Teaching Architectural Acoustics to Students of Various Disciplines

Daniel Butko

Introduction

The words *architectural* and *acoustics* perhaps conjure thoughts of buildings or spaces with specific acoustic requirements (such as music halls, recording studios, auditoriums, and libraries) and/or the design professionals who have spent their careers focused on the topic. However, this is just the beginning, and this article explains the methods of introducing students of various backgrounds and areas of study to the aural aspects of various occupancies and forms of architecture through discussions, lessons, assignments, field trips, and projects. Have you ever noticed that the word *aural* is literally in *a*rchitect*ural*? The actual beginning and end of the word spell out the entire point of this article: the integration of the aural in architecture and the built environment. I ask students, "Are all aural?" Say it slowly, and the play on words begins a discussion of building types that require acoustical attention. The compound answer becomes evident: all aspects of the built environment have an aural component.

Sound waves are all around us; they come in many shapes (frequency) and sizes (amplitude) and are felt as much as heard by the human body through vibrations in even those without the ability to hear. Although the qualities of sound waves vary, there are sources of sound, paths in which the sound waves travel, and receivers who then receive, process, and/or record the information. Most people tend to anecdotally quantify sound, and its often-undesirable counterpart noise, based on feelings or preferences. That's one way to begin; listen and be receptive of how vibrations through air and materials make you feel. Observations, coupled with quantifiable data, influence designers toward supportive acoustic design concepts. Architecture is more than meets the eye, especially when it meets the ear.

This article outlines the introduction and application of acoustical vocabulary, lessons, and criteria through the following educational opportunities: (1) assigned required courses; (2) elective and independent-study courses; and (3) research, practice, and service-learning projects.

Why Architecture?

To discuss architectural acoustics, there should be some relationship between what an architect does and how someone begins a career in architecture. We all likely know that architects design buildings. The scope of responsibilities of the word *design* relating to the health, safety, and welfare of the building occupants is usually not as glamorous as the aesthetics or landmark status associated with some projects. With requirements for training and licensure in place around the world, the days of being a self-professed architect/master builder are gone. Aside from numerous states now offering alternate/alternative paths to licensure that do not always include a formal postsecondary education, a high percentage of eventually licensed architects opt for at least a Bachelor of Architecture degree that typically spans 5 years (10 semesters), followed by an internship in a firm and a multiphase Architectural Registration Exam (ARE). On the other hand, at the time this article was written, it is believed only the state of Oregon offers a license for acoustical engineers, so the path toward acoustician/acoustical consultant is less regulatory, but the knowledge and experience are still vital in the shaping of acoustically successful architecture. It is the intersection of these career paths that sets the stage of how to teach acoustics housed within an accredited architecture program to various disciplines and emphasizes the importance of the art and science in the profession.

Prospective architecture students may be influenced through various forms of media, rendering architecture through visual means and text, and often find the formal training different from preconceived expectations. An understanding of and appreciation for architecture is often the result of experiencing it through occupant senses, including the aural environment created when materials are erected and a form is created. Those of us fortunate

https://doi.org/10.1121/AT.2022.18.2.24

enough to be in teaching/instruction roles have opportunities to not only share our knowledge but to also build new experiences with students as we explore the many facets of architecture. As the Dunning-Kruger effect reveals, we don't know what we don't know and we aren't aware that we don't know it (Dunning, 2011). Keeping an attitude of a lifelong learner helps break our limited awareness and align perception with reality. Although there are various influences that lead students to study architecture, I have not met a student who answers the "What led you to enroll in architecture courses" question with anything to do with acoustics or the aural environment. Perhaps more acousticians need to attend high-school career days! Nonetheless, I am pleased to introduce students to the invisible realm of acoustics pertaining to health, safety, and welfare in the built environment.

I brought my love and knowledge of acoustics to the University of Oklahoma (OU; Norman) Gibbs College of Architecture (GCA) through an introduction to design concepts and sensibilities, technical and material science, and passive and active systems. The GCA houses various majors and offers courses to students from colleges across campus, so my sphere of influence is not limited to architecture students. To date, I have introduced over 1,500 undergraduate and graduate students of diverse backgrounds and disciplines to architecture and associated aural environments. The GCA does not have a dedicated acoustics laboratory (yet) or series of courses specializing in this area of study, so the scaffolding of topics is completed through hands-on experiments, field measurements and data collection, the study of musical instruments, precedent studies and literature reviews, laboratory and manufacturing facility tours, and material prototype fabrication with industry partners. Combining experience and an interest in architecture and acoustics as a common thread of pedagogy throughout various teaching opportunities helps students analyze and design spaces that are acoustically supportive for their functions.

Pedagogy: Method and Practice of Teaching

Students learn the results of shaping space not from merely the cool factor of twisting planes in software or molding physical materials into an attractive form but from how the shape of space and the materials used to delineate an enclosure have embodied results that impact the health, safety, and welfare of occupants. The enclosing elements, which define exterior from interior space, often have codependent/symbiotic thermal, structural, air quality (from outgassing), fire and smoke resistance, and acoustical properties that can be measured and accounted for during design. Obviously, there are various other factors such as how color, texture, patterns, and the composition of materials impact/affect the mood and atmosphere. Learning how design decisions result in compound relationships with occupants helps students base architectural decisions on more than mere aesthetics. Beauty can be the functional result of all the influences.

What is a pedagogical approach or, more specifically, my approach to teaching architecture with a relationship to acoustical properties? My passion is for people to understand architecture in a way that encourages, edifies, educates, entertains, and evokes responses from occupants. There are various approaches to teaching that are expressions of personalities, experiences, and attempts to convey content coupled with audience reception. Architecture programs are evaluated through an accreditation process requiring assignment goals and learning objectives to be defined as demonstrated through understanding and ability. Lecture and design studio courses provide opportunities for students to convey knowledge through exams, assignments, and design proposals that embody the course content. Assessment of acoustic impact on successful design can be aligned with meeting required program and student criteria.

Vitruvius, a first-century Roman architect, engineer, and author, characterized sound propagation through air and materials like a wave from a pebble cast into a calm pool of water. Those ripples of resonating content are a metaphor for the learning process: repetition, reinforcement, and demonstration of both understanding and ability. Today, I wonder if people do not really listen to their surroundings; they may hear, but do they really listen? All too often the architects of tomorrow are wearing earbuds today. The first step is to encourage students to listen to spaces. Architecture is the physical medium changing a free field into a series of materials that reflect, diffuse, and absorb frequencies. By placing students in that context, they experience how sound waves and vibrations relate to everything in the built environment. I teach students to evaluate the shape of occupied and unoccupied volumes of space, the materials used to define enclosure, and associated quantifiable acoustical data such as sound transmission class (STC);

impact insulation class (IIC); reverberation time (RT); noise criteria (NC); noise reduction coefficient (NRC); and impulse response (IR), clarity (C_{50} and C_{80}), and speech transmission index (STI). It is also important to point students to physical scale models and software as tools for learning and developing spatial relationships.

Students are also introduced to codes, regulations, and guidelines that contribute to aural environments. Building codes and various organizations including Leadership in Energy and Environmental Design, Living Building Challenge, the American Institute of Architects (AIA) Framework/Committee on the Environment (COTE), the International Well Building Institute, the Whole Building Design Guide, and *The 9 Foundations of a Healthy Building* (see 9foundations.com) uphold occupant health, safety, and welfare and advocate for acoustics. The report *14 Patterns of Biophilic Design* (see terrapinbrightgreen.com/reports/14-patterns) showcases several aspects of physiological and psychological restoration through access to nature sounds. Students quickly realize the practically countless aspects of architecture and acoustics are a result of (1) "static" materials and form of the space and (2) "dynamic" interactions (interior and exterior): how people, materials, systems, and weather interact.

It would not be fair to merely focus on airborne sound as the star of the acoustics world. Architecture is a vehicle for all abilities and lies somewhere between form and function. In 1896, architect Louis Sullivan coined "form follows function." The function of the built environment offers an experiential aural environment seldom discussed or presented in the general realm of architecture. It leaves some of us questioning how the function of the space can be supported/successful without attention to how the space sounds. We should not always gravitate toward people with hearing abilities as the only occupants; we need to also account for humans with limited or no ability to hear, animals, technology, and artificial intelligence. During an interview in 1959, architect Ludwig Mies van der Rohe said, "Architecture starts when you carefully put two bricks together," but acousticians are likely asking, for example, "Are the bricks shifted out of plane to create diffusion, what is the cubic volume and RT of the resultant space, and what are the STC and NRC values." Let us also then realize specific acoustical criteria results from the form of the space defined by the surrounding materials.

Another branch of teaching includes inviting guest lecturers from various disciplines, participating in project reviews, reading invited and accepted conference and paper presentations, leading Continuing Education/Learning Unit sessions for various organizations and design professionals, and presenting at school career days that allow for the chance to introduce and inform diverse audiences other than clients and students about the far-reaching aspects of architectural acoustics.

Required Courses: Blending into Everyday Curriculum

The required semester-based Architectural Design Studios, Systems, and Materials and Methods courses in the BArch and MArch programs for which I am assigned include students from other disciplines. Regardless of the course description, most goals and objectives in my courses also include a relationship with architectural acoustics. If the assignment is about rhythm, patterns, or composition, I tie it back to music. If discussions are about point, line, plane, and spatial relationships (aka beginning design standard lessons), I offer comments about how decisions made

Figure 1. ***Top:*** *example of a design studio where students craft additive and subtractive models using materials such as wood, acrylic, foam, and Hydro-Stone.* ***Bottom:*** *wall-mounted and ceiling-hung models from an assignment focused on developing articulated panels that provide lighting and acoustic interactions.*

with those design elements could result in flutter echo or reverberation in occupied spaces depending on materiality, layered arrangements, and cubic volume. Students begin to understand the connections among surface articulation, proportions, and density relating to acoustical reflection, diffusion, and absorption. I also try to find common ground, like relating architecture to the bass and treble controls on their car radio (or a 31-band equalizer for the audiophile), to the hue and contrast adjustments on photographs, or to how architecture might alter wave-based forms of sound and light depending on material qualities and spatial form (**Figure 1**). Architecture becomes the interactive element that can support or deter from true reference, both aesthetically and aurally.

Although I have coordinated and instructed several BArch and MArch program courses, the integrated/comprehensive capstone studio has been a constant throughout the years. Students are required to integrate mechanical, electrical, plumbing, acoustical, fire resistance, thermal properties, site conditions, community engagement, and overall sustainable and resilient design concepts into individual projects. The process includes research of precedent studies, code analysis, data collection, project development through detailed drawings, and feedback from practicing design professionals. Systems courses integrated into design studios allow a deeper understanding of mechanical, electrical, and plumbing (MEP) systems including associated noise. It's one thing to tell students heating, ventilation, and air conditioning systems produce noise, but it helps the learning process to go the extra step and show them through real-time analysis (RTA) graphs the span of frequencies associated with the air handling unit, ductwork, and vents/diffusers, for example. Those measured and understood values then contribute to air handling unit locations, ductwork shapes, distribution distances, and wall and floor assembly layers to achieve desired NC ratings.

I tell students hard parallel walls that are not articulated will likely provide a flutter echo. It also helps to tell them what might appear to be wasted space by splaying or creating odd-shaped cavities between adjacent spaces provide opportunities for mechanical systems or storage areas. It's surprising to most students when I suggest designing spaces without equal or multiples of dimensions to avoid resonant frequencies and then proceed to sound out the woo woo sounds associated with standing waves. We have become sound machines when describing typical acoustical deficiencies. Students go around whooping, clapping, and shouting "reverberation is the persistence of sound" in most spaces they enter, immediately activating the space and yielding responses.

We take a lot of field trips. I have taken students to acoustics labs, consultant offices, music stores, parks, art districts, recording studios, and music halls. I direct attention to MEP system locations and how they relate to or are concealed in floors, walls, or ceilings (**Figure 2**). We discuss sound-isolation techniques, system integration, power-conditioning requirements, and how spaces are shaped to promote accurate audio referencing.

Some design projects challenge students to jump scales and translate function and interaction beyond the typical scaled

Figure 2. *On a field trip, students' attention was drawn upward to the vertical sound baffles concealing mechanical systems (**left**) and a colorful absorbent wall finish flanking a large open staircase (**right**). Students asked questions and connected discussions in class with inhabitable space.*

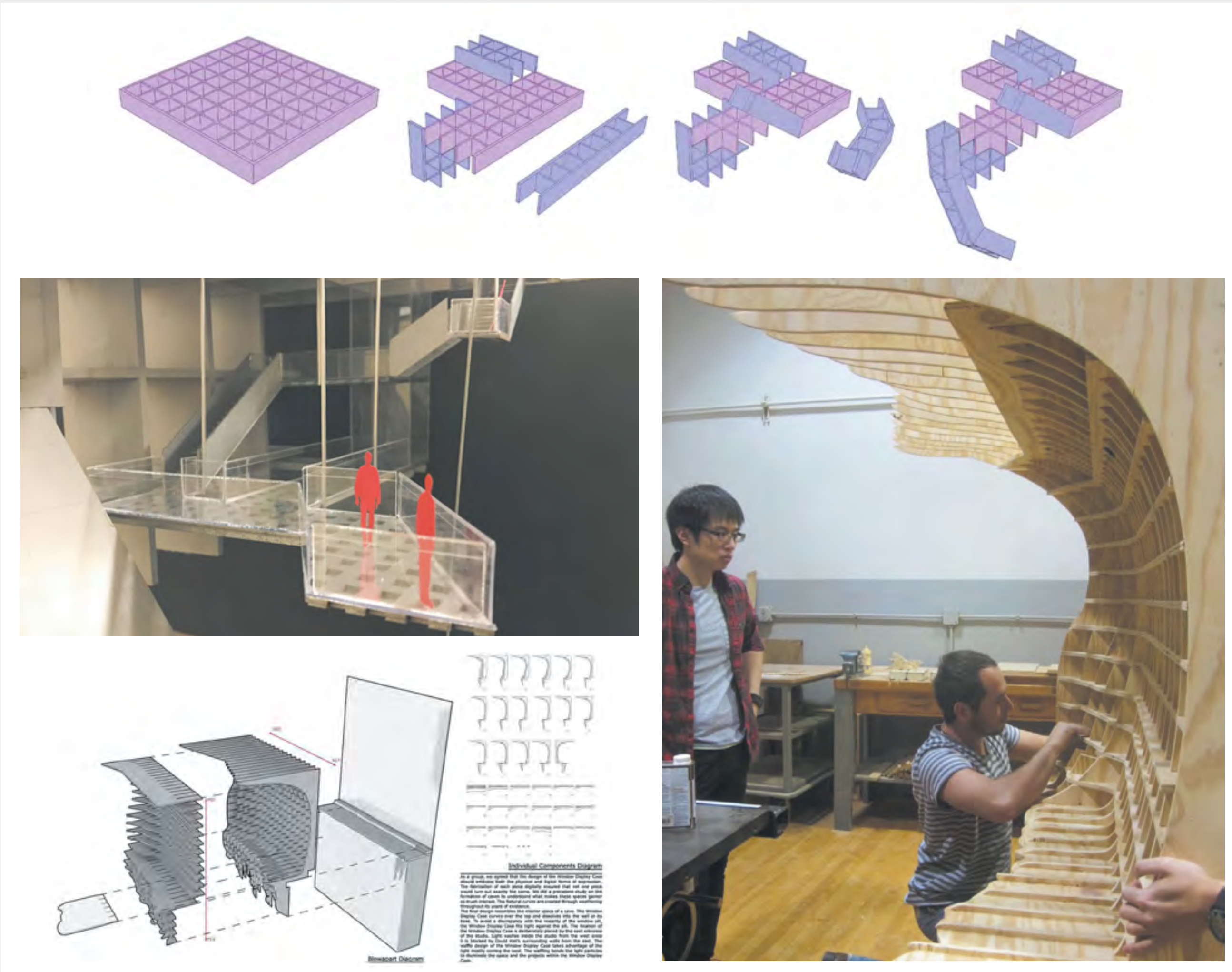


Figure 3. *Examples of two projects addressing a rectilinear grid at different scales.* ***Top*** *and* ***center left****: reimagining 24" × 24" wood space couplers/acoustical diffusers typically used in recording studios into an inhabitable grid (****red figures****).* ***Bottom left*** *and* ***right****: students developing a sculptural tectonic construct to provide acoustical diffusion at a prescribed window location.*

model into reimagined constructs within its surroundings. Both projects in **Figure 3** reference a grid, but the results differ in relation to how sound interacts with occupants. Students also develop design concepts through the lens of the COTE measures that include categories applicable to acoustics. Students have also packaged course projects into submittals for student competitions, resulting in local and national recognition by the AIA.

Acoustic Elective and Independent Study Courses

The Sound of Shaped Space, a reoccurring acoustic elective General Education course for upper division undergraduate and graduate students of various majors, has been offered periodically since spring 2011. This course began from previously developed topics and objectives during my adjunct positions at the University of Florida, Gainesville, and Kansas State University, Manhattan, dating back to 2004. It grew from an interest to share acoustical theory, vocabulary, applications, and the relationship to architectural space through material selections, MEP systems, environmental noise, and precedent projects with students. Students have enrolled in the course based on previous student word of mouth, hearing about the course from their advisor, or an interest in learning more about acoustics after having me as a previous professor or project reviewer. The course has been composed of a variety of different major and minor areas of study across the university and provides a welcomed diversity of experiences and thought, especially in how student interests may lie in acoustic categories other than simply architectural acoustics. Majors have included premed, architecture, interior design, environmental design, and architectural engineering, whereas minors have included history, literature, sociology, chemistry, geography, mathematics, anthropology, computer science, foreign languages, business management, and construction management that make the pedagogical approach unique. This course has also led to several students enrolling in independent study courses for advanced content. The mix of interests has led to successful team projects, presentations across campus and at conferences, involvement in various aspects of the Acoustical Society of America, and Newman Fund medalists.

The students experience acoustics through sound pressure level (SPL) and RTA measurements (**Figure 4**), local and regional field trips, and talking with design professionals and consultants about real-world conditions. The lessons learned allow opportunities applicable to current academic and future professional projects. Historical accounts and lessons learned over time include Greek and Roman theaters, Chladni plates, Martinville's 1860 phonautograph, Edison's wax cylinders, Sabine's vast contributions, the 1929 Noise Abatement Commission, and Robert Newman's recorded lectures from 1970.

We also review research and learn how good acoustic design improves student behavior because over 90% of classrooms exceed maximum background noise levels (Wang, 2013) and students miss up to 50% of what teachers say (Harmel, no date). When reading published resources, students also find relationships between the aural environment and personal productivity, retention, performance, and stress. In his book *Daylighting, Architecture and Health: Building Design Strategies*, Boubekri (2008) associates poor acoustics with various other issues contributing to sick building syndrome. We discuss various topics, including anechoic chambers and psychoacoustic research; acoustic marvels where specific frequencies believed by biobehavioral scientists relate to mood, empathy, and social behavior; restaurant acoustics; mechanical noise; electronic architecture to create various acoustical environments; and technological advances, including wireless charging where ultrasonic frequencies charge electronics. We carry a drum kit around to various places where students volunteer to activate the spaces and foster conversations about frequency interactions.

We also talk about acoustical versions of standardized materials such as a perforated metal deck that allows some frequencies to be absorbed in the roof insulation. Studying spaces with resonant pockets, cavities, and slots allow students to connect patterns, rhythms, and cultural or religious meanings to acoustical results. Students love learning about odd or unusual ways in which people have gathered information, including the use of war tubas and sound mirrors during wartime conditions prior to radar. We study the history of microphones and loudspeakers, including how public opinion originally thwarted full-range loudspeakers due to what was believed to be unnecessary frequencies. Students are also really surprised to hear there are loudspeaker systems well in the multiple

Figure 4. *Examples of memorable learning moments.* ***Left:*** *students investigating the floor isolation of ETS-Lindgren's Cedar Park, Texas hemianechoic chamber.* ***Right:*** *students surprising a motorcyclist leaving a campus parking garage as they enthusiastically approach with handheld sound pressure level meters.*

hundreds of thousands of dollars. A course favorite is the Radio Craftsmen (1957) Xophonic bookshelf speaker that housed 50 feet of plumbing tube/hose to create time-delayed reverberant energy.

It is always wonderful to introduce students to the world of cymatics, visualizing sound waves through different media. Ernst Chladni is credited with discovering the node and antinode patterns from frequencies induced in a plate covered in salt or sand, but credit is also due scientists such as Leonardo da Vinci, Galileo Galilei, Robert Hooke, and Sophie Germain. We might not see sound likened to not seeing wind, but we see the effects of the wind. Online videos of Schlieren photography catch students' attention because the rippling of sound waves are visible. Although we don't dive deep into human anatomy, we discuss the basics of the ear to understand how vibrations are translated and energy is converted into something understandable. An opera singer hitting certain frequencies and breaking a glass has some form of cool factor, but it's surprising to students to learn of the modulus of elasticity as the glass is wobbling in a slow-motion video just before the modulus of rupture. The cornstarch monster is fun to demonstrate (see youtube.com/watch?v=kevqQHZSeao), but I have destroyed a few speakers in the process. Students have also expressed interest in the cultural-, social-, and gender-related aspects of stereotypes and damaging effects of "vocal fry."

Although most students don't recognize David Byrne as the lead singer of the rock band Talking Heads, they like hearing about his collaboration with some other artists and musicians to activate spaces known as "playing the building" (Byrne, 2005). People pressed keys on a modified organ to trigger solenoids and hammers connected to beams, sprinkler lines, and pipes to reveal the aural personality of the space through the direct and reverberant energy. The space was activated beyond its typical occupancy and made us question if the result was noise, art, music, or a combination. This helps introduce an assignment to design and build a homemade instrument with found materials.

Sonic deception is also a hit with the students. What is known as the Ghost Army (The National WWII Museum, no date) strategically placed inflatable tanks and amplified wire recordings up to 15 miles away from enemy lines during World War II. The sights and sounds were convincing and successful. On another note, who knew water could be bent with low-frequency sound waves, sound deprivation therapy tanks exist, fire could be extinguished with low frequencies, or conversations could be captured through vibrating glass? Thank you, inventors and scientists who disseminated them.

I use photos and videos of places I have visited as teaching tools. Musikverein in Vienna, Austria, is always referenced due to its articulation, shoebox-shape proportions, and how people experience the natural acoustics. Every New Year's Day, the audience chairs are removed and stored in a cavity below the floor for the annual ball, which means the audience is typically sitting on what could be likened to an acoustic guitar resonant chamber. Notre-Dame du Haut in Ronchamp, France, emphasizes the binaural characteristics between proximity to the faceted/chamfered/splayed heavy concrete wall versus the opposing planar wall. Other examples include Myerson Hall in Dallas, Texas, and KKL in Lucerne, Switzerland, which are both flanked by an operable reverberant chamber and overhead canopy. There are sectional models of the Paris Opera House that help convey how distance and layers nestle the performance area away from the street noise and deep within the confines of structure. Red Rock Amphitheater in Colorado and 333 Feet Underground in Tennessee provide examples of rock formations resulting in diffusion and envelopment. These examples help tie conversations about materials, distances between stage and audience, and number and slope of seating to historic Greek and Roman architecture.

Research and Practice: Demonstrating Principles into Reality

In addition to teaching students through traditional courses, I demonstrate and practice those principles through funded research, publications, service-learning design-build projects, and professional practice. The advancement of knowledge through pedagogy stirs student and community interest into tangible and measurable physical results. The active process of creating and making results in real-time design to occur while developing both small and full-scale prototypes. The teaching tool is simple: students not only see but also hear the connection between materials and the resultant environment, weaving acoustics and aesthetics together. I also share professional projects where I have been architect and/or acoustical consultant, including collaborations with other firms. These new and adaptive use projects show future generations methods of implementing concepts into practice and learn from lessons in the field (**Figure 5**).

Figure 5. ***Top:*** *palette of interior finish materials shared in the classroom to teach color, texture, and related acoustical properties prior to experiencing spaces in person.* ***Bottom:*** *students visiting the Booker T. Washington High School for Performing and Visual Arts recording studio in Dallas, Texas, with Russ Berger and Richard Schrag, to teach audio production. The field trip allowed the relationship of theory and principles as students asked questions about stretched fabric, sloped laminated glass, and infrastructure/routing such as microphone inputs, isolated grounds, and rack equipment.*

Court Appointed Special Advocates Playhouse

Within an intensive three-week summer course, students were tasked with designing and constructing a playhouse to be raffled at a local mall to benefit Court Appointed Special Advocates (CASA). This opportunity provided a seldom-offered model where the course included students from multiple-year levels. They learned how design decisions based on modularity, transportability, and available materials resulted in specific acoustical properties. Seated children in the lower space hear their voice reflected back in an additive manner due to the twisting and stepping of the cedar, cypress, and acrylic layers. Similarly, this project embodies the essence of "undergraduate courses in acoustics for a School of Architecture." Marshall (1963) states the relationship between acoustics and a design process must be identified "first in terms of the process, and second in terms of the aesthetic judgments which by definition are integral with 'design.'" The playhouse demonstrated acoustical results of materials and shape through immersive learning (**Figure 6**).

Stabilized Compressed Earth Block

A collaborative multidiscipline team of OU students and faculty explored earthen design and construction techniques through an elective course that led to an Environmental Protection Agency (EPA) P3 Award and Grant. The team then partnered with Cleveland County Habitat for Humanity (CCHFH) to design and construct a stabilized compressed earth block (SCEB) residence and a conventionally wood-framed version of equal layout, area, volume, apertures, and roof structure on an adjacent site. Through both laboratory

Figure 6. ***Left:*** *students and faculty designed and built the playhouse in the University of Oklahoma Gibbs College of Architecture Creating_Making Lab.* ***Center:*** *delivery and installation of the playhouse to the raffle winner's property.* ***Right:*** *child climbing the interior stepped and faceted enclosure also responsible for the acoustical results.*

tests and field validation, researchers demonstrated the structural, thermal, economical, and acoustical values of SCEB as a viable residential building material.

Interactive Synchronicity

Another small group of students designed, constructed, and calibrated an inhabitable interactive installation based on the Buskuhl Gallery space in the OU GCA Gould Hall's lively acoustics and outward display to campus, employing excessive reverberation time and resonance as a method of visually demonstrating the persistence of sound waves. The amalgamation of materials and acoustical sensors defined the visual translation of acoustical impulses into rhythmic patterns and textures of light. People quickly realized the lights were triggered by airborne impulses such as voices or laughter, and impact impulses such as footfall or slamming doors. They equated continual light flutter to lingering impulses outside human perception. Some participants were instantly provoked to make more or specific sounds to cause illumination, whereas others attempted to cease the dancing lights. People physically inhabiting the space were the participants and critics, not by their words as comments in a formal jury setting but by their real-time reaction to their personal interaction.

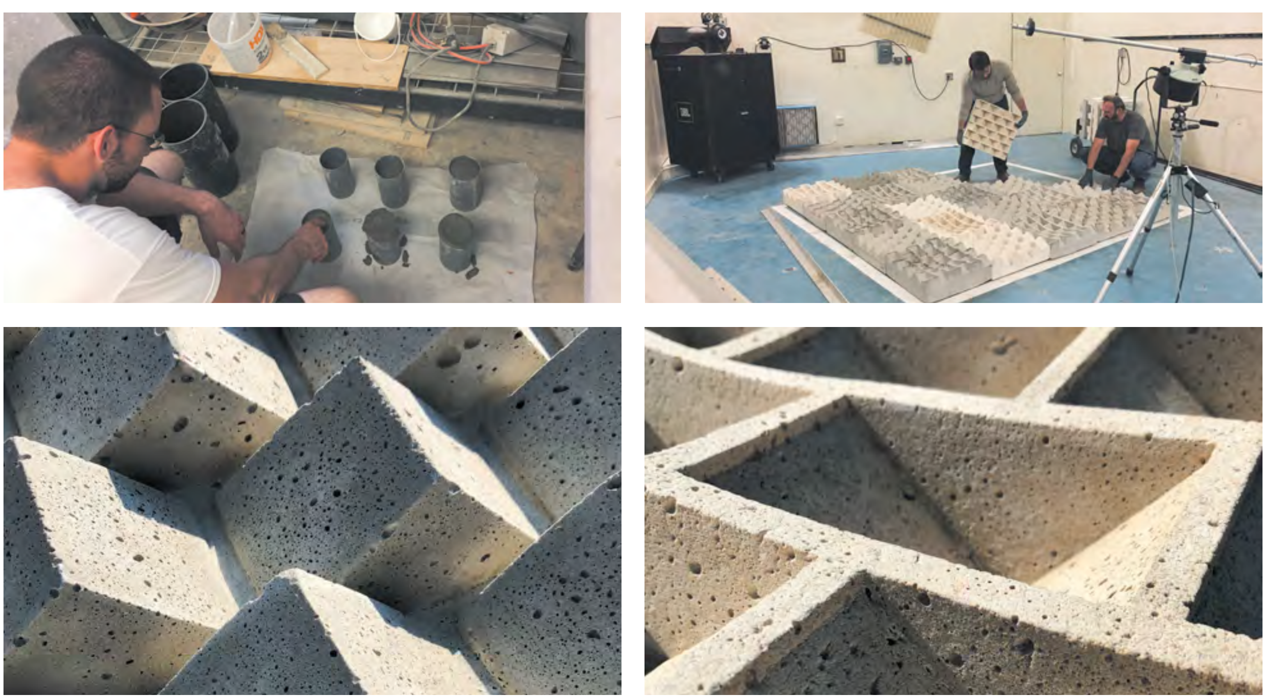
On Display

Students have also constructed instruments and loudspeakers as part of an assignment or as an expression of their interests to unite acoustics and craft into particular listening environments. A disabled veteran student who is legally deaf in one ear created loudspeaker enclosures linked to a wall stud cavity that was displayed at a local art gallery. The wall cavity between framing members and the wall finish was part of the installation, thereby actively integrating acoustics into architecture. People were able to hear and experience what the student created related to an occupied space. It was not just theory but was demonstrated through creating and making.

Acoustically Diffuse and Absorbent Lightweight Aerated Concrete

Students in the spring 2017 acoustics elective course began the initial process of basic data collection that led to prototypes, modeling in various software applications including EASE, feasibility studies, and compiling

Figure 7. ***Top left:*** *student developing concrete mixes in various size compression strength test cylinders.* ***Top right:*** *student placing acoustically diffuse and absorbent lightweight aerated concrete (ADALAC) panels in the Riverbank Acoustical Laboratories reverberation chamber.* ***Bottom:*** *close-up photographs of both the sawtooth (**left**) and recessed (**right**) prototype panels showing shapes and surface porosity responsible for reflection, diffusion, and absorption.*



applicable precedent studies. I led a team of students to evaluate the frequently occupied Buskuhl Gallery space as a test bed for acoustical research. The data-driven design process allowed students to measure and understand quantifiable values beyond anecdotal opinions and related occupied space with acoustical criteria. Undergraduate and graduate students worked with me to evaluate space through the collection of acoustical data that then fueled the development of material science as the vehicle to address deficiencies. The resultant acoustically diffuse and absorbent lightweight aerated concrete (ADALAC) prototypical panels (**Figure 7**) combine the atypical use of concrete to employ reflection, diffusion, and absorption in typical speech frequencies, yielding substantial increases in laboratory- and field-measured acoustical values (Butko, 2021). This project introduced and bolstered various phases of architectural acoustic principles and led to expanded collaboration with other colleges and another university.

Summary/Conclusion

Architecture is a tapestry of theory, intent, and realism hovering somewhere among the poetic, the technical, and the material, resulting in improved health, safety, and welfare of occupants. Participants begin to understand materials, shapes, room volume, and programmatic adjacencies as interdependent and symbiotic entities. Students, and occasionally clients, typically don't know what they don't know. The process of introducing acoustics opens their eyes and ears to more of the various aspects of architecture. I hope this article has inspired you in some manner either to have a new interest in acoustics or perhaps to open the door to an aspect that you would like to explore further. Everyone can learn and has some outlet of educating others.

Acknowledgments

I thank Venda Burgess, Charles Block, Gary Siebein, Bob Coffeen, and Russ Berger who taught me countless aspects of academia and the profession. Thank you to Arthur Popper and all the *Acoustics Today* editors for the article invitation and constructive manuscript feedback. I also acknowledge support from Coreslab Structures (OKLA) Inc., Oklahoma City, OK; the Vice President for Research and Partnerships Office and the Gibbs College of Architecture, University of Oklahoma (OU), Norman; the numerous students from the University of Florida, Gainesville, Kansas State University, Manhattan, and OU, with special thanks to Zachary Maggia; and my family who knows my love for teaching acoustics.

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Daniel Butko, an architect and Associate Professor of Architecture, has academic and professional experience spanning over 30 years in all phases of design, client management, construction administration, and consultation focused on architectural acoustics, material science, and data-driven design. Notable achievements include an Environmental Protection Agency (EPA) P3 Award, a Disney Dreamers and Doers Award, an Acoustical Society of America Rossing Prize, an Architect Magazine R+D Award, American Institute of Architects and American Concrete Institute awards, and advisor to award-recognized student projects. Daniel's teaching career has allowed instruction to over 1,500 undergraduate and graduate students.