in a precise five foot grid. The measurements were taken for the entire two story, 22,000 square foot studio spaces and hand-recorded on grid-lined plans provided by the faculty. Due to the size of the space and the time limitations of the course, students worked in groups to take measurements for one zone. Following the class period, students collaborated with other groups to combine the measurements from their zones with the other zones to create full plans for both floors. Students then compared their initial qualitative observations with the quantitative maps and analyzed both to find any areas of inconsistency. An additional request added to the lab by faculty members requested that the students propose design solutions to modify the existing building to improve daylighting in areas that were underserved according to the measurements gathered in the laboratory.

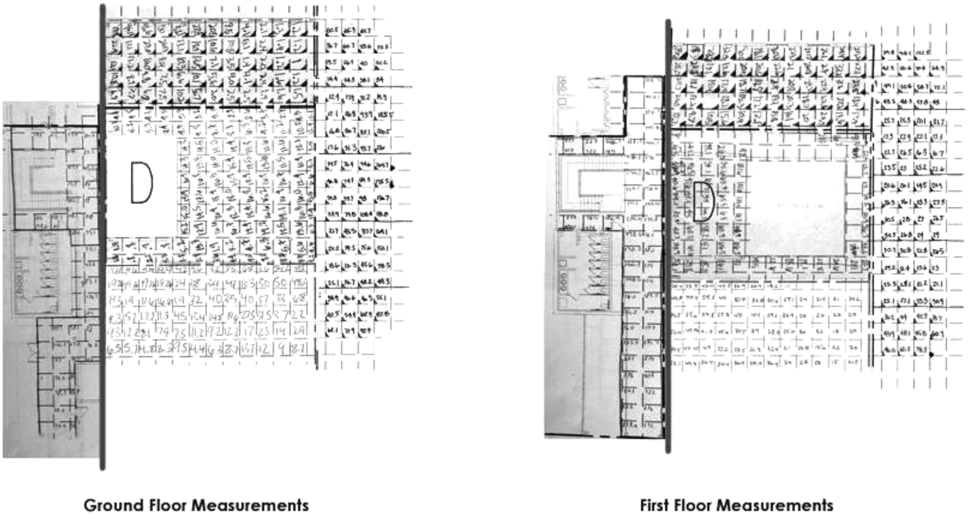


Figure 2: Student measurements in foot candles for ground floor and first floor. Source: (Romero, 2012)

The format and content of the study increased student interest in a few distinct ways. The students' portion of the work was used in conjunction with similar efforts by numerous universities in North America, Europe, South America, and Australia. Beginning student exercises typically focus on skill-building with a very limited potential impact in the larger context of the profession; the high profile of this project encouraged students to be diligent in their work and precise in their measurements. This was furthered by the knowledge that their work would represent the architecture program, the College and the University in an international effort, which was a unique experience usually reserved for upper level undergraduate students or graduate students. Secondly, working with a prominent software platform also intrigued the students. The University uses a peer-to-peer formal mentoring system in the initial year of the program. The mentoring program matches beginning students with students in later stages of the program. The relationships established in this early phase of the students' academic careers often endure through the entire program and even into practice. The beginning students frequently ask the mentors about current software preferences and strive to engage the digital tools as early as possible. The popularity of the Rhinoceros modeling software, and the increasing integration of Grasshopper, DIVA and other plug-in programs made the younger students feel that they were contributing to the refinement of a digital tool that was valued by their mentors and would be valuable to the students themselves in the future.

Participation in the project did not detract from the traditional module objectives. This section typically uses a portion of the same building to note areas of inadequate daylighting, and propose design adjustments to remedy the affected areas. The work for the study imparted the basic skills included in the laboratory from previous semesters: judging daylight within a space intuitively, using light meters to take precise measurements, recording data graphically, and comparing the qualitative outcomes to the initial judgments. The final element of proposing a design solution to address the shortcomings of the building was easily added to the base project work. In short, the benefits of working in an international context, and knowledge that the work would contribute to the improvement of an advanced digital tool dramatically increased student interest. The authors suggest that increasing opportunities for beginning student involvement in high profile research projects would benefit both students and professors, and should be considered as an underserved area within the academic realm.

2.0 CASE 2: PROBLEM SOLVING ALIGNED WITH STUDENT SELF-INTERESTS

The second case study involves a laboratory project working with third year Bachelors of Architecture students to investigate well-known acoustical issues within their studios and review spaces. This project was created with the input of the students and in conjunction with a second course in the College (Horwitz, 2012). During a preliminary lecture on acoustics, the students noted that their primary work spaces had serious acoustical issues which made it difficult to hear professors within the studio and review spaces. Previous acoustic laboratories had focused on precedent projects or a problem in a non-existent space. While these projects allowed students to investigate issues of acoustic geometry, absorption and reflection, and reverberation, the exercises were disembodied from firsthand experience. The opportunity to address problems within their own built environment motivated the students to deeply investigate the problem and propose a creative design solution.

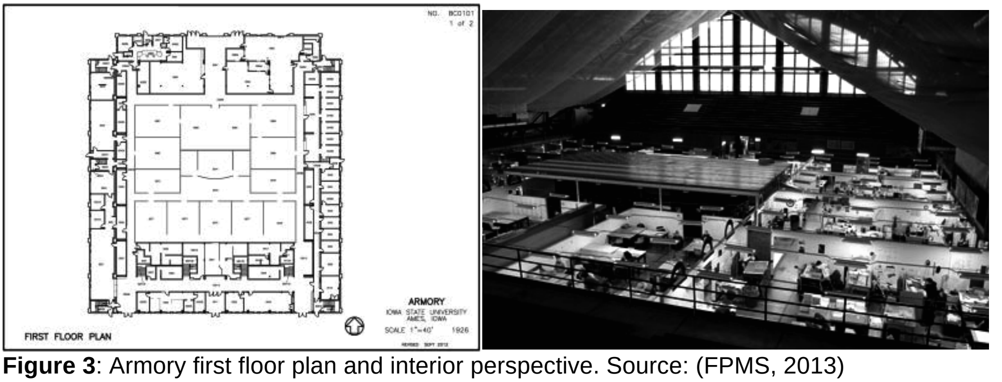


Figure 3: Armory first floor plan and interior perspective. Source: (FPMS, 2013)

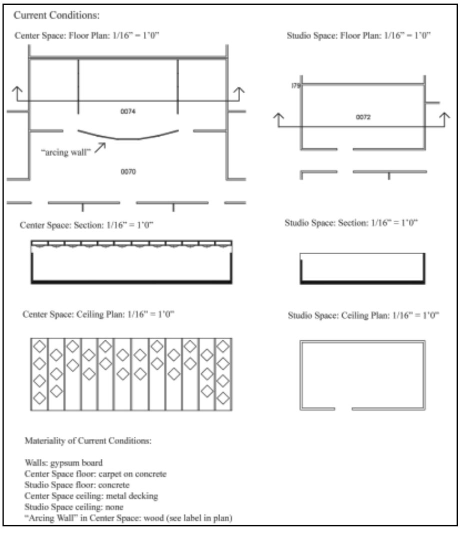
The current space used by the third year students is a 90,000 square foot, triple-height barrel-vaulted armory built in 1924. The space originally was used for sporting events, and second story bleacher seating remains in balconies running the full length of the building at the arched ends. The studio spaces are located on the main floor and shared between students in landscape architecture, architecture, and industrial design. The studios are arranged in a ring around a large review pavilion in the center of the space. The review pavilion is the only space with an immediate ceiling condition; all other spaces are open to the barrel vaulted structure above. The pavilion has partial height walls for displaying work, leaving large gaps between the tops of the walls and open webbed joists and metal deck ceiling structure. The sheer number of students in the space, along with the variety of activities from the different courses, causes ongoing conflict. Studios in review are disturbed by other studios using power tools to build models, or adjacent instructors speaking very loudly, by necessity, to be heard by their students. Within the studios themselves, it is hard for students to hear and understand announcements, leading to frequent work stoppages to gather students into a small area. Any group discussion requires reservation of alternate space, limiting the types and numbers of interactions possible within the studio.

Faculty delivered two 45 minute lectures on basic acoustic principals and methods of evaluation. These lectures were followed by a laboratory, which culminated in student proposals to improve their studio and review spaces. The initial steps of the project involved making intuitive judgments regarding the nature of the acoustical problem – did the problem derive from the geometry of the space, from the materials within the space, or from the openings between the spaces? Many students identified the large volume above the studio spaces as an issue; many also noted the openings between spaces with non-complimentary uses as a concern. Still others noted prevalence of reflective materials, and the absence of absorptive materials in the studios as problematic.

Table 2: Student responses regarding major deficiencies in the Armory. Source: (Author, 2013)

Response	*Number of Responses*
Excessive Reverberation Time	7
Geometry of the Space	14
Materials in the Space	31
Lack of Ceilings	28
Adjacent Spaces not Isolated	5

The students then engaged in formal calculations involving the volume of the space, and the types and amount of each material in the space (Stein, 2010). This phase allowed students to more closely identify the true problems in the spaces. As an example, many students initially felt that the openings between the walls and ceiling would be the primary problem in the review pavilion, but calculations revealed that the major issue was the reverberation time. These openings were allowing desirable sound from speech within the space to escape, but this was not the major issue. The excessive reverberation time was allowing sound to linger in the space and mask speech (the primary function for the pavilion.) Students correctly predicted that the open top of the studio spaces was the primary problem in this case. Many students proposed interesting tensile acoustic solutions, which incorporated absorption to counteract the predominantly reflective surfaces within the studio spaces. Other solutions proposed hard ceiling panels, and softer acoustic panels on the walls and carpet or similar absorptive surfaces on the concrete floor. These solutions were primarily designed using hand calculations. However, students in the third year are beginning to engage more complex studio projects, and the desire to incorporate more sophisticated digital analysis is present in the more advanced students. This lab incorporated an extra credit portion to allow students to verify their hand calculated results by building and testing a simple model in Autodesk Ecotect, version 2011.



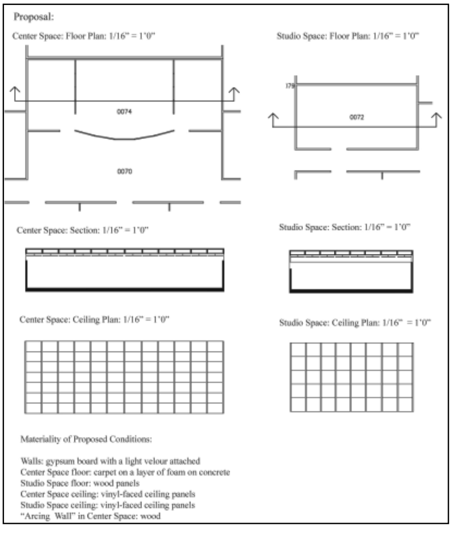


Figure 4: Existing and revised proposals. Source: (Wamples, 2012)

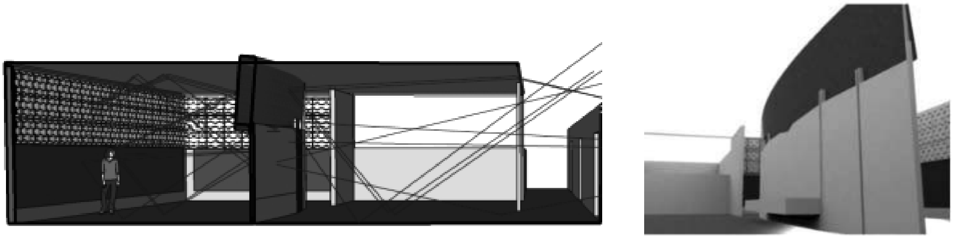


Figure 5: Autodesk Ecotect acoustical analysis. Source: (Khesroh, 2012)

The authors proposed that incorporating student self-interest into the building technology laboratory, both by incentivizing the opportunity to learn advanced digital analysis tools and to propose improvements to a notably flawed daily environment encouraged greater student engagement with this project. The most sophisticated solutions were packaged for presentation to College administration to show several unique options to improve the learning environment.

3.0 CASE 3: STUDIO INTEGRATION AND ITERATIVE DIGITAL ANALYSIS

The final case study involves a laboratory project which integrated the uBTS with advanced students in the pre-comprehensive studio project located in Columbus, Indiana. The studio program requests a 40,000 square foot museum to house innovative industrial design objects, and documents and models from the architectural archive for the numerous notable architectural projects in the community. This project is completed in the first semester of the fourth year of the Bachelors of Architecture program, and tied into the studio project at the beginning of the building massing phase. At this point in the semester, students were making major decisions about the form of the building, which specifically affected the daylighting strategies for the gallery components.

Faculty members delivered two 45 minute lectures regarding daylighting opportunities and limitations in museums. The lectures featured methods to hand calculate foot candle and daylight factor values, and showed numerous contemporary precedents. Allowable levels of light exposure for various media and materials were also discussed, which formed the basis for the laboratory assignment. Daylighting was presented as a potential opportunity, widely viewed by curators as the ideal light source for a gallery; but also as a potential source of permanent damage for many fragile works on paper, or composed of delicate natural materials such as fur, feathers or cloth. Baselines for material classes were presented as design parameters, which heavily influence building form and materiality.

Table 1: Light exposure levels recommended for museum objects. Source: (PMA, 2013)

Light level	Material
200 lux (20 footcandles)	ceramics, glass, and metals
150-200 lux (15-20 footcandles)	oil and tempera paintings, leather, lacquer, wood, horn, bone, ivory, stone
50 lux (5 footcandles) or less	watercolor paintings, dyes, manuscripts, prints, drawings, textiles, photographs

The initial laboratory task required students to create a three-dimensional digital model of a proposed gallery space. Many students utilized existing digital models from their studios which were created in Autodesk Revit or Google SketchUp. These models were simplified, eliminating voids and excessively detailed geometry and imported into Autodesk Ecotect. The daylight analysis tool was used with an analysis grid to evaluate the amount of natural light in the student design proposals. The resulting daylight levels were combined with the types of artifacts displayed and compared to the baselines from the lectures. Nearly all of the students determined that their initial proposals allowed daylight to be admitted to the galleries in an uncontrolled manner, which resulted in foot candle levels that far exceeded the baselines established in the lectures.

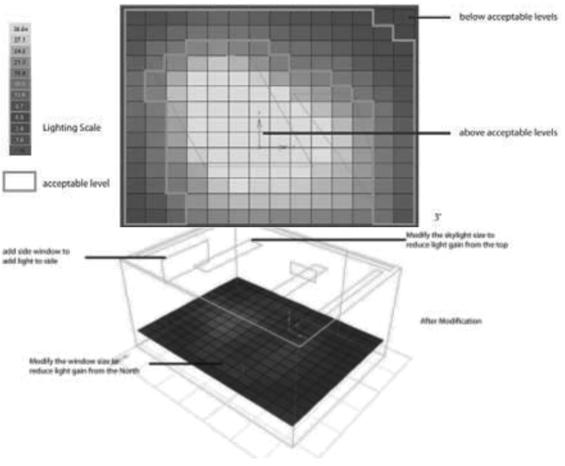


Figure 6: Initial results (left) and modified proposal (right). Source: (Zhao, 2012)

The second task involved using digital analysis, in conjunction with design revisions to improve performance through controlling and reducing the footcandles admitted to the display zones within the gallery. This required students to use the analysis in an iterative process, which was documented at each major proposed revision. Students found that successful strategies were possible utilizing top lighting or side lighting, however, most proposals found that layered diffusing elements or multiple reflectors were necessary to adequately control the daylight admitted to the gallery. Integrating the lab in the middle of concept design allowed students to avoid development of proposals that were infeasible from a building performance perspective, and to focus on solutions more suited to a typology driven by display and preservation of valuable objects. Students were required to revisit the process at the conclusion of the semester, when the final exam for the module required digital analysis grids showing the daylight levels for their completed museum proposal.

Student feedback noted that the process, although demanding, resulted in gallery geometry that was materially engaging, provided high-quality diffused daylighting, and protected valuable objects from damage. The learning curve for the software proved slightly frustrating for many students, but the powerful information yielded from the process overcame many initial reservations. The work was well received by professional guests visiting for final reviews, and the integration efforts in the course were noted as especially successful by the NAAB accreditation committee when top projects were presented in the following semester. The authors propose that integrating highly technical, digital analysis software into advanced building technology courses allows students to make more informed design decisions and respond intelligently to environmental factors which must necessarily shape design in demanding project typologies. Furthermore, these skill sets are particularly valuable for upper level students, trying to differentiate themselves from many similar students seeking positions in graduate schools or in professional employment.

CONCLUSION

The uBTS endeavors to inculcate the necessary design processes of careful data gathering and diligent analysis though a variety of project opportunities. The examples listed in this paper attempted to generate greater student enthusiasm for learning objectives by aligning the uBTS project goals with elements outside of the course which are highly valued by students. These elements range from perceived prestige through association with numerous respected Universities and valued visualization software, through improvement of one’s own environment, to gaining the ability to use advanced digital analysis tools to demonstrate technical skills valued in academia and in the profession. The subject matter is approached from a variety of perspectives to allow students to gain a level of comfort with different approaches across disciplines and practice environments, apply multiple methods to cross-check personal work, and to develop hybrid approaches as a complex world demands. The methods are sequentially layered in a way that is designed to reinforce learning from previous semesters, while pressing for the integration of more advanced concepts and analysis tools in the development of complex thinking and proposals. This mixture of methodologies effectively engages each level of the undergraduate architecture program in the challenging task of comprehending the invisible forces in architecture through perception, measurement, simulation, and the synthesis of environmental factors as key components of successful and sophisticated spaces.

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FIGURES

Figure 1 C Lui, student worksheets from ARCH 245 assignment

Figure 2 F Romero, student assembled floorplan from ARCH 245 assignment

Figure 3 "Armory First Floor Plan," FPMS, accessed October 31,2013, http://www.fpm.iastate.edu/maps/buildings/docs/ARMORY/plats/pdf/First_Floor.pdf.

Figure 4 S Wamples and C Widlowski, student work from ARCH 342 assignment

Figure 5 M Khesroh, T Gonzalez and J Bassett, student work from ARCH 342 assignment

Figure 6 C Zhao, student work from ARCH 445 assignment

TABLES

Table 1 "Light exposure levels recommended for museum objects, Philadelphia Museum of Art,
accessed November 2, 2013, http://www.philamuseum.org/conservation/10.html?page=2

Table 2 Author, Student responses from Arch 342 assignment