Acoustic Engineering Workstation at the College of the Ozarks

Geoffrey A. Akers
James P. Keeter School of Engineering
College of the Ozarks
Point Lookout, MO USA
gakers@cofo.edu

Nicolas C. White
James P. Keeter School of Engineering
College of the Ozarks
Point Lookout, MO USA
nicolascwhite@student.cofo.edu

David E. Frey, Enable Audio, Branson MO, enableaudio@gmail.com

Abstract— **The College of the Ozarks is developing the ability to provide acoustic engineering services to customers on and off-campus. The College is the only federally recognized work college with an undergraduate engineering program, which means students do not pay tuition and are assigned workstations on campus to help defray expenses and to generate income for the College. This paper addresses the purpose and administration of the workstation and how it is unique from other service-learning programs, the perceived benefits to the student workers and the engineering program, recent workstation accomplishments, lessons learned, and future plans.**

Keywords—acoustics, engineering services, work college

I. INTRODUCTION

The undergraduate, multidisciplinary engineering program at College of the Ozarks (C of O) began in 2016 and plans to seek ABET accreditation after graduating its first engineers in May 2020. The school is a private Christian, liberal arts college and is a federally recognized work college. As stated by the college president, Dr. Jerry Davis, "C of O is unique among higher education institutions in America: no tuition is charged, all students work on campus, debt is openly discouraged, and no federal, state or private loans are made [1]." Of incoming students, 90% have demonstrated financial need. C of O is currently ranked #3 in Regional Colleges Midwest by U.S. News and World Report [2].

All full-time students work 280 hours per semester at on of about 80 workstations on campus in lieu of paying tuition. Some of these workstations allow the College to avoid costs, such as custodial, landscaping, construction, cafeteria, and the information technology help desk. Other workstations on campus are dedicated to generating income, such as Edwards Mill, the Fruitcake and Jelly Kitchen, and the Keeter Center, a top-rated restaurant and a "2019 Travelers' Choice" small hotel [3]. The College also manages pork, dairy, and beef farms. These farms provide some income to offset expenses, though their primary purpose is to provide vocational learning opportunities for agricultural students.

Following the farms' approach to vocational learning, the Engineering Services workstation began in the spring semester of 2018 with one engineering student supervised by an engineering faculty member. The long-term goal is to provide engineering services to the local community, with enough paying customers at least cover the costs of the workstation. More important than generating income for the College, the mentored experience gained by undergraduate engineering students providing those services is designed to complement their academic program.

This paper first discusses the unique aspects of the Engineering Services workstation and its objectives. The approach to providing practical engineering and project management experiences is then presented. Initial experiences on the first two projects of the workstation are discussed next. Lessons learned and future plans for the workstation and the conclusions section complete the paper.

II. ENGINEERING SERVICES WORKSTATION

Workstations at C of O help students develop strong work ethics, as well as effective communication teamwork skills. The Engineering Services workstation also seeks to integrate practical engineering design experience by providing engineering consultant services. The goal is for an engineering faculty member as the workstation supervisor to function as a technical program manager and the student workers to fill the roles of project engineers.

The value of learning experiences beyond the lectures in the classroom is well-recognized. The Engineering Accreditation Commission of ABET requires engineering programs to provide "a culminating major engineering design experience" [4]. As a result, many engineering programs, including the program at College of the Ozarks incorporate capstone courses to provide project-based student experiences, which often include real-world design experience incorporating material from the courses they have taken to that point.

Some engineering programs have integrated significant project-based courses into their undergraduate programs. "Project-based learning is a comprehensive approach to teaching and learning that is designed to engage students in the investigation of authentic problems." Two of many examples of programs with significant project-based course content are Massey University, which has courses incorporating project-based learning across the four years of the engineering program [5], and the Iron Range Engineering (IRE), which is a 4-year collaborative engineering program accredited through Minnesota State University, Mankato. "By interfacing with local industry through a unique project-based approach, IRE continues to bring the learning experience closer to engineering practice than ever before [6].”

Some programs have added a community focus to the projects in project-based learning. One of the most recognized is EPICS founded at Purdue in 1995, whose goal is “development, design, and support of technology-based solutions to meet needs in the local and global communities [7].” Another program at UMass Lowell is Service-Learning Integrated throughout the College of Engineering (SLICE), which incorporates service-learning into at least one course every semester in the core curriculum of each of their engineering programs [8].

Federal work-study jobs seek to give students relevant experience outside the classroom and are a popular approach for students with financial need to help fund their academic pursuits [9]. The Work Colleges Consortium (WCC) carefully distinguishes between federal work-study programs and workstations at the eight federally recognized work colleges. All work college students, not just those with financial need, are required to work a set number of hours, and the work contributes directly to the operation of the college. All resident students participate in the work-learning service program and “are given responsibility, counted upon, gain valuable work experience, while reducing the cost of education [10].” These contributions include cost-avoidance, such as administrative, maintenance, and construction, as well as revenue generation, which is unique for each institution. Each student worker is formally evaluated each semester and provided individual feedback.

The Engineering Services workstation is distinct from project-based and service-learning courses. As with other workstations within the WCC, no academic credit is assigned and a set number of hours per semester are prescribed. Unlike the federal work-study program, the hours students work in a workstation are credited toward tuition instead of a paycheck. Other distinctions of the engineering workstation are that projects are not limited to multiples of a semester, and the small size of the workstation ensures one-on-one or one-on-a-few mentorship between the faculty supervisor and student workers and job-like interaction between student workers.

Students recognize the opportunity to apply their budding engineering expertise, so the Engineering Services workstation assignment is highly sought after. To date, one hand-picked student has been allowed to participate with a planned addition of one part-time student is in the fall of 2019.

A. *Establishing the Workstation*

The Engineering Services workstation was envisioned to be part of the engineering program from its inception. The Program Director recognized the value of service learning and a soup-to-nuts engineering design experience. As mentored workstations are integral to work colleges and serving others is integral to the Christian worldview, a workstation focused on serving on and off-campus customers using the engineering design process seemed a natural fit.

An engineering advisory board (EAB) consisting of engineers from industry in the region is also key to defining objectives and methods of the multidisciplinary engineering program at C of O. The EAB recognized the similarities in purpose between the College’s dairy, beef, and hog farms for the agricultural students and what an engineering services workstation could provide engineering students. The farms afford students a practical farm experience in a supervised environment. Milk, beef, pork, and live animals are sold to offset operation expenses. Dubbed the “engineering dairy farm”, the EAB envisioned an engineering services workstation employing a significant number of engineering students. The workstation could provide tiger teams for small projects, such as designing a replacement motor drive circuit for an old milling machine, as well as larger teams with longer-term projects, such as an aquaponics system for Christian mission organization in Ecuador. The goal would be for the workstation to be self-sustaining financially, with a mix of paying nonpaying customers and not compete directly with local industry.

Currently, C of O has more work to do than student workers available. The cost model prevents significantly increasing enrollment, as students do not pay tuition. For this reason and the current workload of the engineering department as they develop new courses, order equipment, move into new facilities, and prepare for accreditation, the workstation started small.

B. *Acoustics Focus*

College of the Ozarks is near Branson, Missouri, which has a large entertainment industry. Acoustic engineering is in demand by theaters, local churches, as well as manufacturing companies desiring to reduce machine noise within the facilities. As a result, the Engineering Services workstation was initiated with an acoustics focus.

A Work College Consortium (WCC) grant was pursued to provide seed money for the hardware needed for acoustic measurements. The grant application was used to lay out the purpose and scope of the workstation. In addition to applying for funding, the College process of approving the application gained buy-in from the Dean of the College, as well as the Dean of Work. This buy-in effectively established the Engineering Services workstation.

When the WCC grant was approved an NTi XL2 Audio and Acoustic Analyzer with the Extended Acoustic Pack and a Level 1 measurement microphone were purchased [11]. Beginning the spring semester of 2018, a student worker was shared between the engineering department and the engineering services workstation. About 10-12 hours per week of the student’s time was spent with engineering services and 3-5 hours per week with the department grading or helping the nascent program prepare for classes and labs and move into the new Dee Ann White Engineering Center.

The supervisor of the engineering services workstation is an electrical engineer with background in radar and had no significant experience with acoustics. As a result, the supervisor and student worker have had the opportunity to learn some of the technical aspects of the workstation together. A member of the program's EAB with acoustics expertise has provided free consultation and mentorship for both the faculty and student.

III. LEARNING STRATEGY

The primary objectives of the workstation are to provide the student workers with opportunities to implement the engineering design process and to develop professional skills. The strategy to achieving these objectives has effectively created an engineering consultant experience for the student workers. As previously mentioned, the supervising faculty fills the role of project manager, while the student workers are the project engineers.

A. Technical Approach

Beginning with the first semester "Introduction to Engineering" course, students learn the fundamentals of the engineering design process and gain experience managing a project as a team. These fundamentals are further developed through the engineering curriculum, culminating with the senior capstone sequence, a two-semester engineering design team experience. In parallel with the engineering courses, Engineering Services workstation aims to give selected students the opportunity to participate in practical experiences with engineering design and project management, while providing needed engineering services to campus and community customers.

The first objective of a workstation providing engineering services is to allow students opportunities to practice engineering design in an environment where failure is more acceptable than is often the case in industry. The student is stepped through the engineering design process as seen in Figure 1, which is a tailored version of Kosky's engineering design process [12] presented in "Introduction in Engineering". The dashed lines represent content that has been added to Kosky's figure, and the titles of the blocks have been modified to fit the design process of the Engineering Services workstation.

Defining the problem and understanding its context is the first step in engineering design. Once a customer has been identified, the faculty supervisor and student worker team meet with the customer to understand the objectives and scope of the project, as well as make physical measurements of the facility and perform some preliminary acoustic measurements. The Engineering Services team then meets to develop a plan forward, which includes developing a project description, modeling the facility in software, and writing a proposal with a test plan and an initial project schedule.

Modeling the facility in software to establish the baseline performance and validating that model is key to the design process in many engineering disciplines. A baseline model of the acoustic environment is also in integral step to determining what approaches to improving the acoustics will be most effective.

Steps 2-4 are accomplished as analysis of data from the simulated facility and physical facility are compared, the model is refined, and then the improvements are then recalculated to

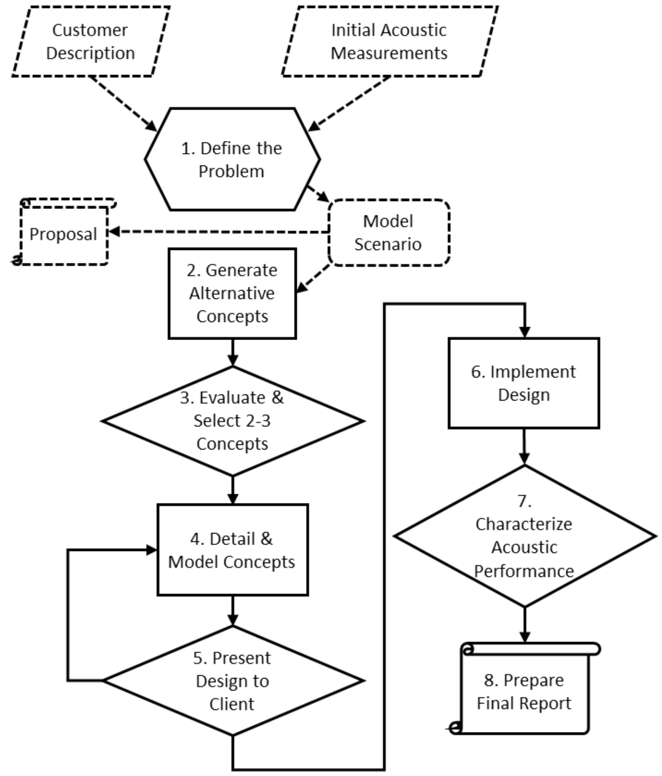

Figure 1. Tailored Kosky Engineering Design Process [12]

dictate if those modifications made a difference. These improvements typically include a mix of acoustic absorbers and diffusers. After the supervisor and student worker agree on one or more potential solutions, a presentation is prepared for the customer, which is step 5 of the process. The customer presentation includes the estimated cost, schedule, and performance for each of the potential solutions. Together with the customer, the acoustic team selects the best-value concept. The customer determines the definition of "best value", as the facility and resources to make the modification are theirs.

Once a concept has been chosen, the design is refined. This refinement often includes optimizing the locations, as well as sizes, shapes, and number of the absorbers and diffusers. Facility modifications are also possible but less desirable from a cost and schedule perspective.

The final design is prototyped in software and reviewed with the customer before implementing in the facility, completing step 6. Once the solution is implemented, measurements are conducted to validate performance, step 7. Step 8 concludes the project as a report is written and delivered to the customer.

B. Project Management Approach

As project engineer, the student worker writes the proposal and final report, presents the design options to the customer, and regularly interfaces with the faculty supervisor. The student worker tracks progress, meets with consultants, allocates resources, and is engaged in managing time throughout the project. These tasks are also covered in the senior capstone sequence of the engineering program and put into practice in the Engineering Services workstation, usually before the student has taken the capstone courses.

An initial schedule is developed for the proposal and illustrated in a Gantt chart developed in Microsoft Project®. The student worker and faculty supervisor review it weekly during team meetings. Understanding concepts such as learning curves helps the student determine how to estimate the length of unfamiliar tasks, such as learning to use new software to model acoustic environments. Balancing duties outside of the project and focusing on certain tasks in order to maintain deadlines forces the student to think several days and even weeks ahead to meet the requirements of the client in a timely order.

Weekly team meetings simulate the professional environment, including sometimes being cut short due to outside influences. Each week the student discusses what the accomplishments and challenges are of the previous week and the plans for the next week. Notes are taken by both faculty and student members for accountability and future reference.

Weekly progress reports are provided to the supervisor. These updates help the supervisor maintain situational awareness, and just as importantly, they are a record of accomplishments for later technical reports, as well as updates from the Engineering Department to the Dean of the College. The headings for the progress report are "Progress made", "Difficulties encountered", and "Tasks to be completed next week".

Communication, professional etiquette, and other interactions in a business setting are emphasized during these processes to teach student workers the importance of understanding and working with other business professionals. Engineering Services is geared toward reflecting the engineering workplace in ways that would prepare the student workers for future careers.

C. Evaluating Student Worker Performance

All student workers at the College receive feedback on their work performance midsemester and at the end of the semester. Additionally, they receive a work grade. If student workers want to change workstations, they must receive a favorable recommendation from their current supervisor. This recommendation is often a deciding factor in whether the student is allowed to transfer workstations, and it was the deciding factor in choosing the current student worker.

Work traits assessed at midsemester and at the end of the semester are: reliability (25%), initiative/motivation (20%), responsibility/accountability (20%), quality of work (15%), teamwork/collaboration (10%), and communication (10%). The work grade is reported on the student's transcript. Additionally, the engineering department requires a work GPA of 3.0 in order for students to apply for an internship course.

IV. INITIAL PROJECTS

Engineering Services has taken on two external projects since its inception in Spring 2018. The first was converting a small room in a residence to be a music studio for a local family band, and the second project was improving the acoustic environment of the choir room in the Gittinger building on the College of the Ozarks campus. By design, the first project was limited in scope but revealed significant deficiencies in the modeling software and the test procedures. The lessons learned were applied to the second project, which was a more significant under-taking and revealed challenges of its own.

Figure 2. Petersen studio with absorber panels on wall and skyline diffusers on stools.

A. Petersen Studio

The project consisted of assisting a local bluegrass band to convert a small room in a residence into a practice studio. The room was approximately 9'x11' with 8' ceilings, laminate flooring, and gypsum drywall walls and ceiling. The goal was to reduce the reverberation (reverb), particularly at the mid and upper frequencies of the audible range, and cost was a significant constraint.

This project was limited to keep the cost and level of complexity low. The workstation did not charge for their services, and all improvements were installed for testing and demonstration then the room was restored to its original configuration. One of the objectives of the project was to get a grasp of how to use the measurement equipment and software, as well as step through developing and implementing a test plan.

During the project execution, the importance of test planning and documenting test procedures and execution was reinforced. Most significantly, the inadequacy of the free software chosen to model the acoustic environment became painfully apparent.

Despite the challenges encountered, the client was pleased with the acoustic modifications to the studio. The absorber panels and floor rug reduced the reverberation significantly. A picture of the studio with absorber panels and diffusers is shown in **Error! Reference source not found.**. The absorber panels designed and constructed, and the skyline diffuser design using an online calculator [13]. The performance of these panels was characterized to be included in the software model of the room before installed in the room and tested. Diffusers require special facilities to characterize, which were not available. Their presence did not have a discernable effect on the acoustics of the studio.

Rockwool is high-density mineral fiber insulation, which has a noise reduction coefficient (NRC) of about 0.8 at 125 Hz and an average NRC of 1.0 across the audible frequencies [14]. The panel consists of 1"x2" furring strips, metal 'L' brackets, rockwool insulation, and a flannel sheet. The frame is 3 feet wide and 4 feet tall. There are two crossbars of furring strips that provide backing and support, each are 6 inches from the base or top. The rockwool is then inserted into the frame, two 1.5 feet by 4 feet slabs fit into one panel frame. The rockwool is then covered tightly with fabric. Flannel bedsheets were used for the demonstration panels; however, other more aesthetically-pleasing materials may be used. The covering is stapled tightly to the back of the frame to prevent sagging of the insulation over time. The total cost of each panel is $12, and construction takes one person around 50 minutes.

B. Gittinger Choir Room

The coordinator of the voice and music ministry programs at College of the Ozarks, Dr. John Cornish, approached the Engineering Department about improving the acoustic environment of the Gittinger Choir Room at the College.

The room had a constant hum at 125 Hz. The ambient sound pressure level (SPL) centered at 125 Hz averaged 65 decibels (dB) but reached 70 dB in certain locations. For comparison, normal conversation has an SPL of 60-70 dB [15]. The constant hum made choir practice difficult. Dr. Cornish also noted the E_4 note was especially “bright”. Misunderstanding the meaning of this comment resulted in an important learning opportunity.

The room is 16 feet tall with a width of 41 feet and a depth of 20 feet. The front wall is angled slightly, which makes the depth of the choir room vary a few feet from front to back. The flooring is carpet tiles over concrete, the walls are ½ inch thick gypsum, and the ceiling is a dropped ceiling, two feet below a concrete roof. The room is half filled with metal risers for the choir to stand on and with two pianos. The total volume of the room is around 12,800 cubic feet. The College choir uses the room to practice, and it is used for voice and piano lessons.

An initial assessment of the facility determined a portion of the west wall was vibrating, which pointed to a mechanical cause of the 125 Hz hum. The College construction team was notified. They replaced an exhaust fan above the choir room, which significantly reduced the amplitude of the 125 Hz hum. This motor was located on the roof directly over a support column. The sound was traveling through the column and into the wall of the choir room.

The focus of the project then became reducing reverb times at and below the E_4 note, ~330 Hz. Reverberation times (RT) were measured using RT20 methods with the sound analyzer purchased with the WCC grant money. RT methods measure the time required for the amplitude of the sound diminish by the value of the number following RT, as measured in dB. The industry objective is the RT60 method; which means the time required for the sound to diminish by 60 dB, or 1/1000th its initial amplitude. However, this requires a sound source that is at least 75 dB above (5623 times) the ambient level of the room. As this is hard to achieve with limited equipment and in some cases, harmful to hearing, the RT20 method was used. RT20 measures the time for sound to decay 20 dB (1/10th the initial amplitude) and then interpolates that measurement to 60 dB of decay. To measure RT20 accurately, a test signal must be produced at least 35 dB above (56 times) the ambient noise of the room [16].

The user manual for the freeware used to model the Petersen studio was written in French, and the software was not user-friendly. An engineer on the engineering program’s EAB, recommended Enhanced Acoustic Simulator for Engineers (EASE). EASE is an “acoustic simulation software for integrators, engineers and acoustical consultants” [17]. EASE is more robust and easier to use than the freeware and was used to model the RT60 values for the choir room.

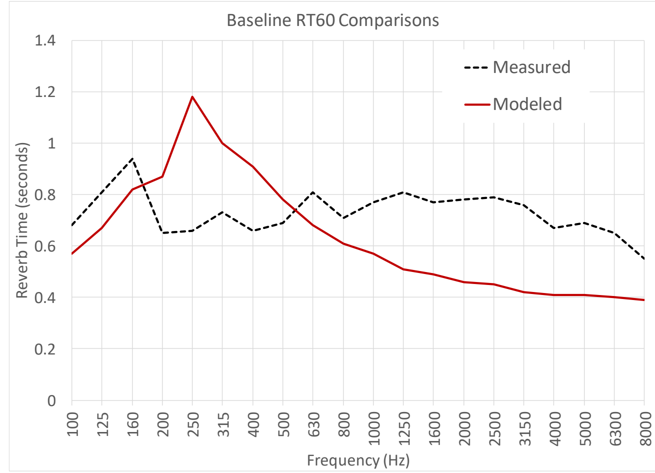

Figure 3. Measured and modeled reverberation time (RT60) of choir room. The desired RT60 is 0.9-1.5 seconds across the audible range.

The measured RT20 values were challenging to acquire, given they did not correlate with the data modeled in EASE as well as hoped, as shown in Figure 3. The differences above 500 Hz may be attributed to the measurements were taken in an empty room, and the model included an absorber field to represent the choir, as illustrated by the darker gray area of the model shown in Figure 4.

The simulation corroborated a “bright” frequency band near 250 Hz. Given the fidelity of the model, this likely corroborates the customer’s complaint about the room’s performance at the E_4 frequency. As a result, the goal became to reduce the reverberation at this frequency band by adding absorbers to the model.

The reverberation times were reduced; however, during the design review with the customer, he clarified that his objective was “liven” the room rather than “deaden” it. Further research revealed an industry standard for a choral room RT60 is 0.9 to 1.5 seconds, uniform across the audible frequencies [18]. The

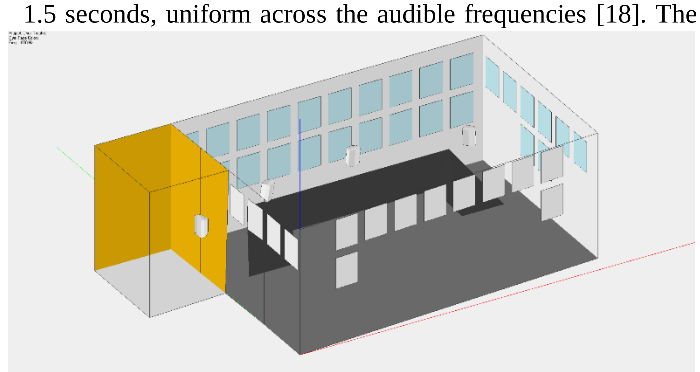
Figure 4. EASE Render of choir rehearsal room with absorber panels on walls. The front of the room is nearest the red line representing the x-axis.

model shown in Figure 4 had times below 0.6 seconds. The presentation to the client resulted in redefining the problem and making a better effort to understand the scope of the project. This learning process emphasized the importance of properly defining the terminology, understanding what the client wants, and interpreting data correctly.

With the problem properly defined, the student continued the engineering process by creating new designs that would enhance the room according to the data gathered in the last attempt. The new design included diffusers that reflect sound from nonplanar surfaces, such as pyramidal ceiling tiles. The diffusers increase the reverb time without resulting in echoes.

V. LESSONS LEARNED AND FUTURE PLANS

A. Lessons Learned

The learning experience of the first student worker are unlikely to be replicated. He independently learned two different acoustic software packages and how to use 3D computer-aided drawing software. Misunderstanding Dr. Cornish's desire to liven the Gittinger Choir Room, rather than suppress reverberation was due to the faculty's and student's lack of acoustics experience.

Both projects revealed deficits in technology and experience. However, there has been significant growth in those areas. Engineering Services designed and tested new products manufactured in-house to offer as solutions. Commercial acoustic software (EASE) was eventually purchased to replace freeware that was not as robust or user friendly.

EASE appears to be performing well and the student worker's familiarity with the software was instrumental in being selected for an internship with an audio/visual design firm in the region.

B. Future Plans

The near-term plans include completing the Gittinger Choir Room project. Acquiring or fabricating ceiling diffusers then installing those diffusers should happen early in the next semester, which would complete step 6 in Figure 1. Acoustic characterization of the modifications, comparison to previous measurements and the simulated performance of the modifications will occur and be incorporated into the final report for the customer, completing the steps of the engineering design process in Figure 1.

Future opportunities to continue researching and implementing affordable remediation for acoustic environments are abundant. Other potential customers from the College and from the community have contacted the engineering department.

Before branching out into other technical areas, the process of knowledge transfer must be demonstrated. A sophomore student will join the workstation as the current student worker enters his senior year. Toward this end, a significant amount of effort has been spent documenting modeling and measurement processes. This documentation needs to be tested while the current student worker is still available to answer questions and refine the process based on personal experience.

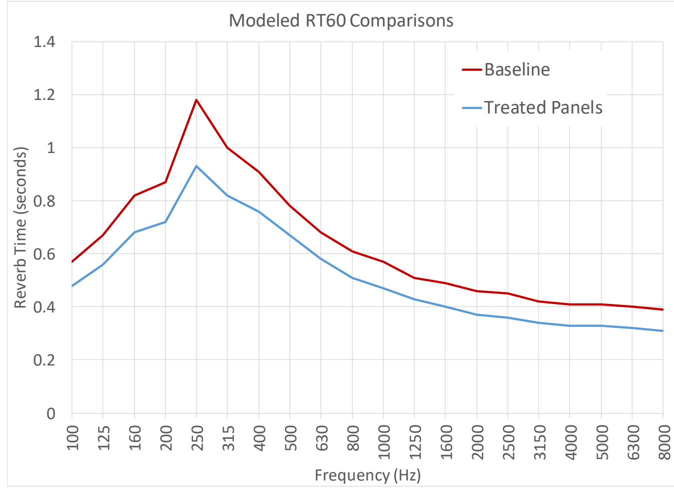

Figure 5. Simulated data of baseline and treated Choir Room

Ideally, one acoustic project per semester is planned to be accomplished once the workstation is fully functioning. As the engineering program grows, the community and College recognize the value of the services provided, and industry validates the benefits of the experience as they hire the student workers, other engineering disciplines are planned be added to the Engineering Services workstation.

VI. CONCLUSIONS

The Engineering Services workstation appears to be a valuable engineering and program management experience concurrent with the academic engineering program at College of the Ozarks. The faculty supervisor's inexperience in acoustics resulted in a learning experience of the first student worker that is unlikely to be replicated. Lessons learned in the first three semesters of the workstation promise a more refined exposure to acoustics engineering, though the variability of problems encountered and associated constraints will ensure future student workers will develop valuable engineering design skills.

Engineering Services provides a unique approach to teaching concepts of the engineering design process and developing professional skills. While the start of the workstation has been challenging, each effort made to improve adds to the value of this experience.

REFERENCES

[1] J. C. Davis, College of the Ozarks, 2019. [Online]. Available: www.cofo.edu.

[2] U.S. News and World Report, "Best Regional Colleges Midwest Rankings," 2019. [Online]. Available: https://www.usnews.com/best-colleges/rankings/regional-colleges-midwest. [Accessed 25 June 2019].

[3] College of the Ozarks, Keeter Center, 2019. [Online]. Available: www.keetercenter.edu.

[4] ABET, "Criteria for Accrediting Engineering Programs, 2019-2020," [Online]. Available: https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-

2019-2020/#GC5. [Accessed 12 June 2019].

[5] A. Shekar, "Project based Learning in Engineering Design Education: Sharing Best Practices," in *121st ASEE Annual Conference & Exposition*, Indianapolis, IN, 2014.

[6] Iron Range Engineering, "Our Model," Minnesota State University, Mankato, [Online]. Available: http://ire.minnstate.edu/about_ire/index.php. [Accessed 25 June 2019].

[7] W. Oakes and A. Pierce, "Engagement in Practice: Scaling Community-based Design Experiences," in *2018 ASEE Annual Conference and Exposition*, Salt Lake City, UT, 2018.

[8] UMass Lowell, "Service-Learning Integrated throughout the College of Engineering (SLICE)," [Online]. Available: https://www.uml.edu/engineering/slice/. [Accessed 20 June 2019].

[9] Federal Student Aid, "Work-Study Jobs," U.S. Department of Education, [Online]. Available: https://studentaid.ed.gov/sa/types/work-study. [Accessed 21 June 2019].

[10] Work Colleges Consortium, "What Is a Work College?," [Online]. Available: https://www.workcolleges.org/about/what-work-college. [Accessed 27 June 2019].

[11] NTi Audio, "XL2 Audio and Acoustic Analyzer," [Online]. Available: https://www.nti-audio.com/en/products/xl2-sound-level-meter. [Accessed 27 June 2019].

[12] P. Kosky, R. T. Balmer, W. D. Keat and G. Wise, Exploring Engineering: An Introduction to Engineering and Design, 4 ed., London: Academic Press, 2015, p. 403.

[13] HiFi Loudspeaker Design, "Calculate Skyline Diffusor with given frequencies," mh-audio.nl, [Online]. Available: http://mh-audio.nl/Acoustics/DiffusorCalculator.asp. [Accessed 4 April 2018].

[14] B. Gold, "Fiberglass, Rockwool, Polyester, Cotton, and Sheep Absorption Coefficients," [Online]. Available: http://www.bobgolds.com/AbsorptionCoefficients.htm. [Accessed 30 March 2019].

[15] National Hearing Conservation Association, "Decibel (Loudness) Comparison Chart," [Online]. Available: https://www.hearingconservation.org/assets/Decibel.pdf. [Accessed 30 March 2019].

[16] International Organization for Standardization, "ISO 3382-1:2009 Acoustics -- Measurement of Room Acoustic Parameters -- Part 1: Performance spaces," 2009.

[17] AFMG Technologies, "EASE - Enhanced Acoustic Simulator for Engineers," [Online]. Available: http://ease.afmg.eu/. [Accessed 30 March 2019].

[18] C. Boner and R. Coffeen, "Acoustics for Performance, Rehearsal and Practice Facilities: A Primer for Administrators and Faculties," National Association of Schools of Music, Reston, VA, 2000.