CLASSROOM ACOUSTICS IN THE POSTSECONDARY SETTING

A CASE FOR UNIVERSAL DESIGN

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Classroom Acoustics in the Postsecondary Setting: A Case for Universal Design

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The Case for Universal Design

Abstract

It is widely known that student hearing is key to academic success in classrooms where spoken communication comprises the majority of instruction. Hearing affects learning for students of all ages. This research aims to assess the acoustic conditions of classrooms in the postsecondary environment and to ascertain why these rooms lack in proper design. College students are not required by law or policy to disclose a disability to their institution of higher education. This can present significant learning challenges to students otherwise assimilated into collegiate life. Research was conducted to review the American National Standards Institute s12.60-2002 standards for classrooms, determine problematic classrooms at the University, measure the acoustics, then recommend improvements for design and proper communication. Recommendations were based on the Universal Design movement, which emphasizes good design for all. Results demonstrated that most classrooms at the University at Buffalo did not meet all ANSI standards. The poor acoustic performance clearly has an impact on many students, not just students with hearing impairments. Furthermore, a survey suggests that subjective student experiences point to other, non-acoustic hearing issues worth researching further.
Classroom Acoustics in the Postsecondary Setting: 

The Case for Universal Design

Introduction

Classrooms on any given college campus vary in degrees of obsolescence. Perhaps the lighting fixtures need replacing, or the lack of outlets throughout the room reflect a time before the need to charge batteries on several devices per person. Perhaps it is the fact that the classroom may not provide the technology to interface a personal electronic device with a projector. No matter what state a classroom may be in, there seems to be an apparent lack of process to ensure that classrooms have the proper acoustical features. The most basic and fundamental needs of the students attending that class are to hear and understand the instructor. The purpose of this research is to determine if University at Buffalo classrooms meet commonly agreed upon guidelines for acoustics, and if students' perceptions of their classroom experiences correspond with those objective acoustic measurements.

Research confirms a relationship between poor acoustics and academic achievement. As much as 60% of classroom activities involve students listening to and participating in spoken communications with the teacher and other students (Ehrlich & Engineer, 2003). Findings such as these are reason enough for postsecondary institutions to evaluate the acoustic conditions of their campus classrooms. Students who do not have full auditory access to spoken information in classrooms (from the teacher or from peers) do not learn at a normal rate. The literature demonstrates that even a slight hearing loss is often accompanied by delayed acquisition of vocabulary, reduced incidental learning, significant academic delay, and limited reading ability (Davis; Nelson, Soli, & Seltz, 2002). It is in the institutions’ best interest to increase the academic achievement of the students who attend classes. Measureable
outcomes should be the driving force behind the implementation of ideal acoustic conditions inside classrooms.

Students enrolling in college represent all levels of hearing ability. The population with the greatest need for good acoustics is that of Deaf and Hard-of Hearing Students (DHH). This population makes up about 2.5% of the entire student body at any college campus. Applying that figure to the University at Buffalo with a student body of 30,648 (Fall 2017), there are likely over 750 students that are DHH (Watson et al., 2007).

Watson, et al., (2007) defines three basic types of hearing loss:

**Conductive Hearing Loss (CHL)** is a reduction in hearing ability, even in the presence of a normally functioning cochlea. Affected are the ear canal, eardrum, and/or ossicular chain; the loss may be temporary or fluctuating in nature. Ear infections and ear wax impaction are two types of CHL.

**Sensorineural Hearing Loss (SNHL)** is decreased hearing ability due to disorders involving the cochlea and/or the auditory nervous system. This type of hearing loss is usually irreversible. Sensorineural hearing losses can be further divided into sensory and neural losses. A sensory hearing loss occurs when the damage to the auditory system is located within the cochlea. Noise-induced and age-related hearing losses are typically sensory in nature. A neural hearing loss occurs when the damage to the auditory system is beyond the level of the cochlea, ranging anywhere from the hearing nerve up to the brain. A tumor on the hearing nerve can be one cause of a neural hearing loss.

**Mixed hearing loss.** Mixed hearing losses occur when both conductive and sensorineural components are present. As in conductive hearing losses, the conductive component of a mixed hearing loss may be temporary and/or fluctuate.

While students with hearing impairments fall into one of the above categories for causes of hearing loss, all DHH students differ on the spectrum of severity of the impairment. For example, some students have slight hearing loss, or may be partially deaf in one ear. There are unique degrees of
hearing loss for students, thus current accommodations to assist with hearing must also vary in application.

**Literature Review**

Colleges and universities, while obligated to provide accommodations for students with disabilities—like partial deafness, do not require students to disclose their disability. Each year, approximately 414,000 DHH students are enrolled at postsecondary institutions. Only 8 percent of all students who report that they have a hearing impairment, have identified themselves to the institution as DHH (Lewis, 1994). In fact, there are increasing numbers of students that are attending colleges and universities with their normal hearing peers (Marschark, John, Sapere, & Sarchet, 2010). Even with modern interactive and collaborative learning environments, students who use accommodations may still not benefit as much as others having direct communications with other students and teachers (Foster, Long, & Snell, 1999).

It can be difficult to obtain demographic data on students with hearing impairments. The trend of towards an inclusive educational philosophy and the acknowledgement of diversity in the student body both welcomes students with disabilities but also encourages them to avoid disclosure of their limitations, particularly if they receive accommodations that could have an impact on the way others perceive and act towards them. The challenge for institutions of higher learning, then becomes how to accommodate for DHH students when their identity and numbers are unknown. Many students may also have undiagnosed hearing limitations. It is also worth noting that, despite the fact that a student has an assistive hearing device, (e.g. hearing aid or cochlear implant) they may otherwise have normal speech. He or she may still have hearing limitations that are not obvious.

Hearing aids and other assistive devices may not provide a complete solution. For example, hearing aids do not work well in noisy environments, outdoors, when multiple people are talking at once,
or when batteries or equipment fail. One hearing aid or cochlear implant may lead to an inability to locate the speaker within a group and limitations with hearing from one side (Watson et al., 2007). Since hearing devices do not always provide full compensation for hearing losses, fatigue from concentrating on understanding what is heard may have a significant impact on students’ ability to record notes (Heylighen, Vermeir, & Rychtáriková). Cochlear implants and hearing aids do not provide the same fidelity as normal speech. Thus, assistive hearing devices should not be viewed as a complete solution, but rather one component of a full strategy to support the students’ communication skills. Good classroom acoustics allow the devices to perform with maximum effectiveness.

Many accommodations are available for DHH students, including captioning for videos, note takers, assistive listening systems, interpreters, etc. Assistive listening systems (ALS) like audio loops, infrared, FM, and Wi-Fi based systems are required by the Americans with Disabilities Act for public assembly areas covered by the Act, including most large classrooms. They are designed to help increase signal level to people with diminished hearing. ALS are available for use in most large lecture halls at the University at Buffalo. However, these accommodations may be expensive, not always available, and often not desirable because they may lead to unwanted attention.

As noted above, hearing impairments are an invisible disability. Unlike blindness or a mobility impairment, DHH students are not easily identified by simple observation. At the collegiate level, almost

The overarching questions:

How do postsecondary classrooms present significant challenges to student hearing?

How are deaf and hard of hearing students affected?

What accommodations do they consider / use?

How do classrooms conform to ANSI/ASA and ICC standards?

Do objective measures corroborate subjective student experiences?

What other factors may influence student perception?

If not, are the standards viable?
all hard of hearing persons identify with those who hear, not those who are deaf (Watson et al., 2007).
Many can assimilate into a crowd of peers. As one student with partial deafness disclosed, "Throughout my time in high school and college, I’ve been able to manage my SSD (Single-Sided Deafness), by sitting up close with my good ear (left) towards the teacher/professor" (Appendix 2). When social inclusion is made a priority, students may accommodate themselves in the most unobtrusive manner possible in order to remain part of the larger group.

**Universal Design**

Good acoustics are fundamental to communication in buildings. They are an essential aspect of Universal Design, a movement that emphasizes design, that benefits all (Steinfeld & Maisel, 2012). Acoustic design contributes to awareness, understanding, and social integration, three key goals of Universal Design. Accommodations for individual students, like ALS and note takers, certainly benefit DHH students, but do not contribute as much to social integration as good acoustic design. Further, individual accommodations will work better when introduced in environments that have good acoustic characteristics. Reliance solely on assistive devices, whether they be personal hearing devices or room based systems like assistive listening systems can actually perpetuate a tolerance for poor acoustics. This can compound the problem for all other building users.

If a classroom environment presents hearing challenges to students of normal hearing, then there will obviously be far greater challenges for those who have hearing impairments. To minimize this, acoustics should be one of the main criteria when planning new classroom construction or existing classroom remodeling.

Students who self-identify as hard of hearing are NOT the sole beneficiaries of good acoustics. They are especially beneficial for the student whose hearing loss is undiagnosed or who chooses not to seek accommodations. If students can hear their instructors better, the instructors will not have to strain to speak loudly enough. Students who are not disabled may communicate better with their peers who are hard of hearing. They can work together on class projects as they broaden their understanding of disability and differences.
Other universal design strategies can be provided to enhance learning and education for everyone. For example, a public address system can provide improved communications between instructors and students. DHH students who have note takers can make those notes available to the entire class. Real time captioning, if projected or displayed at large size, will benefit all students in class. Captioned videos are easier to understand even for those that do not have hearing impairments, especially if people featured in the videos have strong accents or there is a lot of background noise in a scene. Captioning can be implemented in online learning with recorded lectures and in video conferencing, as well in traditional class formats. Implementing a full range of universal design strategies can lead to higher academic achievement, a reduced dropout rate, and increased grade point averages (GPA) for the whole student body (Nelson et al., 2002).

**Acoustic Factors**

Several acoustic factors may affect a listener in a classroom. Sound waves travel through air and permeate all spaces, including classroom interiors. Waves reflect from surfaces causing reverberation. These reflections may lose energy slowly, and deteriorate the quality of speech. Noise is defined as any unwanted sound that interferes with desired listening. Background noise and reverberation times in rooms are determined by many design characteristics, including the shape and size of the room, the materials of the room’s surfaces and walls, the degree to which sound can penetrate through openings, and the adjoining uses and noise levels. These acoustic characteristics affect the educational performance of

**Factors that affect a listener in a classroom:**

- **Reverberation Time**  reflected sounds that arrive to the listener at different times, thus beclouding the direct sound
- **Background noise**  any unwanted sound from inside or outside of the classroom
- **Mechanical Background Noise**  noise made from building systems (HVAC, lighting ballasts, etc.)
- **Impact Noise**  from floors above and/or walls surrounding the classroom (footsteps, etc.)
children with sensorineural hearing loss (SNHL) and children with normal hearing ability who have other auditory learning difficulties. These characteristics also have an impact on elementary school students without hearing or auditory learning limitations (Knecht, Nelson, Whitelaw, & Feth, 2002). Older students, however, tend to have an increased ability to “fill in the gaps” by reading lips or other developed compensatory abilities.

In an effort to improve classroom acoustics, the American National Standards Institute (ANSI) and the Acoustical Society of America (ASA) co-produced a set of guidelines to address the issue of acoustic design in classrooms. The resulting standard is the ANSI/ASA s12.60-2002. These standards are voluntary, though many states and municipalities have adopted these into an enforceable building code, including: New Hampshire State Board of Education, New Jersey School Construction Board, State of Connecticut, Ohio School Facility Commission, New York City Public Schools, and Arlington County (VA) Public Schools (King, 2010). ANSI also worked with the International Code Council (ICC) to address acoustics in classrooms in the larger context of A117.1-2017, Standard for Accessible and Usable Buildings and Facilities. Most state building codes reference an earlier version of this standard, although as time goes on, they will update their reference to the new version.

The obvious goal for leading edge universities would be for all classrooms to have acoustic performance that contributes to measurable academic successes for the student body. If this proves to raise overall student grade-point-averages, it would likely become a benchmark for other institutions in a competitive recruitment environment. Yet, many classrooms do not meet the ANSI/ASA and ICC standards (Knecht et al., 2002). There are many reasons for this, including initial sound intensity, excessive reverberation, and excessive background noise. Moreover, the standards may be difficult to meet in general practice due to the uncontrolled nature of building uses, difficulties in predicting acoustic performance without sophisticated tools, student traffic and talking noise, and the difficulty of completing accurate measurements in the field. They may also not address some issues that have an important impact on the auditory experience.
Universal Design Solution

The Goals of Universal Design (Steinfeld & Maisel, 2012) can assist in the assessment and design of model classrooms. If employed from the beginning of the design process, the end result should be that classrooms are supportive for DHH students, as well as their hearing peers. By contrast, individual accommodations would only benefit an individual.

The Goals and the associated approaches to ideal acoustic conditions may bring about increased improvements to classroom design. For example, classrooms designed with RT60 below 0.7 seconds will become better learning environments, especially for those with reduced hearing abilities. Background noise kept below 35dBA (55dBC), will aid with speech transmission and intelligibility. Students’ difficulty would decrease and instructor communication would increase. This means that less students are at risk for misunderstanding instruction. Even those who use hearing aids would benefit from amplified sound that has a higher signal-to-noise ratio and clearer audio.

Perception of sound is a complex phenomenon. Sounds may be perceived as loud, quiet, smooth, rough, etc. Perception may be different than the physical characteristics because human hearing is more sensitive near the middle of the hearing spectrum. Perceived loudness is frequency dependent, thus somewhat different perceptions of sounds will vary from person to person. Reverberation happens
when a sound or signal is reflected, causing a large number of reflections to build up and then decay as the sound is absorbed by the surfaces of objects in the space. This may enhance a sound, but can decrease intelligibility to the listener.

Psychology plays a role in perception as well. In *The Science of Musical Sound* (Pierce, 1992), the author makes reference to reverberation as having a “mellowing” effect when the sound is welcomed by the listener. Conversely, it may also have a “confusing” sound when unwanted or too powerful. Short reverberation time is always desired when attempting to comprehend speech.

In the study, “The Relationship Between Objective Indices and Subjective Assessments for the Quality of Soundscapes” (Rey Gozalo, Trujillo Carmona, Barrigón Morillas, Vilchez-Gómez, & Gómez Escobar, 2015), the author noted that the objective variable of sound intensity level is enriched with a subjective contribution. Annoyance, unpleasantness, and disturbance were terms used to characterize sounds that were deemed “loud” by participants. The same principle applies to background noise in classrooms. Listeners are distracted by chairs moving, paper shuffling, and hallway noise, etc.
Figure 1 The relationship between acoustical factors and contributing components of sound.

The properties of building materials and products such as drywall, ceramic tile, window glass, and doors affect the way sound is transmitted, reflected, or absorbed. All have either a Sound Transmission Class (STC) or an Outdoor-Indoor Transmission Classification (OITC) to predict the amount of transmission loss from the material makeup. For example, a single layer of 1/2” drywall on each side, wood studs has an STC of 33. The s12.60 calls for a minimum STC of 50, though this may be achieved by adding additional gypsum board and/or other treatments. Where a wall contains windows, doors, or penetrations for ventilation, the composite structure, including the window, doors, or penetrations, must conform to the OITC requirement. Compliance is evaluated by measuring the greatest outdoor one-hour average A-weighted sound level at the proposed location of the classroom or other learning space. The
OITC is then determined based on the sound level. For example, 70dBA measured outside would require a wall with windows to have an OITC of 43 (Ehrlich & Engineer, 2003). Additionally, all building materials are given a Noise Reduction Coefficient (NRC), with 1.0 = 100% absorption to calculate the absorptive properties of the material. For example, carpet with latex back on foam pad has an NRC of 0.35. Adding additional padding would increase the NRC amount, thus increasing the absorption.

Architects should consider these factors in the planning phase of a classroom design:

- furthest distance from instructor to student, speech level needed at that distance to ensure proper transmission of +15dBA over background noise,
- isolation between interior rooms and floors and from outside,
- building materials that can reflect and absorb sound to maximize acoustic performance,
- machines, plumbing, ducting, and electrical infrastructure noise that does not exceed 55dBC (Crandell & Smaldino, 2000).

**Methodology**

The goals of this research were:

1. to determine if postsecondary classrooms at the University at Buffalo meet ANSI/ASA/ICC guidelines, and
2. determine how many and to what extent are deficient
3. investigate whether the objective measurements correlate with the subjective student experiences.
4. Identify what could be done to improve acoustic performance of classrooms that are deficient.
5. Investigate whether achieving the guidelines is feasible in higher education.
Room Selection Process

The research included a series of case studies of rooms at the University that were identified as problematic acoustic environments. A student survey and an interview were used to identify a set of classrooms to study. Several types of rooms were identified for in depth study: large lecture halls, seminar rooms, and other core learning spaces in various buildings. Some rooms had acoustic absorption panels and other acoustic treatment installed after their initial construction. Other rooms were designed and built with modern features and some attention to acoustic character. Still, other rooms fell at various points along the spectrums of obsolescence, technology, and disrepair. All contributed to a representation of the variety of classrooms that a student experiences in collegiate life at UB.

Survey Objectives

Which classrooms present hearing challenges for students?
To what extent did students have difficulty hearing their professors?
Did students feel that there is a relationship between hearing and learning?

Survey

A sample of convenience was recruited to conduct a survey on student experiences in UB classrooms. Undergraduate college students were recruited from one large class to answer a survey questionnaire. The survey was conceived with the intention to learn of students’ subjective experiences in the classrooms, as they related to hearing. The objectives were: 1) to identify classrooms that had particularly challenging acoustics, 2) ascertain whether current students were aware of acoustic issues, regardless of their understanding of acoustics, and 3) learn whether students felt there was a relationship between hearing and learning. The survey was designed with the assumption that these respondents may not have ever considered acoustics of their classrooms before. Approval from the Institutional Review Board (IRB) and the class instructor was obtained before survey distribution.
The survey collected qualitative responses; the respondents’ subjective experiences of classrooms at the University. Questions were fill-in-the-blank or ratings-based. The student respondents helped identify the most problematic classrooms for further study, particularly the first classrooms to assess. To eliminate any interviewer bias, the author was not present at any time during the survey process. Student respondents were able to take as much time as needed to reflect on their experiences without a person in the room, waiting for a response. (Appendix 1)

Interview with a DHH Student

To understand the point-of-view of a student with a hearing disability, the researcher interviewed a current student with Single Sided Deafness (SSD). The student was recruited through an informal process of referral from a mutual acquaintance. The researcher and the interviewee had no relationship outside of this research. This interview was conducted via email at the interviewee’s request. The student was asked about his subjective experiences, his feelings, his disclosure to the University, how he was able to overcome barriers, and what he would like to see from the University in terms of accommodations. (Appendix 2) Responses from this interview specified three additional classrooms believed to have adverse listening conditions. The responses revealed the student had not disclosed his impairment to the University. His reasons for this were not entirely clear, but are in line with general knowledge about the hesitancy that people with disabilities have in disclosing their limitations.

The author also sent an informal inquiry by email to school administrators, health and safety officials, facilities professionals, and faculty members, asking that they identify any classrooms that have been experienced or reported as having poor acoustic conditions. This provided an additional list of six problematic classrooms.

Acoustic Measurements

The classrooms identified were evaluated for compliance with the ANSI/ASA standard for general classroom acoustic performance and the ICC/ANSI standard that defines appropriate classroom acoustics for a population with disabilities. Contained within the ANSI/ASA s12.60 standard are
processes and specified instruments needed to measure acoustic conditions. This included using an ANSI Type 2 Sound Pressure Level Meter for assessing the background noise, both from the human hearing standpoint (dBA), and the “true” acoustic nature of the rooms (dBC). Additionally, an omnidirectional condenser measurement microphone was used in conjunction with Room EQ Wizard software to calculate the reverberation time. The ANSI s12.60 measurement guidelines were followed in all classrooms. All measurements were logged and represented graphically to compare each characteristic with that of the standards. Note that smaller classrooms have somewhat different acoustic standards than the larger lecture halls, etc. Rooms that presented inconsistent data, or were excluded for other reasons, (e.g. lack of access) have been omitted from the findings.

The analyzed results were then averaged and compared with all classrooms measured. The classroom with the lowest reverberation time was selected for the administration of another survey. This survey examined the relationship between the objective measurements and the subjective experiences of students in those classrooms.

**Post-Measurement Survey**

**Figure. 2** shows an example of the data from one classroom.

The above graph represents the reverberation time (RT60) measured at Knox Hall, Room 20, at The State University of New York at Buffalo in October 2017. The vertical axis is the time in seconds (sec). The horizontal plane is frequency, measured in Hertz (Hz). The blue vertical lines are the three frequencies referenced for typical speech bands by the ANSI/ASA s12.60. The orange horizontal line represents the ANSI/ASA s12.60 standard for RT60. The purple horizontal line is the actual measurement of RT60 in Knox 20, at one location. Note that the RT60 is consistently above the recommended levels at the three frequency locations.
Diefendorf Hall, room 146 was found to have the best acoustical conditions compared to all other classrooms measured in this study. The classroom is a mid-sized lecture hall with raked seating. One class of 73 students was surveyed to determine the perceived acoustic experiences. The survey was announced at the beginning of class, so that the students were able to think about sounds that affected them during the period. Near the end of class, the surveys were distributed, then collected. Questions addressed perceptions, experiences, and the overall quality of the sound in the room. Other classrooms could have been selected for the survey but no instructor was willing to let the author take time in a class to administer the survey.

Findings

Initial Survey Results

One objective of the initial student survey was to identify troublesome classrooms. These assessments were purely subjective, as were most responses from the survey. Some notable analysis was:

- 48% of respondents indicated that they occasionally experiences hearing difficulties in the classroom.
- 70% of respondents did not consider themselves hard-of-hearing.
- 52% of respondents believed that an installed sound system would help themselves and other hear better in class.

Selected qualitative responses:

- "We should either invest in better microphones or better speakers in certain larger lecture halls."
- "Squeaky chairs in Knox often add to frequent/loud noises making it hard to focus most of the time."
- "Ambient noise within the room can be deafening even if theirs (sic) is already a loudspeaker system. Even lubricating chairs to make them silent would help and have any sort of sound dampening."

"
“In the classrooms on the 4th floor of Fronzcak you can constantly hear what is going on in the classroom next door.”

“In the basement of Jacobs you can constantly hear the heating/ventilation system.”

**Interview with a DHH Student Results**

The student interview with a partially-deaf student resulted in the following notable responses:

- **Do you have a diagnosed hearing impairment?**
  Yes, single sided deafness (SSD)

- **If Yes, Is the University aware of this?**
  No, I don’t mention it to my professors because, most of the time, I am in a small classroom with professors that speak loud and clear. I am also uncomfortable telling people about my disability. I sit towards the front right which allocates my good ear to do most of the hearing. I’m deaf in my right ear.

- **If you have difficulty hearing an instructor, what do you think are the reasons?**
  This semester, I have two extremely soft spoken professors. One is in a small classroom and one uses a microphone in a lecture hall. I struggle to hear these professors and often miss words that are mumbled or not spoken directly towards the students. This extra effort causes me to dose off in these classes.

- **Do you feel that the University does a good job at modernizing classrooms and lecture halls to reflect the needs of current students?**
  Not in particular. I haven’t seen any improvement throughout the time I’ve been enrolled. The lecture halls seem like they try to improve the acoustics, somewhat.

- **How so?**
  The teacher sometimes uses a microphone, but even then it doesn’t have enough volume.

The student survey, student interview, and respondent emails from University Professionals identified 11 classrooms to measure:

- Diefendorf Hall 146, 147
- Hayes Hall 327, 328
- Natural Sciences Complex 201, 225
- Knox Hall 104, 20, 110
- Norton Hall 112
- Fronzcak Hall 422

**Acoustic Measurement Results**

Classroom acoustics were measured and results referenced the specifications of the ANSI/ASA s12.60 Guidelines: RT60 <0.7 seconds, <35dBA, and <55dBC, (see Appendix 3).
As detailed above in Figure 3, the reverberation times vary widely amongst measured classrooms.

As revealed in Figure 4, the majority of rooms do comply with the background noise requirements, in terms of simulated hearing response (A-weighted, expressed in dBA). However, those
same rooms are at or above the recommended guidelines for mechanical background noise (C-weighted and expressed in dBC). This may be a significant factor in respondents’ claims that rooms are problematic. Rooms that have excessively loud HVAC, lighting, projection, or other system noises can obscure speech intelligibility and create distraction.

**Post-Measurement Survey Results**

Results from the survey conducted April 2018, do suggest a correlation between room acoustics and student experiences. There were 9 classrooms researched for this project, and Diefendorf 146 produced background noise and reverberation times closest to recommended standards by ANSI/ASA

### Results of Classroom Acoustic Measurements

- 90% did not meet guidelines for RT60 of <7 seconds for large classrooms.
- 44% did not meet guidelines for A Weighted Sound Pressure Level <35dBA for background noise.
- 77% did not meet guidelines for C Weighted Sound Pressure Level <55dBC for mechanical background noise.

A majority of students do not have hearing issues in this class but the findings demonstrate there are an unexpectedly large number who do. Students often attribute any issues to other students and distracting behavior, as revealed in the short answer responses.

The survey results showed that 1% strongly agree that they have hearing impairment, while 4% agree that they have a hearing impairment. These responses closely resemble the research statistics presented by (Watson et al., 2007), which found that 2.5% of the entire student body on U.S. college campuses have a hearing impairment.

Yet, 37% of the students responded that they sometimes have difficulty hearing the instructor during class. 4% often have difficulty hearing the instructor. These responses point to other, perhaps non-acoustic issues that are adversely affecting the students. 34% agree and 4% strongly agree that they are distracted by other noise. Subjective responses, such as “noisy chairs, people talking”, were common
amongst students. Specifically, 21 of 25 respondents explained that other students talking and/or other
to noise inside the classroom was the cause for distraction. While distraction does not necessarily mean that
there is a hearing issue as a result of poor acoustics, it does indicate that there is a relationship between
hearing and distraction, and that these other factors should be considered when assessing classroom
conditions. But, the acoustics of the classroom can contribute to the intensity of the distracting sounds.
The longer reverberation times at the higher frequencies found in the measurement survey may amplify
sounds like high pitched voices, whispering and squeaky chairs. See Appendix 4 for complete survey
results.

Discussion

A study of the viability of the ANSI/ASA/ICC guidelines is needed. Most classrooms at this
University do not meet the guidelines, so perhaps the guidelines are too strict? Since the guidelines do not
specifically address postsecondary classrooms, perhaps there is a need for separate guidelines for these
institutions.

The need for a Universal Design approach for corrective measures is substantial. Universal
Design can address the social factors, as well as the understanding of the most basic factors in classroom
acoustics. Students must adapt to the ever-present challenges in the diverse classroom environments,
obtain accommodations if they are qualified to receive them, or communicating the problems to the
University.

Many issues for DHH students are compounded by the “invisibility” of their disability. They need
do not disclose their disability to the University, but this only makes their individual problems much more
difficult to overcome. Without research like this, university officials may not know how serious the acoustic
problems are in their classrooms. A student’s success depends on many factors, some of which may need
to overlap with the institutions’ policies and accommodations, DHH students prefer to assimilate with their
non-DHH student peers (Cawthon, Schoffstall, & Garberoglio, 2014). However, under the Americans with
Disabilities Act, (ADA) of 1990, unless students disclose their identities to an institution through an Office
of Student Services, there is no formal system for identifying individuals on a campus or in a training
program with a disability. This onus is on the student to provide any personal information.
Because of this, it is relatively safe to assume that there are underreported impaired students taking classes without the assistance needed to comprehend at the same level as their non-disabled peers. A Universal Design approach to the design of new buildings would help identified and non-identified DHH students succeed in the postsecondary educational environment by raising the overall acoustic quality.

Maintenance may play an important role in acoustic quality. How often are rooms monitored and/or maintained for appropriate environmental conditions? If HVAC systems were kept to minimal operating noise levels, could this help with background noise issues? The University may need to implement a preventative maintenance schedule to address this question.

Is the classroom technology (sound system) operating properly? Do the instructors receive adequate training on the operation and troubleshooting of these systems? Would this alleviate some other issues? The University may need to explore how to inform instructors about operating sound systems properly.

Though many University at Buffalo classrooms do not meet the guidelines, it does seem that the issue of acoustics was not of urgent matter at time of the study. It may simply be that not enough complaints are made to warrant giving this issue more attention. Perhaps more evidence supporting student achievement may bring the institution to the table for improving acoustic conditions.

Conclusions

The research identified acoustic deficiencies in many University at Buffalo classrooms. This indicates that acoustics have not received priority attention in the design and renovation of classrooms. While the research does not directly tie acoustics to learning performance, the literature on this subject indicates that there is a relationship – poor acoustics impedes learning.

The measured rooms were found to have longer RT60 from 1000Hz and below, which is where the majority of speech resides. Rooms with these lengthy times are likely to be problematic for many students, regardless of hearing ability. Background noise levels in these rooms only exceeded the recommended guidelines modestly, while the dBC measurements of mechanical background noise showed significantly higher levels, and thus are likely problematic.
Previous studies have shown in many colleges and universities worldwide, many classrooms do not meet the ANSI/ASA and ICC standards (Knecht et al., 2002). There are many reasons for this, including initial sound intensity, excessive reverberation, and excessive background noise. Do ANSI/ASA s12.60 requirements increase difficulty for measurement accuracy if there are so many contributing components? Is there a useful tool that could simplify the measurement process? Is there computer software that could meet the basic instrument requirements set forth by the s12.60? To answer these questions, some new products may need to be tested and verified by ANSI before approval for analysis.

Additional results of this research demonstrated a relationship between subjective student experiences and objective measurements, as none of the classrooms met the ANSI/ASA or ANSI/ICC guidelines for classroom acoustics for either reverberation time or background noise. This indicates a need for acoustic design that address the fundamental issues of poor acoustics. It should be noted there are many additional factors that affect student hearing, outside the scope of the guidelines. These include: distracting behaviors, sight lines, malfunctioning technology, and social pressures to fit in with peers. But, these are issues that have little to do with acoustic design.

Further research would identify a room on campus that does meet the recommended guidelines, or at least performs at a significantly improved level. Surveying students in such a room and in some of the lower performing rooms would be useful to identify whether there is a relationship between acoustic conditions and perceptions. It is likely that the student experience would be more positive in the room that met the standards and worse in rooms that performed worse than Diefendorf 146. Such a finding would lend support to increasing the priority given to acoustics in classrooms. It would also provide compelling evidence that interventions can make a difference.

Many interventions could be implemented to bring these problematic rooms into compliance with these standards. One approach may be to devise a checklist for designers and University Facilities staff in order to help facilitate corrective measures. Another would be to launch an inclusive design / build demonstration project where a before and after acoustical assessment is conducted. This project, if successful, could serve as a model for interventions in other classrooms. If interventions prove
unsuccessful, there may be a need to reassess the achievability of the standards and develop standards that are more feasible.

A larger study, incorporating several Universities may yield better data to understand just how widespread non-conformity is. Maybe there are similar institutions that have taken steps to address these issues? If so, then maybe there are already good practices that could be adopted to streamline the assessment and intervention process.

**Design Recommendations**

There are many ways to improve acoustic performance in classrooms like those studied. This author proposes the following, but in no way endorses any products:

**Figure 5.** Cloth-covered foam acoustic absorption panels used to reduce sound reflections. Placing these panels on the face of reflective wall surfaces like painted concrete block walls can help increase speech intelligibility. These come in various shapes and thicknesses, based on application. These panels are measured by their noise reduction coefficient, the effectiveness of their absorption properties.

**Figure 5** Sound absorption Panels at University at Buffalo.

E. Burlingame

Figure 6 shows deflector panels, suspended from the ceiling. These are employed to direct the incident sound to the listeners seated in the lecture hall. These panels help disperse the sound of speakers to the desired listening locations in the classroom. Panels are made of a laminate wood to be highly reflective, while the top side (not shown) is lined with rock-wool fiber for ceiling reflection reduction. Also in Figure 6 are diffuser panels, attached to the walls. Panels are made of wood, cut into uneven lengths and spaced with cloth-covered porous foam. These provide uneven surfaces to scatter sound waves and reduce room resonances. Room resonance is the characteristic “tone” of the room, usually a that remains long after the incident sound loses energy. This characteristic is caused by parallel walls and highly reflective surfaces. Diffusers break up these resonant low-pitched sounds.

Figure 6 Reflective ceiling panels and diffuser wall panels at University at Buffalo.
Figure 7 shows suspended, fabric wrapped panels that absorb sound at the surface, as well as the reflected sound from the ceiling. Panels are made of open-celled foam and designed to reduce reverberation. This option works effectively in large rooms with high ceilings, such as gymnasiums, auditoriums, hallways, and lecture halls. They are not practical for ceilings below 12 feet high.

Figure 7

Absorptive ceiling “clouds”
http://www.architectureanddesign.com.au

Figure 8 shows suspended drop ceiling tiles made from insulation foam. They are employed to lower a high ceiling and increase speech privacy and speech intelligibility. Reflections are significantly reduced, and panels also serve to increase thermal insulation, as well as conceal infrastructure (conduit, plumbing, heating & cooling ducts). This application is highly effective for ceilings under 24 feet high. Panels are best used in classrooms, offices, businesses, and other environments where speech intelligibility is needed. Units are easily damaged and should not be utilized in spaces where physical contact may happen.

Insulated Ceiling Tile
www.archtoolbox.com

The diagram in Figure 9 illustrates duct silencers (attenuators). These foam inserts reduce noise from heating, ventilation, and air conditioning units, lowering the background noise in a classroom. These inserts may be purchased and installed if the HVAC unit is in close proximity to the classroom, or if there are too few vents to lower the airflow. These items can be expensive when considering the application to an entire building, but can remedy a noisy situation with relatively little effort. Inserts must be installed by an HVAC-certified technician. Other options, such as regular maintenance of ductwork and HVAC systems may help to reduce noise by identifying noisy components, such as loose drive belts and vibrating grates.

**Figure 9**

![Air Duct Supply/Return Attenuators](https://cdn1.npcdn.net/userfiles/18888/image/duct_silencer_application_02.jpg)

Figure 10 shows acoustic underlayment, often used to reduce impact noise. This product is commonly utilized for renovation, or other remodelling work, after the initial design phase. If impact noise were to be addressed early in the design process, the need for these expensive products would likely be less or not need at all. Product is highly effective in reducing noise from foot traffic and other impacting actions. It can benefit the existing floor level, in addition to the room(s) below. Product is normally made of rubber and is placed between the sub floor and the carpet. Adding acoustic underlayment further reduces impacts.

Figure 10

Acoustical Underlayment and Mat
www.diynetwork.com

**Figure 11** shows triple-paned windows, which serve to reduce unwanted background noise from outside the classroom, such as traffic, construction noise, airplane noise, and other outdoor noises. Glass panes are sealed together for the outer layer. Next is an airgap to trap any sounds that have "leaked" through. The inside pane is the treated with a chemical coating that allows flexibility, yet keeps sound out. Though this glass is effective in noise reduction, it is never 100% effective. For example, building vibrations from construction equipment or other heavy machinery are not attenuated with these windows. Any low frequency sound does have potential to enter the classroom.

**Figure 11**

Triple-paned Windows for Outside Noise Reduction

http://www.viracon.com

Appendix 1

Are you a student currently enrolled at The University at Buffalo?

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
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<td>yes</td>
<td>100.0%</td>
<td>25</td>
</tr>
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<td>no</td>
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<td>0</td>
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<tr>
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<td>25</td>
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<tr>
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Are you a

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</tr>
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<tr>
<td>Graduate Student</td>
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<tr>
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Which campuses do you attend classes?

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</tr>
<tr>
<td>South Campus</td>
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</tr>
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<td>Downtown Medical Campus</td>
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<td>0</td>
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<td>Online</td>
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<td>0</td>
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<tr>
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### What types of classrooms do you attend?

<table>
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<th>Response Percent</th>
<th>Response Count</th>
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</thead>
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<td>Lecture Hall</td>
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</tr>
<tr>
<td>Lab</td>
<td>60.0%</td>
<td>9</td>
</tr>
<tr>
<td>Seminar</td>
<td>73.3%</td>
<td>11</td>
</tr>
<tr>
<td>Studio</td>
<td>13.3%</td>
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<tr>
<td>Other (please specify)</td>
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<td>0</td>
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#### answered question: 15

#### skipped question: 10

### About how many hours per week do you spend inside of a classroom?

<table>
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<th>Response Percent</th>
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</tr>
<tr>
<td>4-6</td>
<td>4.0%</td>
<td>1</td>
</tr>
<tr>
<td>7-9</td>
<td>8.0%</td>
<td>2</td>
</tr>
<tr>
<td>10-12</td>
<td>20.0%</td>
<td>5</td>
</tr>
<tr>
<td>more than 12</td>
<td>68.0%</td>
<td>17</td>
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</tbody>
</table>

#### answered question: 25

#### skipped question: 0

### Have you ever experienced difficulty hearing the instructor in class?

<table>
<thead>
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<th>Response Percent</th>
<th>Response Count</th>
</tr>
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</tr>
<tr>
<td>Rarely</td>
<td>32.0%</td>
<td>8</td>
</tr>
<tr>
<td>Occasionally</td>
<td>48.0%</td>
<td>12</td>
</tr>
<tr>
<td>Often</td>
<td>16.0%</td>
<td>4</td>
</tr>
<tr>
<td>Always</td>
<td>0.0%</td>
<td>0</td>
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</table>

#### answered question: 25

#### skipped question: 0
Have you ever experienced difficulty hearing the instructor in class?

If so, why do you believe you had difficulty hearing the instructor?

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>No. Definitely Not This</th>
<th>I Don’t Think So</th>
<th>N/A</th>
<th>I Think So</th>
<th>Yes! It Was This</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>The instructor is a &quot;low talker&quot;</td>
<td>4</td>
<td>8</td>
<td>1</td>
<td>9</td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>The room is too big.</td>
<td>3</td>
<td>9</td>
<td>2</td>
<td>7</td>
<td>3</td>
<td>24</td>
</tr>
<tr>
<td>I don’t sit close enough.</td>
<td>11</td>
<td>4</td>
<td>2</td>
<td>7</td>
<td>0</td>
<td>24</td>
</tr>
<tr>
<td>The heater / air conditioning noise interferes with the instructor’s voice.</td>
<td>8</td>
<td>2</td>
<td>2</td>
<td>7</td>
<td>5</td>
<td>24</td>
</tr>
<tr>
<td>There is excessive noise from people OUTSIDE of the classroom.</td>
<td>10</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td>There is excessive noise from people INSIDE of the classroom.</td>
<td>4</td>
<td>7</td>
<td>2</td>
<td>9</td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>I consider myself hard-of-hearing.</td>
<td>17</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>23</td>
</tr>
<tr>
<td>I usually sit near the back of the classroom.</td>
<td>12</td>
<td>6</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>24</td>
</tr>
<tr>
<td>Other (please specify)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

answered question | 24

skipped question | 1
I believe that if _________ it would help myself and others hear the instructor better in class.
Are you able to specifically identify any classrooms that should be studied, regarding hearing issues? Please name building and room number, if possible.

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>Response Count</th>
</tr>
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<tbody>
<tr>
<td>answered question</td>
<td>13</td>
</tr>
<tr>
<td>skipped question</td>
<td>12</td>
</tr>
</tbody>
</table>

NSC 225
Cooke 121
Bonner hall classrooms are very loud
No
NSC 225
All of them have them installed
The lecture halls in Knox, especially when the teachers microphone isn't working correctly
Not any specific ones.
Knox 20
I do not remember the room number specifically
Hochstetter 114, Norton 102 and 104
The Filmore one
Jacobs B32
Fronzcak (4th floor classrooms)

Are there any additional comments that you feel are important to this topic?

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>answered question</td>
<td>8</td>
</tr>
<tr>
<td>skipped question</td>
<td>17</td>
</tr>
</tbody>
</table>

Squeaky chairs in Knox often add to frequent/loud noises making it hard to focus most of the time.

no thank you
No
Thank you!!
We should either invest in better microphones or better speakers in certain larger lecture halls.
No, this survey sums it up decently.
Ambient noise within the room can be deafening even if theirs is already a loudspeaker system. Even lubricating chairs to make them silent would help.. and have any sort of sound dampening
In the basement of Jacobs you can constantly hear the heating/ventilation system.
In the classrooms on the 4th floor of Fronzcak you can constantly hear what is going on in the classroom next door.
Appendix 2
An Interview with a Student that has Partial Deafness

Are you a student currently enrolled at this University?
Yes

Are you an Undergraduate Student?
Yes, senior year.

Which campus(es) do you attend classes?
North

What types of classrooms do you attend?
Lecture Hall, Seminar, Lab, Studio, Other?
This Semester: 3 classrooms and one lecture hall

About how many hours per week do you spend inside of a classroom? (approximate)
10-11 hours

Have you ever experienced difficulty hearing the instructor in class?
Absolutely

Do you have a diagnosed hearing impairment?
Yes, Single Sided Deafness (SSD)

If Yes, Is the University aware of this?
No, I don’t mention it to my professors because, most of the time, I am in a small classroom with professors that speak loud and clear. I am also uncomfortable telling people about my disability.

Do you require any accommodations to assist you?
If so, what are they?
I sit towards the front right which allocates my good ear to do most of the hearing. I’m deaf in my right ear.

If you have difficulty hearing an instructor, what do you think are the reasons?
This semester, I have two extremely soft spoken professors. One is in a small classroom and one uses a microphone in a lecture hall. I struggle to hear these professors and often miss words that are mumbled or not spoken directly towards the students. This extra effort causes me to dose off in these classes.

Do you feel that hearing most of what the instructor says is important to your understanding of the course subject material?
Yes, I am often lost in my lecture hall because I cannot stand how monotone and quiet my professor is. Monotone professors cause me to become sidetracked; professors who have passion in their voices and express dynamics with their speech are the ones I respond to.

Do you feel that other students in the classroom have a difficult time hearing the instructor most of the time?
I’d imagine so because I’ve never had professors as quiet as these two.

What do you feel would help yourself and others hear the instructor better in class?
Throughout my time in high school and college, I’ve been able to manage my SSD by sitting up close with my good ear (left) towards the teacher/professor. I’ve researched hearing devices to help me cope with my disability on a daily basis. I’ve become fascinated with the Phonak Cros 2 (among other devices) to deal with my SSD. I scheduled a hearing exam for myself and will look into investing in one soon.

Do you feel that the University cares whether students can hear properly inside all classrooms?
I’m not sure, I’ve never opened up to the university about my disability because, like I said, it hasn’t been too much of an issue until this semester. I’m not sure how the university would help either.

Do you feel the University does a good job at modernizing classrooms and lecture halls to reflect the needs of current students?
Not in particular, I haven’t seen any improvement throughout the time I’ve been enrolled.

The lecture halls seem like they try to modify the acoustics somewhat.
How so?

The teacher sometimes uses a microphone, but even then it doesn’t have enough volume.

Do you believe that you are at a disadvantage to others in classrooms when you cannot hear properly?

Definitely.

Can you explain?

I know that I’ve missed out on notes. Sometimes, I’ll see a test question and wonder if I’ve missed something said in class, or in the reading assignments. This is awful when I’m second guessing myself during tests. I’ve also been embarrassed a few times when the teacher calls on me to answer a question, and I hadn’t really heard what they said.

Are you able to specifically identify any classrooms that should be studied, regarding hearing issues?

No

Why not?

(Laughs) I know one of the rooms is in the NSC [Natural Sciences Complex], and one on the fourth floor of Fronczak [Hall]. I just don’t know the room numbers. Sorry.

That’s fine. Is there anything else you would like to mention that was not addressed here?

This interview made me realize that I should talk to my quiet professors about my disability. I have trouble talking openly about it, however. While I do believe my new hearing device will help me, I’ve come to realize that I should have told them from the beginning.
Appendix 3

Reverberation Times and Background Noise of all researched rooms.

<table>
<thead>
<tr>
<th>Room</th>
<th>P1 250</th>
<th>P2 250</th>
<th>P3 250</th>
<th>P4 250</th>
<th>P5 250</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diefendorf 146</td>
<td>0.84</td>
<td>1.18</td>
<td>1.3</td>
<td>1.03</td>
<td>1.53</td>
<td>1.06</td>
</tr>
<tr>
<td>Diefendorf 147</td>
<td>0.84</td>
<td>1.18</td>
<td>1.34</td>
<td>0.99</td>
<td>1.37</td>
<td>1.21</td>
</tr>
<tr>
<td>Hayes 327</td>
<td>0.84</td>
<td>1.3</td>
<td>1.49</td>
<td>1.72</td>
<td>0.92</td>
<td>1.18</td>
</tr>
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<td>Hayes 328</td>
<td>0.84</td>
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<td>1.91</td>
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<tr>
<td>NSC 225</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.976</td>
</tr>
<tr>
<td>Knox 20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.967</td>
</tr>
<tr>
<td>Knox 104</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.926</td>
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<td>Fronszack 422</td>
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<tr>
<td>Average</td>
<td>0.84</td>
<td>1.214</td>
<td>1.32</td>
<td>1.01</td>
<td>1.534</td>
<td>1.162</td>
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<td>P1 500</td>
<td>0.69</td>
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<td>P2 500</td>
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<td>1.37</td>
<td>1.26</td>
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<td>P3 500</td>
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<td>1.79</td>
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<td>P5 500</td>
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<td>1.83</td>
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<td>Average</td>
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<td>1.39</td>
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<td>0.76</td>
<td>0.95</td>
<td>1.34</td>
<td>1.22</td>
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<td>1.6</td>
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<td>0.92</td>
<td>1.34</td>
<td>1.18</td>
<td>1.64</td>
<td>1.6</td>
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<td>P3 1000</td>
<td>0.76</td>
<td>0.95</td>
<td>1.37</td>
<td>1.6</td>
<td>1.95</td>
<td>1.05</td>
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<td>P4 1000</td>
<td>0.76</td>
<td>0.8</td>
<td>1.45</td>
<td>1.76</td>
<td>1.06</td>
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<td>P5 1000</td>
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<td>1.41</td>
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<tr>
<td>Average</td>
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<td>1.34</td>
<td>1.2</td>
<td>1.464</td>
<td>1.632</td>
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<tr>
<td>P1 2000</td>
<td>0.76</td>
<td>0.84</td>
<td>0.99</td>
<td>0.88</td>
<td>1.49</td>
<td>1.45</td>
</tr>
<tr>
<td>P2 2000</td>
<td>0.76</td>
<td>0.88</td>
<td>0.99</td>
<td>0.88</td>
<td>1.49</td>
<td>1.45</td>
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<td>P3 2000</td>
<td>0.76</td>
<td>0.84</td>
<td>1.41</td>
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<td>0.94</td>
<td>0.95</td>
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<tr>
<td>P4 2000</td>
<td>0.76</td>
<td>0.84</td>
<td>1.53</td>
<td>1.45</td>
<td>0.91</td>
<td>0.92</td>
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<tr>
<td>P5 2000</td>
<td>0.76</td>
<td>0.88</td>
<td>1.56</td>
<td>1.49</td>
<td>0.91</td>
<td>0.92</td>
</tr>
<tr>
<td>Average</td>
<td>0.76</td>
<td>0.856</td>
<td>0.99</td>
<td>0.88</td>
<td>1.496</td>
<td>1.458</td>
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<tr>
<td>P1 4000</td>
<td>0.64</td>
<td>0.69</td>
<td>0.92</td>
<td>0.84</td>
<td>1.11</td>
<td>1.07</td>
</tr>
<tr>
<td>P2 4000</td>
<td>0.64</td>
<td>0.69</td>
<td>0.92</td>
<td>0.84</td>
<td>1.11</td>
<td>1.07</td>
</tr>
<tr>
<td>P3 4000</td>
<td>0.61</td>
<td>0.69</td>
<td>1.15</td>
<td>1.15</td>
<td>0.66</td>
<td>0.73</td>
</tr>
<tr>
<td>P4 4000</td>
<td>0.65</td>
<td>0.61</td>
<td>1.15</td>
<td>1.11</td>
<td>0.76</td>
<td>0.76</td>
</tr>
<tr>
<td>P5 4000</td>
<td>0.65</td>
<td>0.73</td>
<td>1.11</td>
<td>1.07</td>
<td>0.76</td>
<td>0.73</td>
</tr>
<tr>
<td>Average</td>
<td>0.626</td>
<td>0.682</td>
<td>0.92</td>
<td>0.84</td>
<td>1.126</td>
<td>1.094</td>
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</table>

Total Average Rt60: 0.7428

SPL all rooms

<table>
<thead>
<tr>
<th>Room</th>
<th>Diefendorf 146</th>
<th>Diefendorf 147</th>
<th>Hayes 327</th>
<th>Hayes 328</th>
<th>NSC 201</th>
<th>NSC 225</th>
<th>Knox 20</th>
<th>Knox 104</th>
<th>Knox 110</th>
<th>Norton 112</th>
<th>Fronszack 422</th>
</tr>
</thead>
<tbody>
<tr>
<td>dBA Slow</td>
<td>30.1</td>
<td>27.85</td>
<td>45.5</td>
<td>36.9</td>
<td>37.5</td>
<td>33.3</td>
<td>34.9</td>
<td>31.1</td>
<td>44.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>dBC Slow</td>
<td>55.4</td>
<td>55.86</td>
<td>61</td>
<td>61</td>
<td>58.3</td>
<td>73.6</td>
<td>63.8</td>
<td>62.6</td>
<td>59.2</td>
<td>67.8</td>
<td></td>
</tr>
<tr>
<td>AVG</td>
<td>42.75</td>
<td>41.855</td>
<td>53.25</td>
<td>47.6</td>
<td>55.5</td>
<td>48.55</td>
<td>48.75</td>
<td>45.15</td>
<td>56.25</td>
<td></td>
<td></td>
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</tbody>
</table>

Does the room meet ANSI/ASA s12.60 standards?

<table>
<thead>
<tr>
<th>Room</th>
<th>s12.60 RT60 y/n</th>
<th>s12.60 dBA y/n</th>
<th>s12.60 dBC y/n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diefendorf 146</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Diefendorf 147</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Hayes 327</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Hayes 328</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>NSC 201</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>NSC 225</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Knox 20</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Knox 104</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Knox 110</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Norton 112</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Fronszack 422</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
</tbody>
</table>

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Appendix 4

Survey of students in Diefendorf Hall Room 146

2. How often do you have difficulties hearing the instructor?

<table>
<thead>
<tr>
<th>1 Always □</th>
<th>2 Often □</th>
<th>3 Sometimes □</th>
<th>4 Rarely □</th>
<th>5 Never □</th>
</tr>
</thead>
</table>

Mean Response: 3.73

3. The instructor doesn’t speak loud enough.

<table>
<thead>
<tr>
<th>1 Strongly Agree □</th>
<th>2 Agree □</th>
<th>3 Neither Agree or Disagree □</th>
<th>4 Disagree □</th>
<th>5 Strongly Disagree □</th>
</tr>
</thead>
</table>

Mean Response: 2.9
4. The instructor doesn’t speak clearly enough.

Mean Response: 2.99

5. The instructor has a strong accent.

Mean Response: 3.15
6. The instructor is too far away.

<table>
<thead>
<tr>
<th>1 Strongly Agree</th>
<th>2 Agree</th>
<th>3 Neither Agree or Disagree</th>
<th>4 Disagree</th>
<th>5 Strongly Disagree</th>
</tr>
</thead>
</table>

Mean Response: 3.52

7. I am distracted by other noise.

<table>
<thead>
<tr>
<th>1 Strongly Agree</th>
<th>2 Agree</th>
<th>3 Neither Agree or Disagree</th>
<th>4 Disagree</th>
<th>5 Strongly Disagree</th>
</tr>
</thead>
</table>

Mean Response: 3.06

Please explain. ____________________________

*When there are bees in the room in summer, it can get distracting.*
Everyone want to listen

Other people moving around, leaving the room. Doors are very squeaky.

Outside sounds in the hallway ppl being loud

noisy chairs, people talking

other students -n doors/desks/etc

When people pack up before the end of class

Doors

Other people talking

People talking in back

Food wrappers, whispering

Chairs squeak, noise from outside the class

sometimes in the hallway though

other students typing

shuffling paper after quizzes

people nearby talking

People sitting nearby

Loud Classmates

Other students

Depends if people are talking

Rustling through bag

Simon is distracting
Students talking

the noise doesn't bother me

Students talking during class

8. The room is too big.

<table>
<thead>
<tr>
<th>1 Strongly Agree</th>
<th>2 Agree</th>
<th>3 Neither Agree or Disagree</th>
<th>4 Disagree</th>
<th>5 Strongly Disagree</th>
</tr>
</thead>
</table>

Mean Response: 3.67

9. The room is “echoey”.

<table>
<thead>
<tr>
<th>1 Strongly Agree</th>
<th>2 Agree</th>
<th>3 Neither Agree or Disagree</th>
<th>4 Disagree</th>
<th>5 Strongly Disagree</th>
</tr>
</thead>
</table>

Mean Response: 3.71
10. I have a hearing impairment.

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Strongly Agree</td>
<td>1%</td>
</tr>
<tr>
<td>4</td>
<td>Agree</td>
<td>4%</td>
</tr>
<tr>
<td>3</td>
<td>Neither Agree or Disagree</td>
<td>52%</td>
</tr>
<tr>
<td>4</td>
<td>Disagree</td>
<td>5%</td>
</tr>
<tr>
<td>5</td>
<td>Strongly Disagree</td>
<td>4%</td>
</tr>
</tbody>
</table>

Mean Response: 4.34

Other. Please Explain. ____________________________________________________________

Shitty 1980's Architecture

sometimes? I feel like some professors don't talk into mic

11. The sound system does not function properly.

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Strongly Agree</td>
<td>7%</td>
</tr>
<tr>
<td>4</td>
<td>Agree</td>
<td>16%</td>
</tr>
<tr>
<td>3</td>
<td>Neither Agree or Disagree</td>
<td>47%</td>
</tr>
<tr>
<td>4</td>
<td>Disagree</td>
<td>3%</td>
</tr>
<tr>
<td>5</td>
<td>Strongly Disagree</td>
<td>3%</td>
</tr>
</tbody>
</table>

Mean Response: 3.29
Does not usually happen

I have no idea

I don't know

Sometimes

something doesn't work

12. It happens

<table>
<thead>
<tr>
<th>1 Always in this classroom</th>
<th>2 Often in this classroom</th>
<th>3 Occasionally in this classroom</th>
<th>4 Not often</th>
<th>5 Never</th>
</tr>
</thead>
</table>

Mean Response: 3.64

13. If you feel that it may be difficult to hear the instructor, how would you change the classroom conditions so that all students may hear the instructor clearly?

Reminder to the instructor to use a mike

Not sure what would help

Make them use the mic properly

IDK I'll leave that for you to figure out
place the speakers up higher

talk into mic!

Better sound system that always works.

Speakers in the back

Steepen the rows to be closer

Better sound system

Better louder sound system

Ask instructor to use microphone

Loud speakers

be able to hear in the back

Make mic louder

Make it more box shape

Louder microphones

some other professors don’t speak clearly enough

size of room

Have instructor walk around isles

All the students should remain quiet

better sound system

I would change the seating arrangement

Most of my problems come with strong accents.

Not difficult
Make it like a coliseum

14. If there are other classrooms that present hearing issues to you, Please list, if any________________.

147 Diefendorf (4)

143 Farber

148 (Diefendorf)

144 Farber (6)

Butler Aud. B28
References


King, S. B. (2010). *Texas architects’ knowledge and attitude regarding an ANSI standard for classroom acoustics.* (Au.D.), Central Michigan University,


Watson, D. E., Schroedel, J. E., Kolvitz, M. E., DeCaro, J. E., Kavin, D. E., & Pepnet. (2007). *Hard of Hearing Students in Postsecondary Settings: A Guide for Service Providers*. Retrieved from http://buffalo.summon.serialssolutions.com/2.0.0/link/0/eLvHCXMwtV3PS8MwFA6CColHxYkJtuTkrlTCrnsFD2qrBWeZbCKeRtkWHCTuM6_3_eStLWiggcvoSRT2n55TV_a73uPEJud9Kwvc4LH7ISdurwnHe4zT3LOXHjkhuIYSPgAtrcrDoX0XONGTGzcpQpu6fx14q1OhRyHtHwa_7hQqYBtMAEowAih_N4M69Y9Q3-rhvnsbXRKUpFgMU_vAtfDApjzY6kY0AstVb9ZZkKHAzeTCSoKIG5v9sEfeWnUW5YJV9OqaP7sPL8VUm5APlzzs23xct7pnL0lwo0ZTdpjmQyERRh-p0z6ap-j4xaNiAyqJG45g2Uu52X0swAF-F2f4xxjifywpx2VvPYzhdQouGSajulwjjBhg9jOE9E9v_8kWWdPLIG2ylvMdco-g0IKlRagUqznLZApRWoZ_SCKkgpQEoNpLSGtEO61-HkKrlw1NNXHQBkW0S2yWbHIUleakEi2KPB_WXx64ZTKd9Z0UHGgw-BR_ddmO6Ce2v0863_Z18EP9ldoU02S1RQMUXe6R9dkyhc3iAyiOLF4