THE UNIVERSITY OF TENNESSEE KNOXVILLE

Journal of the Association for Technology in Music Instruction

Volume 3 | Number 1 Article 1

Defining the Hourglass Framework of Technical and Musical Concepts in Music Technology Education with Two Case Studies in Course Development

Timothy Hsu
Indiana University Purdue University Indianapolis, hsut@iu.edu

Defining the Hourglass Framework of Technical and Musical Concepts in Music Technology Education with Two Case Studies in Course Development

Cover Page Footnote

This research was supported in part by a grant from the IUPUI Center for Teaching and Learning and the IUPUI Department of Music and Arts Technology.

Journal of the Association for Technology in Music Instruction

Vol. 3, No. 1 (2022)

Defining the Hourglass Framework of Technical and Musical Concepts in Music Technology Education with Two Case Studies in Course Development

Timothy Hsu
Assistant Professor
Department of Music and Arts Technology
Indiana University - Purdue University Indianapolis

ABSTRACT

As the field of music technology connects music with a vast array of technical fields, a mature music technology program ideally challenges and develops students that incorporate musical contexts of technical ideas and the technical concepts of musical ideas. The educational challenge of music technology programs lies in the balancing of technical and musical material in the curriculum. In structuring this balance, this paper proposes an hourglass framework, where music technology sits at the neck of two sides, where one side is built on the tradition of Western and non-Western music history, theory, and repertoire, and the other side is constructed based on the development of engineering, computer science, design, physics, and other technical fields. This paper defines and discusses this hourglass framework, shows the curricular need, and presents two case studies of an undergraduate and a graduate course that employ balance through the hourglass framework. Through audio circuits, physics of sound, and acoustics synthesized with musical contexts, students discover and learn how technical concepts directly impact musical decisions, and vice versa. This paper discusses not only the methods employed by both classes, but also possible growth areas for continual improvement in exploring the intersection of technical and musical concepts.

Introduction

Music technology can be defined broadly as the use, application, creation, and development of technologies for music, and the associated careers span widely traversing musical and technical fields. While some music technology graduates pursue more creative

Hsu, Timothy. (2022) Defining the Hourglass Framework of Technical and Musical Concepts in Music Technology Education with Two Case Studies in Course Development. *Journal of the Association for Technology in Music Instruction*, 3 (1).

careers as electronic music performers, producers, and composers, more technical jobs can include audio software engineers, artificial intelligence developers for music information retrieval and classification applications, acousticians, and electroacoustic engineers. To prepare students for these careers, currently, undergraduate and graduate curricula in music technology revolve around studying, analyzing, performing, and creating with the techniques and tools that stem from technology (Rees, 2012). However, the curricular challenge is that music technology is an interdisciplinary hourglass discipline. This paper first defines and presents the hourglass framework and then presents case studies with two courses that use the hourglass as a guide for course design. The undergraduate course, Music Technology Lab III, aligns electrical engineering circuits concepts with musical applications, balancing technical concepts with musical applications and evaluations. A graduate course, Applied Acoustics, develops a technical understanding of acoustics and sound within music technology through analysis, aural evaluations, and composition. Ultimately, both classes address the same philosophy: that technical decision making is musical decision making, and that without technical knowledge, music technologists will unintentionally cede musical decisions to engineers and tool developers that potentially lack formal music training.

Background

The Hourglass

Music technology sits at the confluence of disparate areas, broadly encompassing aspects that include, but are not limited to, music performance, composition, music theory, software and hardware development, signal processing, music therapy, neuroscience, acoustics, design, computer science, machine learning, and psychology. There is an inherent challenge of generating such a list as this, implying that designing a curriculum to meet these topics is even more daunting. An hourglass framework can be used to describe the field, where music technology convenes at the neck of an interdisciplinary hourglass, with one side filled with musical concepts, and the other side filled with technical concepts, as seen in **Error! Reference source not found.**.

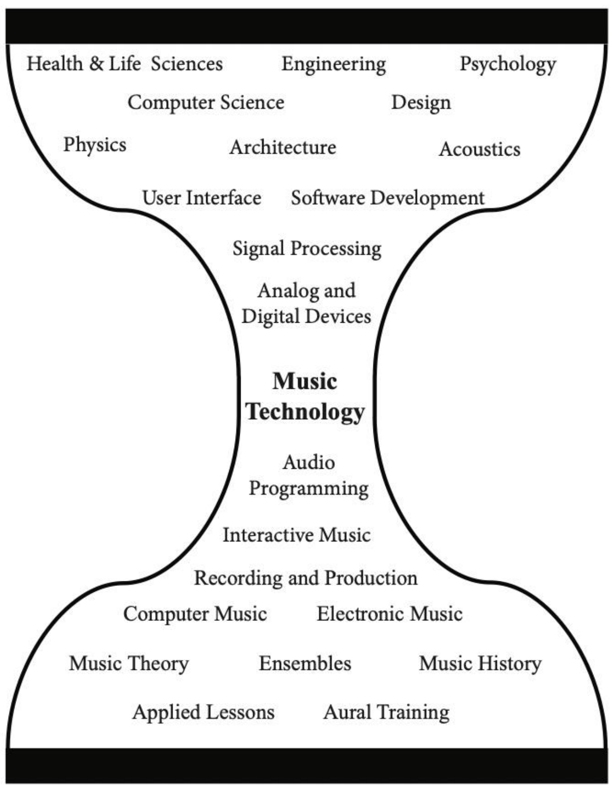

Figure 1: *Music Technology as an interdisciplinary hourglass discipline*

Historically, engineers and musicians have collaborated in exploring new sonic possibilities of technology in creative applications. Leon Theremin studied physics, astronomy, and electrical engineering while Robert Moog received a degree in physics and electrical engineering, and both inventors' instruments have been seminal in music technology history. Theremin and Moog are examples of individuals on the technical side of the hourglass reaching into the musical side. As for more traditional musicians reaching into technical aspects of music, Eric Whitacre can serve as an example of a traditional composer who embraced technology through his virtual choirs, and the Kronos Quartet has embraced using technology in performance, even using click tracks with some pieces. Traditional musicians may use technology such as black boxes -- a tool that has inputs and outputs but the inner workings and theory are unknown to the user (Ashby, 1956). An example of this may be a guitar pedal, where a guitarist knows the input and can hear the output but does not know what components are inside the pedal and does not analyze the theory of the circuit analyses. As music technology progresses, a mature curriculum should formally train students on both sides of the hourglass.

As the hourglass is presented here, the topics further from the neck are more general fields and topics closer to the neck are more directly aligned with music technology. Conceptually, a curriculum faces the challenge of incorporating topics that are further apart vertically in the hourglass. Thus, music technology programs can create their identity through how they approach this hourglass in their curricula. One program may approach their curriculum from the technical side, and another may use their strengths from a more traditional music program in building their technology degrees; however, programs should challenge their students to go back and forth between the two sides and to explore the inside of the black box.

This paper specifically addresses programs that approach music technology from the musical side of the hourglass. Thus, the pedagogical challenge involves creating ways to propel music technology students upwards in the hourglass to expose students to technical knowledge. A modified bottom-heavy hourglass, as seen in **Error! Reference source not found.**, could be utilized that includes more courses near the neck covering applied technical aspects. Music information retrieval, audio circuits, audio programming, and electroacoustics for example, can be natural topics in which students can learn about programming, statistics, hardware design, and engineering design through the lens of music. These topics allow students to traverse more easily through the neck to develop stronger technical knowledge. Ultimately, the outcome of this bottom-heavy hourglass is the creation of music technology students who possess strong musical backgrounds with in-depth technical knowledge. This type of student may be more appealing to the music technology industry and workforce than an engineering student with informal music training.

Using this bottom-heavy hourglass framework, this paper describes two case studies where 1) electrical engineering music technology concepts are taught in an undergraduate course, and 2) physics of sound and acoustic concepts are explored with creativity in a graduate course.

Curricular Need

Electrical Engineering Topics at the Undergraduate Level

As the number of jobs requiring hardware or signal processing experience increases, a student in a traditional music program may need to enroll in electrical engineering courses outside the department. This model leaves the synthesis between music and electrical engineering concepts to the students, as these engineering classes generally stay on their side of the hourglass. Additionally, not all music students have the technical background to enroll in engineering courses thereby alienating music students from even an introduction to technical knowledge.

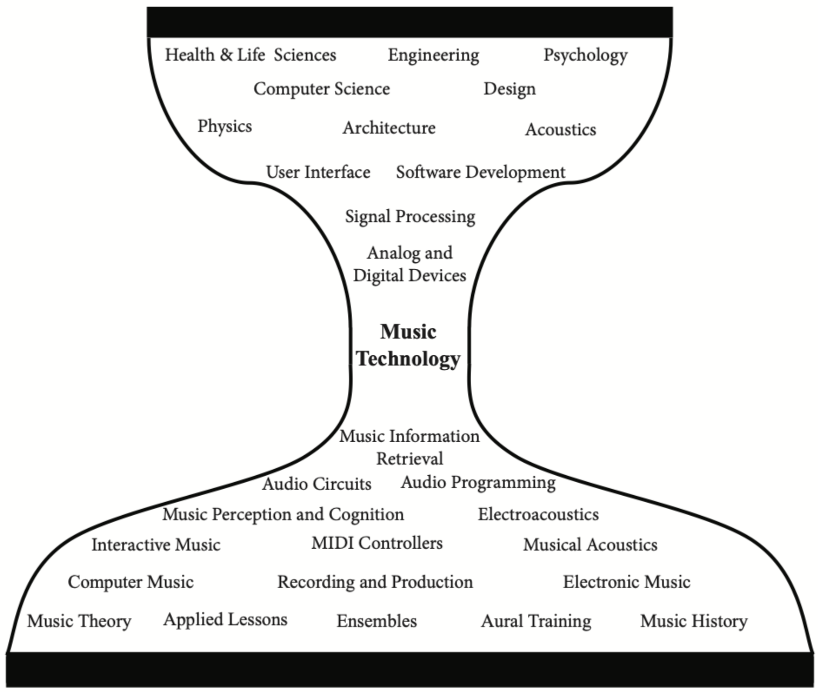

Figure 2: *Modified bottom heavy hourglass with technical focus*

Some music technology departments developed application-based methods to introduce electrical engineering concepts. One such method is novel circuit bending/hacking music ensembles (Ben-Tal & Salazar, 2014; Belojevic, 2014; Palamara & Cooney, 2020). These ensembles, utilizing hands-on hardware in music performance, align with the DIY and maker-model of music technology education (Hughes, 2018). This approach, however, can be viewed as the counter equivalent to the engineer with non-formalized music knowledge. In this case, students have strong music backgrounds but non-formalized technical knowledge. In the context of circuits, for a student to breach that hourglass neck, the curriculum should reflect more technical knowledge of how circuits design and theory affect music directly. The undergraduate course, described in this paper, is designed with the bottom-heavy hourglass framework in mind, where electrical engineering circuits concepts are balanced with musical applications and evaluations.

Acoustics and Sound Topics at the Graduate Level

Acoustics, an inherently interdisciplinary field, stems from fundamental physics of mechanical radiation and phonons and extends into theories and applications in areas of earth/life sciences, health, engineering, and arts and music (Lindsay, 1964). Even with such diversity, acoustic courses are not ubiquitous. The effect of the general lack of acoustic courses is that music technology students miss the deeper technical content that can shape musical decisions. Historically, acoustics education research ranges in topics concerning undergraduate acoustics research opportunities (Ronsse, 2015), courses involving music (Hsu, 2015), and acoustics to non-technical students (Jaramillo, 2015). Additionally, acoustics appears in physics pedagogy (Gee & Neilsen, 2014), speech production education (Arai, 2007), and computer-based education and signal processing (Rahkila & Karjalainen, 1998). Acoustics textbooks are also diverse, with some focusing on physical acoustics and theoretical methods (Pierce, 1998; Blackstock, 2000), while others approach acoustics through engineering (Bies et al., 2018), musical instruments (Hall, 2006), and architecture (Long, 2014). More generalized books (Rossing, 2014; Fahy, 2007; Raichel, 2000) make connections between interdisciplinary fields but may lack technical rigor for some. Furthermore, interdisciplinary efforts of teaching acoustics have used sonification

(Cabrera & Ferguson, 2007) and hands-on demonstrations (Arai et al., 2006). One study at Brigham Young University (BYU) aligned student-based learning outcomes with course activities and assessments (Neilsen et al., 2012). Modernization strategies of the course included hands-on demonstrations, physical models, videos, discussions, labs, and hands-on activities. Although this study introduces teaching and learning methods in acoustics education, this particular course does not address music technology directly.

Musicians and designers have historically collaborated on the creation of music spaces. For example, Mozart worked closely with Emanuel Schikaneder, an opera impresario who built theaters (Radice, 1998). This collaboration led Mozart to premiere some of his operas in Schikaneder theaters. Modern acoustic simulations revealed some of the acoustic characteristics that Mozart may have encountered (Westergaard & Hsu, 2018). More recently, the Elbphilharmonie employed designers, computational acousticians, and structural engineers to create custom digitally fabricated panels (Koren & Müller, 2017). Thus, musical acoustics is a natural cross-section of music, vibrational analysis, numerical methods, and other engineering fields.

As a graduate course, the course design and the students must reach further into both sides of the hourglass to meet the interdisciplinary nature of acoustics. This deeper approach challenges graduate level thinking in connecting concepts that are further apart vertically in the hourglass.

Course Designs

Undergraduate Course Design with Electrical Engineering Topics

A case study is presented here for addressing technical topics in an undergraduate music technology lab course that was introduced in Fall 2019 and has regularly continued every semester. The course goals are to synthesize electrical engineering concepts with music technology ideas using audio specific circuits, activating students' sonic and musical discovery through hands-on labs and aural evaluations, and teaching technical evaluation and analysis methods through musical devices. Students work in an electronics lab equipped with function generators, power supplies, and oscilloscopes. They also have access to electronic kits, consisting of a multimeter, resistor/capacitor/inductor sets, a mini-speaker, and operational amplifiers.

Representative Activities

The weekly lab activities, reinforcing lecture topics, connect the electrical engineering concepts to realized sonic outcomes. In each lab activity, a speaker is attached to the circuit where students hear how changing the circuit changes the sound. Early in the semester, students initially listen to sine waves and view them with oscilloscopes. Then, they explore the harmonic series by changing the function generator output. The students' familiarity with pitch and octaves helps them uncover wave properties such as period, amplitude, and frequency.

Students in music technology are generally familiar with high and low pass filters. Building upon this experience, this class opens up the black box and introduces resistors, capacitors, inductors, impedance, and transfer functions to show known audio filter properties such as cutoff frequency and filter slope. In lab activities, students build variable high and low pass filters and directly hear the effect of filter parameters on white noise and on music. Furthermore, this activity demonstrates how to measure a frequency response, allowing students to physically see, hear, and measure the amplitude of a sine wave at different frequencies. This activity connects the measurement of amplitudes, representing the technical side of the hourglass, to filter curves in digital audio workstations on the musical side of the hourglass.

Students also work with operational amplifiers, where they learn about phase and gain. Operational amplifiers offer opportunities to learn about intentional and unintentional clipping, as seen in an oscilloscope and heard through speakers. Whereas a more traditional engineering course may present clipping as undesirable, the music technology approach allows for the discussion of intentional and unintentional clipping. As students play music through a clipping circuit, they hear what undesirable distortion is, but they also discover how clipping in operational amplifiers is used successfully in distortion pedals.

These representative activities show how curation of engineering and music technology concepts can be linked in an exploratory, hands-on fashion. Not only are engineering tradeoffs explored, but musical tradeoffs as well. Most importantly, the use of speakers requires music technology students to link sonic outputs with technical concepts—directly showing how a designer creating an audio circuit is making both musical and technical decisions.

Graduate Course Design with Acoustics and Sound Topics

An example graduate level course covers topics of acoustics relevant to applications for music technology and engineering in order to investigate the intersection between the technical and the musical, based on individual student's musical and technical backgrounds. As this is a graduate course, the objective is to go deeper into both sides of the hourglass. Furthermore, student pods, a group of interdisciplinary students with diverse backgrounds, encourage and incite collaborative learning. Specifically, the class objectives are to connect technical and creative ideas through acoustic design projects, to understand objective sound metrics as they relate to musical outcomes, and to use collaborative hands-on opportunities to explore technical concepts with musical outcomes.

Student Pods

One unique aspect of this course is the interdisciplinary student population. As this course potentially draws students from engineering, music technology, and physics, the interdisciplinary student pods create a fertile environment for collaborative learning, not simply cooperative learning. These hand-selected pods capitalize on the specialty areas of each student, creating organic opportunities for discussion, with students with more technical backgrounds (on one side of the hourglass) supporting those with more musical backgrounds (on the other side of the hourglass), and vice versa. For example, in the Spring 2020 semester, one student pod consisted of four students: an Indian Classical musician, a student with an electronics engineering bachelor's degree, a guitar player with a music technology undergraduate degree, and a recording engineer. Each student brought expertise from their own background where the commonality was their interest in music technology, with the goal of creating a balanced hourglass of knowledge for the entire pod. For example, when discussing acoustic resonance, the electronics engineer learned from the Indian Classical musician and the guitar player about instrument resonances and playing techniques, and the Indian Classical musician and the guitar player learned about the math and physics that govern the resonances from the recording engineer and electronics engineer. These pods are the core of this graduate class, as nearly all activities involved collaborative pod work.

In-class exercises, such as working with acoustic demos, measuring sound levels, and programming and listening to convolution reverb through MATLAB are done in pods where each student subsequently presents their individual findings to the rest of the class from their own perspective. In project work, as described further below, each iterative design results in individual evaluations of each pod member, which seeds the collaborative discussion that drives the next iteration. Ultimately, the incorporation of the pods creates balance deeper in the hourglass and strengthens student learning by employing strengths of the diverse academic training.

Projects

The projects compel students to rely equally on both technical and musical knowledge. The students are tasked with designing music spaces: composing and simulating music for these spaces, evaluating the spaces aurally and musically, and iterating their designs to reach both technical and musical goals. The student pod discussions necessitate an acoustic analysis to uncover the space's impact on the music and vice versa, thereby assimilating technical and musical ideas.

There are three projects in this course, each one building upon the previous project. The first project consists of designing a rectangular recording studio with accompanying computer models and calculation of room modes. Additionally, the students use computer prediction software to obtain a frequency response of the room and use a digital audio workstation to recreate and simulate the frequency responses of these rectangular recording studios. They then evaluate different pieces of music through these simulations to sonically hear how room shape itself affects the recording and mixing experience.

In the second project, the room is enlarged to a small concert hall for unamplified chamber music. Building on the tools from the first project, the second project introduces ray tracing, reverberation, and other concert hall room parameters. The ray tracing produces an impulse response in which the students use MATLAB to generate convolution reverb rather than using an existing plug-in. By using MATLAB, the students utilize programming to explore the theory of convolution with musical outcomes. The students again iterate their designs to produce different reverberations to suit the needs of different musical styles.

The final project culminates in a musical composition where the room acts as a critical musical component in the composition, rather than as just an audio effect. Unorthodox rooms are encouraged to produce frequency responses and impulse responses that go beyond the limits of real spaces. The goal is to create acoustic rooms that produce unique musical ideas beyond typical audio effects. In this case, all previous technical tools are utilized, and the technical design decisions require the understanding of the physics of sound, acoustic metrics, material properties along with technical skills such as computer modeling, audio programming, and acoustic simulation. Acoustic decisions that directly lead to musical outcomes are needed in the development of the composition, implying that the acoustic decisions are not simply an add-on but rather an integral part of the musical expression for this final project. In other words, students will realize that technical decisions made can propagate and directly impact a music making. The result of these three projects is a scaffold of acoustic concepts, from room modes to unique room design that parallel musical and sonic exploration of frequency response of music to composition.

Outcomes and Discussion

Undergraduate Class Outcomes and Discussions

Positive Outcomes

The undergraduate class was assessed through labs reports, projects, and exams. In general, music technology undergraduate students have shown understanding through the summative assessments, such as being able to apply Ohm's Law and calculate for cutoff frequencies. As this class is not open for non-music technology majors, no comparisons can be made to a general undergraduate population. For hands-on activities, students demonstrated proficiency in using analytical tools, lab equipment, and breadboard circuits while also analyzing quantitative results through graphs, tables, and figures. Figure 3 illustrates passive and active filters that the students designed. Using a function generator and oscilloscope, they analyzed and compared the frequency response between the two designs. Observed positive outcomes include incidences where students used extra time in the lab to create a Morse code buzzer, play melodies together with function generators (excitedly claiming that the function generator is an instrument in itself), and build guitar pedals as part of an Honors project. Students have also made broader connections to applications on their own in subsequent semesters with anecdotes of students applying circuit knowledge to applied lessons. This long-term outcome is an example of positive synergy of music technology students with technical knowledge.

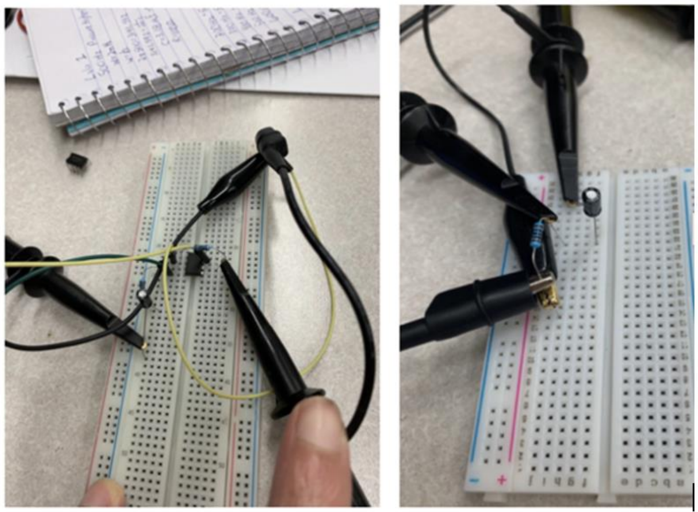

Figure 3: *Breadboard circuit of simple passive (left) and active filters (right).*

Despite the positive outcomes, several growth possibilities will be employed in future semesters. Students showed varying math abilities, with some students having more difficulty than others. Updated student support strategies include specific math focused office hours, additional examples in class, and math web resources, with longer term goals of peer tutoring networks, integrating mathematical concepts in prerequisite courses, and custom spreadsheets and programs that bypass advanced math. Balancing mathematical skill, music technology, and technical understanding is a continual challenge in technical courses.

Graduate Class Results and Discussion

In the graduate class, formative assessments consisted of projects and discussions. Three projects were scaffolded as students performed spectral and impulse response analyses multiple times, demonstrating advanced conceptual understanding resulting in enhanced discussions and conclusions. An example of mastery of material is shown in **Error! Reference source not**

found., where the synthesis of topics produced a complete theater design based on specified compositional needs. Through composition and music making, students all used technical tools such as room design software and sound level meters and they had experience in programs like Microsoft Excel, MATLAB, and Room EQ Wizard.

Summative assessments took the form of project tasks and exams to assess outcomes across Bloom's taxonomy. Each project task incorporated different levels of Bloom's Taxonomy. Early projects required them to "remember" concepts and equations, "understand" how the equations governed room design, and "apply" the concepts in calculating room parameters. Later projects required them to "analyze" their results with both technical and musical "evaluations" to drive the "creation" of a new space for music. There are similar applications of Bloom's Taxonomy for exams, with questions that involved identification/definition tasks ("remembering/understanding"), acoustical predictions through models and equations ("applying"), musical discussions of concepts ("analyzing and evaluation"), and the design of spaces around specified criteria ("creating"). Initially, the students performed better at the lower levels of Bloom's taxonomy; however, by the end of the semester, performance at the higher levels showed generally positive results as connections were made in their designs.

Figure 4: *Complete design of musical space for final project.*

As this class had students with various undergraduate backgrounds, an informal anecdotal comparison can be made with outcomes comparing those with a more technical background with those with a more musical background. These types of comparisons are challenging with this not being a double-blind study, having a small sample size of students, and potential teacher bias. The results here can give some insight, though, into the potential impact of these curricular choices. The students with a more technical background had only a ~5% increase in final grade as compared to students with more musical backgrounds. The small class size of eight students provides anecdotal indications that the more musical students are grasping the technical material and generally keeping up with the more technical students. Tracking this data over the future semesters will show the effectiveness of the hourglass-inspired course design. The students reported that the pods were helpful in understanding the concepts and connecting the technical with the creative. High impact approaches and collaborative learning between diverse students can give students the musical and technical skills needed to reach into the neck of the hourglass and break through to the top half in curated projects and course design.

Conclusion

As examples of the potential impact of careful curricular design, the two classes presented here show a case study where students can acquire both technical and musical knowledge. Increased technical and musical results will be achieved by supporting students through math resources, taking advantage of interdisciplinary student pods that fertilize diverse collaborative learning and training, and utilizing hands-on approaches. If music technology programs aim to produce students who transcend the hourglass neck, then more technical topics weaved with music technology concepts are critically needed. Essentially, music technology curricula should no longer approach technical concepts as black boxes. By opening these boxes, more mature music technology programs will further students' technical skills without sacrificing musical outcomes by balancing both sides of hourglass in their curricula.

References

Arai, T. (2007). Education system in acoustics of speech production using physical models of the human vocal tract. *Acoustical Science and Technology*, 28(3), pp.190–201.

Arai, T., Satoh, F., Nishimura, A., Ueno, K. and Yoshihisa, K. (2006). Demonstrations for education in acoustics in Japan. *Acoustical Science and Technology*, 27(6), pp.344–348.

Ashby, W. R. (1956). Chapter 11. In *Introduction to Cybernetics*. London, UK: John Wiley & Sons.

Belojevic, N. (2014). Circuit Bending Videogame Consoles as a Form of Applied Media Studies. *New American Notes Online*, 5.

Ben-Tal, O., & Salazar, D. (2014). Rethinking the musical ensemble: A model for collaborative learning in higher education music technology. *Journal of Music, Technology and Education*, *7*(3), 279–294.

Bies, D. A., Hansen, C. H., & Howard, C. Q. (2018). *Engineering noise control*. CRC Press - Taylor & Francis Group.

Blackstock, D. T. (2000). *Fundamentals of Physical Acoustics*. Wiley.

Cabrera, D., & Ferguson, S. (2007). 13th International Conference on Auditory Display. *Sonification of sound: Tools for teaching acoustics and audio*. Montreal, Canada.

Fahy, F. J. (2007). *Foundations of engineering acoustics*. Elsevier.

Gee, K. L., & Neilsen, T. B. (2014). Resource Letter APPO-1: Acoustics for Physics Pedagogy and Outreach. *American Journal of Physics*, *82*(9), 825–838.

Hall, D. E. (2006). *Musical acoustics*. Thomson Learning.

Hsu, T. (2015). 169th Meeting of the Acoustical Society of America. *Navigating and developing acoustics research and curriculum within the Georgia Tech Center for Music Technology*. Pittsburgh, PA.

Hughes, A. (2018). Maker music: Incorporating the maker and hacker community into music technology education. *Journal of Music, Technology & Education*, *11*(3), 287–300.

Jaramillo, A. (2015). 169th Meeting of the Acoustical Society of America. *Teaching acoustics to people with non-scientific backgrounds*. Pittsburgh, PA.

Koren, B. S., & Müller, T. (2017). Digital Fabrication Of Non-Standard Sound-Diffusing Panels In The Large Hall Of The Elbphilharmonie. *Fabricate 2017*, 122–129.

Lindsay, R. B. (1966). The Story of Acoustics. *The Journal of the Acoustical Society of America*, *39*(4), 629–644.

Long, Marshall (president, Marshall Long Acoustics, Sherman. (2014). *Architectural acoustics*. Elsevier Science Publishing Co.

Neilsen, T. B., Strong, W. J., Anderson, B. E., Gee, K. L., Sommerfeldt, S. D., & Leishman, T. W. (2012). Creating an active-learning environment in an introductory acoustics course. *The Journal of the Acoustical Society of America*, *131*(3), 2500–2509.

Palamara, J., & Cooney, E. (2020). The Missouri Experimental Sonic Arts Festival. *Destructive and Inventive Instrument Development with IUPUI's DISEnsemble*. Warrensburg, MO.

Pierce, A. D. (2019). *Acoustics: an introduction to its physical principles and applications*. Springer.

Radice, M. A. (1998). *Opera in context: essays on historical staging from the late Renaissance to time of Puccini*. Amadeus Press.

Rahkila, M., & Karjalainen, M. Considerations of computer based education in acoustics and signal processing. *FIE '98. 28th Annual Frontiers in Education Conference. Moving from 'Teacher-Centered' to 'Learner-Centered' Education. Conference Proceedings (Cat. No.98CH36214).*

Raichel, D. R. (2000). *The science and applications of acoustics*. Springer-Verlag.

Rees, F. J. (2012). Redefining Music Technology in the United States. *Journal of Music, Technology and Education, 4*(2), 149–155.

Ronsse, L. (2015). 169th Meeting of the Acoustical Society of America. *Strategies for guiding undergraduate acoustics students through independent research projects*. Pittsburgh, PA.

Rossing, T. D. (2014). *The Science of Sound*. Pearson.

Westergaard, B., & Hsu, T. (2018). Sound and Music. *Simulating the Acoustic Environment of Two Historical Viennese Theaters*. Limassol, Cyprus.

Author Note

Timothy Hsu ORCID iD: 0000-0001-5620-8116 https://orcid.org/0000-0001-5620-8116

Confidentiality Disclosures and/or Acknowledgments: This research was supported in part by a grant from the IUPUI Center for Teaching and Learning.

Contact Information: Correspondence concerning this article should be addressed to Timothy Hsu, Department of Music and Arts Technology, Indiana University Purdue University - Indianapolis, 535 W. Michigan St, Indianapolis, IN 46202. E-mail: hsut@iu.edu

About the Author

Dr. Timothy Hsu is an Assistant Professor in Music and Arts Technology (MAT) at IUPUI and leads the Acous-Tech Lab. Dr. Hsu received a B.M in Piano Performance and in Recording Arts and a M.A in Acoustics from the Peabody Institute of the Johns Hopkins University. He also received a M.S. and a Ph.D. in Mechanical Engineering from Georgia Tech. Prior to IUPUI, he was a Visiting Assistant Professor at the Georgia Tech School of Music and Center for Music Technology and was the Georgia Tech Chorale director. His research area spans vocal acoustics, musical acoustics, and architectural acoustics. Recent projects include work with diffusers and shape grammar, music technology and STEM education, and health applications of acoustics. Additionally, he is a member of the Acoustical Society of America and Audio Engineering Society.