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COMPARISON OF ACOUSTICAL CRITERIA AND ARCHITECTURAL ACOUSTICAL SYSTEMS FOR MUSIC EDUCATION SPACES

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ABSTRACT

In the United States, school boards, sustainable building certification programs, professional trade associations, and ANSI standard 12.60 provide some criteria for acoustical performance in music education spaces. Comparisons of the criteria from these groups and ISO 23591 are provided. Acoustical measurements in 2 new and 2 renovated music rehearsal spaces are presented with qualitative feedback from music instructors provided during interviews to illustrate the strengths and weaknesses of the criteria. For example, one large school district provides recommendations for ceiling heights, reverberation times, minimum percentages of sound absorbing and diffusing surfaces, background sound levels, and sound isolation ratings for separating assemblies along with narrative explanations of desired acoustical qualities in the larger rehearsal rooms for band, orchestra, and vocal groups. These design guidelines were developed prior to ISO 23591 but contain many similar recommendations to those in the standard. Most of the sources of criteria have far less guidance than this school district or the ISO standard. Most offer only some guidance on background sound levels, STC ratings of enclosures or RTs. The case studies with the comments from faculty about the perceived acoustical qualities of the rooms allow reflection on the need for specific criteria for music rehearsal spaces in educational occupancies.

Keywords: *music room acoustics, music rehearsal, music education rooms, reverberation time*

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1. INTRODUCTION

There are no comprehensive criteria or standards in the USA for the acoustical properties and qualities of music education and rehearsal spaces in secondary schools, colleges, and universities. Therefore, acoustical consultants, architects, faculty, and the institution must identify criteria on a project-by-project basis. This results in individual consultants or institutions developing criteria that vary widely from one institution to another. Furthermore, there is little guidance in the literature regarding acoustical qualities for music education and rehearsal spaces. This paper presents a summary of criteria that have been developed in the technical literature for these spaces as well as standards, codes, and other sources of criteria that are applied to the design of these spaces. Interviews with faculty using the rooms reveal insights into how well the criteria are employed and how the rooms support the music curriculum.

1.1 Criteria in the Literature

Siebein (2021) presented a summary of criteria that have been developed in the technical literature relating acoustical measurements made in music education spaces to qualities of sound heard in the rooms. This included ground-breaking research by Tsaih (2011) who found that hearing each other, playing in time and in tune; dynamics and articulation were important acoustical qualities in music education spaces that both students and instructors listen for. She found that these qualities are enhanced by sound reflections from wall and ceiling surfaces between students and the instructor and also among students. She also found that understanding speech was an important acoustical quality in music education spaces due to the information exchanged between the instructor and students. Gade (1988) proposed a criterion called Support for musicians' ability to hear each other on a stage. Support was defined as the logarithmic ratio of early reflected sound energy from

the stage enclosure (20 to 200 ms.) to the energy in the direct sound and perhaps a reflection off the floor (0 to 10 ms.). Wenger (2008) has published design guidelines for music practice rooms in schools that include recommendations for floor area, ceiling height and room volume per student. The National Association of Schools of Music (2000) provide guidelines for Reverberation Times (RT) for choral, orchestra and wind ensembles that should have a relatively flat frequency response. They also recommend floor area, room ratios, ceiling heights and the need for sound diffusing surfaces in the rooms.

Sabine (1964), Parkins and Humphrey (1958), Knudsen and Harris (1950), Beranek (1971), Doelle (1972), Meyer (2009), and Egan (1988) among others have addressed architectural acoustical issues for music rooms. These early texts include recommended reverberation times in music practice spaces. Some, such as Doelle; Knudsen and Harris; and Parkins and Humphreys; included a discussion of concepts for the acoustical design of the rooms with practical guidance provided. Pirn (1973) conducted experiments with a constant power sound source in rehearsal spaces to determine that increased ceiling heights were desirable to reduce the build-up of reflected sounds in the rooms when numbers of musicians played which would help control excessive loudness.

Early studies by Sabine (1964) conducted in rooms in the New England Conservatory of Music in 1900 involved having a piano played in relatively small rooms and gradually adding sound absorbent materials in the rooms to incrementally reduce the reflected and reverberant sound fields in the rooms. The musicians were asked which conditions they preferred to practice in to arrive at some initial recommendations for preferred reverberation times in the rooms. The preferred reverberation times for listening to piano music were between 1.0 and 1.1 seconds in rooms that were approximately 4 m tall with volumes of 74 to 210 m^3.

1.2 Criteria in Standards and Recommendations

Some of the standards and recommendations mention reverberation time and other room acoustic properties of music practice and instructional spaces in schools. Only a few have criteria for sound isolation and mechanical system noise and vibration control. LEED 4.1 does not have specific requirements for music rooms in schools. ANSI S12.60 Acoustical also does not have requirements for music rooms with volumes > 566 m^3 (20,000 ft^3). It does recommend background sound levels of 40 dBA/60 dBC in rooms of this size. A Sound Transmission Class (STC) rating of 60 is required for music performance spaces.

ISO 23591 contains general discussion about the nature of music practice and rehearsal for different sizes of ensembles with clear explanations of why acoustical criteria are important in these rooms and why there should be different criteria for different types of rooms. There are recommendations for mid frequency and octave band reverberation times for 3 groups of music spaces: those for quiet acoustic music and vocal music; those for louder acoustic music; and those for amplified music. The 3 groups of music spaces are further categorized by the number of musicians and relative size of the space including individual practice rooms for 1 or 2 people or teaching studios; small ensemble rooms for 6 to 12 musicians for acoustic music; medium ensemble rooms for 13 to 30 musicians; and large ensemble rooms for > 25 musicians for quiet acoustic music. Fewer musicians are accommodated in each category for amplified and loud acoustic music with the latter two types of music ensembles having respectively greater room volume per musician due to the increased loudness of the sound. There is an added category for rehearsal rooms used as performance spaces. Recommendations for sound absorbent materials, bass absorbers, sound diffusing panels, angling of walls, and room dimension ratios are provided. There is an annex that provides a method to calculate the overall strength or relative loudness of the sounds in rooms for specific numbers and types of instruments, dynamic expression, and room volume. Variable acoustic treatment is recommended in rooms serving multiple types of music or multiple sizes of ensembles. General guidance on background noise levels in the rooms is provided. Sound isolation between music rooms is not addressed in specific ways. There is no equivalent document in the United States at this time.

School District 1 is in a large city that is also the primary municipality in the County. It has produced extensive Design Guidelines for educational spaces divided into 3 general categories for elementary, middle and high school levels of instruction. The document for high school music rooms contains requirements for background noise levels, mid-frequency reverberation times, minimum ceiling heights, need for bass traps in some rooms, minimum percentages of wall and ceiling areas for absorbing and diffusing surfaces, and minimum thickness of sound absorbing material for different categories of rooms including band, orchestra, choral, music labs, piano labs, ensemble, small practice rooms, and recording studios. The RTs for each category of room and the corresponding ceiling heights tend towards the dryer end of the similar categories in ISO 23591. Hard surface floors are specified.

General planning strategies for music rooms and suites of rooms are also provided including general sound isolation

principles such as locating buffer spaces between primary music rooms and using a minimum Sound Transmission Class (STC) rating for walls of STC 60 with doors having the same rating as the walls. Sound lock vestibules are called out as an alternative to the STC 60 doors. Guidelines for planning the heating, ventilating and air-conditioning (HVAC) systems in the rooms are also provided. These include use of silencers in the ducted air path, distances from the air handling units to the rooms, air velocities in the ducts and other system parameters. Variable acoustic treatments are required when rooms are used for more than one of the identified functions.

School District 2 is a large County that has one large city at its core with a large number of municipalities around the central city. They have produced Educational Specifications for different type of rooms in schools including an extensive document on music rooms. There are introductory statements about the nature of music instruction and the acoustical qualities of rooms necessary to support the educational mission. Extensive lists of all of the rooms and the individual instruments to be used in each room are provided. Similar to School District 1, they have included specifications for mid-frequency Reverberation Times (0.70 to 1.2 seconds with a relatively flat frequency response), minimum ceiling heights of 4.3 to 4.9 m (14 to 16 ft.) and background sound levels (25 dBA). The need for sound absorbent and sound diffusive treatments is called out in general terms. Carpeted floors are called out. General planning strategies are mentioned such as angling walls, arranging rooms to control sound bleed, HVAC system acoustical design concepts, and proportions of room dimensions. Careful selection of paint and orienting rooms across the diagonal are also mentioned.

None of these documents provides guidance on the locations of the materials in the room relative to the instructor or ensemble, the possible arrangements of the ensembles, or specific configurations that may result in achieving the acoustical criteria. There are some indications in Tsaih (2011) that the configuration of the impulse response between those seated close to a musician (near) and those seated farther away from a given musician (far) determine the quality of the acoustical communication between and among musicians in the room. This possibly indicates that the sound paths of early reflections from individual musicians (sources) to other musicians (receivers) which are determined by the location, shape, angle, and other physical characteristics of the room boundaries could possibly be configured to help achieve the acoustical qualities student musicians and instructors listen for during practice and rehearsal.

2. CASE STUDIES OF MUSIC PRACTICE ROOMS IN SCHOOLS

Case studies of new and existing music practice rooms in schools illustrate the ways that these recommendations are applied in actual buildings and the thoughts of instructors and students about the acoustical qualities in the rooms obtained through interviews. The context for the projects is important to understand. All of the schools had existing music rooms that did not meet the needs of the music program and faculty. The existing rooms had relatively low ceiling heights, acoustical tile ceilings, carpeted floors.

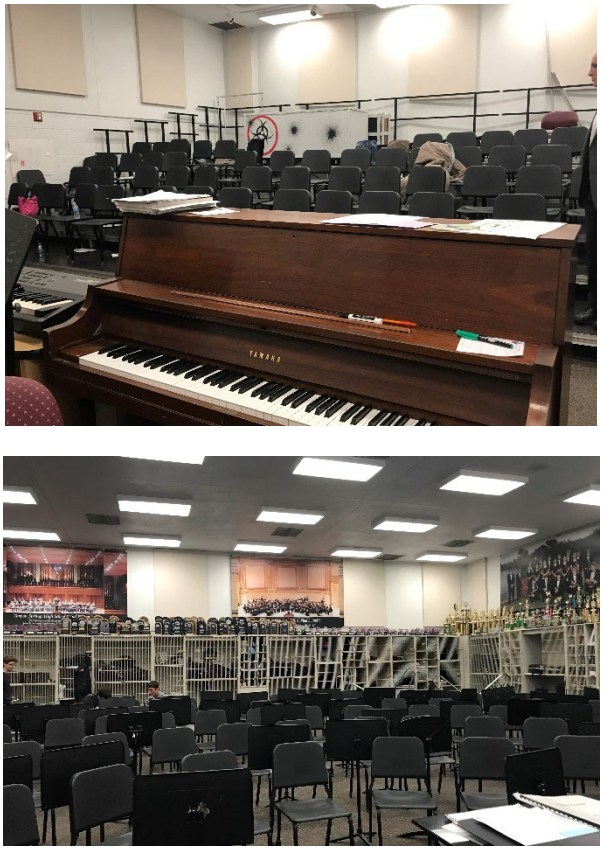

Figure 1. Photographs of existing music rooms in 2 of the schools that new rooms were built.

The RTs were often shorter than the guidelines and HVAC system noise levels were higher than the recommended levels. Comments from instructors stated that it was difficult to hear the students, sounds were not clear or blended and the rooms tended to be too loud.

2.1 High School 1

High School 1 is a private school with an active performing arts program including theater, music and dance. Neither the school nor the local school district have any acoustical criteria for music rooms. The newly constructed room had a ceiling height of approximately 4.3 m (14 ft) at the front with a floor area of 163 m^2 (1,753 ft^2) and a volume of 695 m^3 (24,542 ft^3). There is a network of sound diffusing panels, sound reflective panels and some absorbing panels in a standard ceiling grid. The Reverberation Time was 0.80 seconds. The walls were painted gypsum board with sound diffusing and sound absorbing panels, windows to the exterior on the rear wall and a vinyl floor on manufactured risers. The RT criterion was met in this room as well as the recommended percentage of sound diffusing panels. However, the floor area, room volume, and ceiling height were at the very minimum of the recommended dimensions. The teacher commented on the significantly improved listening conditions in the room compared to the original room and could hear students clearly.

Figure 2. Photograph of the Band Rehearsal Room in High School 1.

2.2 High School 2

High School 2 is a public school with an active performing arts program including theater, music and dance. The County School Board has acoustical criteria for reverberation times, background sound levels, including sound diffusing panels, minimum ceiling heights and qualitative statements about the essence of music instruction. This music room was part of a major renovation of the entire campus. It was decided to move the Band Room to an existing room that would be completely renovated. The floor area is 180 m^2 (1933 ft^2). The room had a ceiling height of approximately 4.3 m (14 ft) at the front and has a slight slope towards the rear of the room and a volume of 766 cu m^3 (27,062 cu ft^3). with a network of sound diffusing panels, sound reflective panels and some absorbing panels in a standard ceiling grid. The Reverberation Time was 0.9 to 1.2 seconds. The walls were painted gypsum board with sound diffusing and sound absorbing panels, windows to the exterior on the rear wall and a vinyl floor. The RT criterion for the school district was met in this room as well as the recommendation to include some sound diffusing panels. However, the room volume, and ceiling height were at the very minimum of the recommended dimensions. The teacher commented that the acoustics were wonderful and much improved compared to the original room.

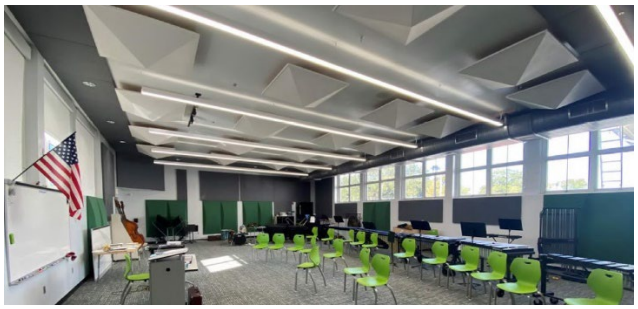

Figure 3. Photograph of the Band Rehearsal Room in High School 2.

2.3 High School 3

High School 3 is a public school with a "magnet" performing arts program including theater, musical theater, instrumental music of all types, vocal music, and dance. High School 3 is in the same County as High School 2 so the same criteria apply to this project. This music room was part of a major renovation of the entire performing arts portion of the campus. Originally the band room was going to be renovated and a new auditorium constructed. Initial architectural and acoustical studies demonstrated that it would be more cost effective to renovate the existing auditorium and build a new band room so that both rooms could meet the acoustical criteria for the County and the faculty. The floor area of the new band room is 225 m^2 (2,419 ft^2). The room had a ceiling height of approximately 6.4 m (21 ft) and a volume of 822 m^3 (29,028 ft^3). with a network of sound diffusing panels, sound reflective panels and some absorbing panels in a standard ceiling grid. The Reverberation Time was 0.7 to 0.9 seconds which is on the lower end of the County criteria. The walls were painted gypsum board with sound diffusing and sound absorbing panels, windows to the exterior on the side wall and a vinyl

floor. The RT criterion for the school district was met in this room as well as the recommendation to include some sound diffusing panels. However, the instructor thought that the room was too dry and a plan was developed to remove some of the absorbent panels from the room. The teacher commented that he could hear individual students and enjoyed the clarity of the room.

Figure 4. Photograph of the Band Rehearsal Room in High School 3.

2.4 Community College 1

Colleges and universities do not have specific criteria for acoustics of music and performance spaces in the United States. Acoustical criteria for these spaces are often based on input from faculty and administrators in the music program and/or derived from the technical literature by consultants on a project-by-project basis. Community College 1 had a growing music and theater department. A large performance hall had been built on the campus in 1966 and remodeled in 1999. New music and theater practice rooms were built in 2007. The instrumental rehearsal room was originally built as a band room with a RT of approximately 0.7 seconds. As the music program grew more diverse and sophisticated, more types of music ensembles had to be accommodated. Sound absorbent panels were removed to brighten the room.

The new room was to accommodate a wide range of percussion ensembles. The room has a ceiling height of 6.7 m (22 ft) with a floor area of 89 m^2 (960 ft^2) and a volume of 598 m^3 (21,120 ft^3). The mid frequency RT 1.3 to 1.5 seconds when the drapes were completely retracted and 0.5 to 0.7 seconds with drapes fully exposed given a wide range of reflective and reverberant conditions to support the wide variety of ensembles using the room. There are custom designed, field fabricated acoustical "clouds" over the portion of the room where the ensembles would be located to provide cross room sound reflections so the students can hear each other. There is a perimeter soffit with flat acoustical ceiling tile. There is also an acoustical "shelf" on the upper side walls to also cast reflections from students playing on one side of the ensemble to those playing on the other side.

Figure 5. Photograph of the new Percussion Rehearsal Room in Community College 1.

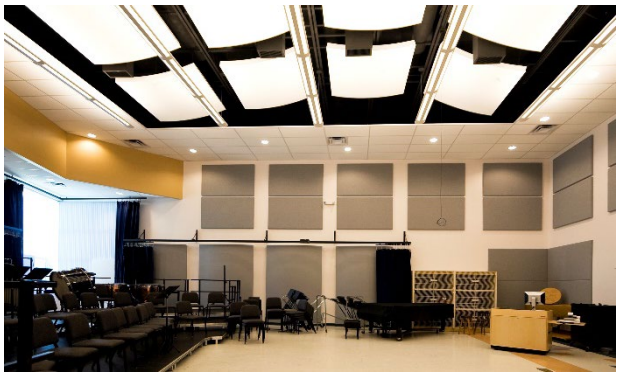

Figure 6. Photograph of the original Band/Instrumental Rehearsal Room in Community College 1.

There are large convex-curved panels on the side walls that cover recesses where acoustical drapes are stored when not in use. There are also large windows in the room that can be covered with acoustical drapes when desired. There are also large bass traps in the corners of the upper walls on the side of the room opposite the ensemble that are built into a soffit that extends along 2 of the walls in the room.

2.5 University 1

University 1 is a private school with a growing fine arts program. A stand alone choral room was built in 2014. This was followed by a new College of Arts and Media facility with band, percussion, recording studios, faculty studios and practice rooms that were built on the lower levels of a multi-story, multi-purpose building with offices and spaces for other academic programs and dormitory rooms housed on upper floors. The instrumental music room has a ceiling height of 6.4 m (21 ft) to the underside of the acoustical clouds. The room has a floor area of 354 sq m^2 (3810 sq ft^2) and a volume of 1906 m^3 (67,321 ft^3) The RT with the drapes fully retracted is 1.1 to 1.2 seconds. This can be reduced to 0.70 seconds when the drapes are fully deployed. There are custom designed, field fabricated acoustical "clouds" over the portion of the room where the ensembles would be located to provide cross room sound reflections so the students can hear each other.

Figure 7. Photograph of the Band Rehearsal Room in University 1. The drapes can be retracted to expose large, curved sound diffusing wall planes below the acoustical shelf that surrounds the room at the upper level below the clerestory windows. The instructor commented that the acoustics are remarkable and the students enjoy playing in the room.

There is also an acoustical "shelf" on the upper side walls to direct reflections from students playing on one side of the ensemble to those playing on the other side. There are large convex-curved panels on the side walls that cover recesses where acoustical drapes are stored when not in use. There are also clerestory windows in the room above the acoustical shelf.

2.6 University 2

University 2 is a private school with a growing fine arts program. A 4-story Center for the Arts was constructed in 2021 for music, theater, and fine arts that included orchestral, vocal, piano, and instrumental practice rooms, a recording studio with separate voice over and percussion rooms and state of the art control room, faculty studios, and practice rooms largely on the 4th floor of the building. A 200 seat recital hall was located on the first floor. A black box theater, workshops, painting sculpture, dance and other studios with faculty offices and instructional spaces were interspersed throughout the building. The orchestral practice has a ceiling height of 5.2 m (17 ft) to the underside of the acoustical clouds. The room has a floor area of 262 m^2 (2,824 ft^2) and a volume of 1,274 m^3 (45,000 ft^3) The RT with the drapes fully retracted is 1.0 to 1.3 seconds. This can be reduced to approximately 0.60 to 0.70 seconds when the drapes are fully deployed. There are custom designed, field fabricated wood veneer acoustical "clouds" over the portion of the room where the ensembles would be located to provide cross room sound reflections so the students can hear each other.

Figure 8. Photograph of the Band Rehearsal Room in University 2.

There is a combination of manufactured wood sound diffusing panels on the side walls located between large, convex curved gypsum board elements. The sound absorbing acoustical drapes can be stored behind the curved elements. The floor is vinyl. The 4th floor location of the room is right across a narrow alley from the central chiller plant for the campus. There is a massive, multi-wythe masonry wall on the exterior wall of the room facing the cooling towers on the upper level of the chiller plant. The

instructor has commented that the room sounds like a concert hall and he enjoys playing and teaching in it.

A summary of the criteria and if they are met in each room is included in Table 1.

Table 1 Summary of Acoustical Criteria in Each Room

Room	Floor Area	Criterion Volume	Ceiling Height	RT	Diffusion	Variable Acoustics	Background Noise
High School 1	✓			✓	✓		✓
High School 2	✓			✓	✓		✓
High School 3	✓	✓	✓	✓	✓		✓
Community College 1	✓	✓	✓	✓	✓	✓	✓
University 1	✓	✓	✓	✓	✓	✓	✓
University 2	✓	✓	✓	✓	✓	✓	✓

3. CONCLUSIONS

The case studies illustrate that the acoustical criteria for music rooms in secondary schools, colleges, and universities can be met using either site built or manufactured acoustical systems for sound reflection, absorption and diffusion. Comparing criteria among the projects raises questions such as is a reverberation time alone a satisfactory acoustical criteria for these spaces or if volume, ceiling height, areas per student, areas of diffusing panels and other criteria would be helpful to provide the acoustical qualities for successful music instruction. Should the schools adopt a standard similar to the ISO standard or the more detailed Design Guidelines of the large school district that cover multiple aspects of the acoustics of the rooms. This may be important in high schools and colleges as well in earlier education settings where students are still mastering their own instruments and learning to play in ensemble.

Higher ceiling heights often result in instructors being able to hear students more clearly when diffusing surfaces are present on the walls and ceilings of the room.

Some of the instructors preferred more lively rooms that had similar acoustical qualities to the performance halls in which they play. Some preferred a dryer acoustical environment so they can hear individual students or groups of students more clearly without room effects added.

Many of the rooms have multiple ensembles that use the rooms. These may include marching band, symphonic band, orchestra, wind ensembles, brass ensembles, guitar ensembles, percussion, vocal groups of various sizes and types among others. Therefore, when possible, providing variable acoustic systems in the multi-use rooms was helpful to adjust the acoustics of the rooms to suite the qualities desired by individual instructors and to more optimally accommodate the various ensembles that use the rooms.

Patel (2020) developed a useful framework for the analysis of the acoustical aspects of architectural spaces in outline form. Each building type is discussed in a table that deals with room acoustics; speech intelligibility; audio/visual system design; external sound insulation; internal sound insulation; speech privacy; impact/vibration isolation; mechanical and electrical system noise; structure-borne noise, and environmental noise. This framework will be applied to this building type to analyze the acoustical and architectural issues in each type of music room in the future.

The progression of work is also leading to the development of a "kit of parts" for architectural acoustical systems for music education spaces that includes ceiling height; floor area; planning concepts; locations, types and amounts of sound reflecting, absorbing and diffusing surfaces; sound isolation systems; background noise design; variable acoustical systems when appropriate, and other pertinent features of the rooms.

More thorough post occupancy evaluations are currently being conducted in the rooms using a questionnaire format to further discern the perceptions of the faculty of the acoustical qualities of the rooms.

4. REFERENCES

[1] ANSI Standard S 12.60 Part 1: *Performance Criteria, Design Requirements and Guide Lines for Schools.* Washington D.C.: American National Standards Institute, 2010.

[2] ISO Standard 23591 *Acoustical Quality Criteria for Music Rehearsal Rooms and Spaces.* Geneva: International Standards Organization, 2021.

[3] G.W. Siebein: *The Soundscape of Music Education* in Ronsee, Bradley, Kanter and Lawless (eds). Rooms for the Learned Musician: A 20-Year Retrospective on the Acoustics of Music Education Facilities. New York: Springer Publications, 2021.

[4] L.S. Tsaih *Soundscape of Music Rehearsal in Band Rooms.* Dissertation University of Florida, 2011.

[5] A.C. Gade, (1981) *Musicians Ideas About Room Acoustic Qualities.* Technical University of Denmark Report No. 31, 1981.

[6] Wenger Corporation (2008) *Planning Guide for School Music Facilities.* https://www.wengercorp.com/Construct/docs/Wenger%20Planning%20Guide.pdf

[7] NASM (C. Boner, R. Coffeen) Acoustics for Performance, Rehearsal and Practice Facilities. Reston: National Association of Schools of Music, 2000.

[8] W.C. Sabine *Collected Papers on Acoustics.* New York: Dover Publications, 1964.

[9] P.H. Parkin, H.R. Humphreys *Acoustics Noise and Buildings.* Praeger: 1958.

[10] V.O. Knudsen, O. Vern, C.M. Harris. *Acoustical Designing in Architecture.* Published for the Acoustical Society of America by the American Institute of Physics. 1950

[11] L. Beranek, *Noise and Vibration Control.* USA: McGraw-Hill, 1971.

[12] L.L. Doelle, *Environmental Acoustics.* USA: McGraw-Hill, 1972.

[13] J. Meyer, Preface (p. vi) to *Acoustics and the Performance of Music.* New York: 5th edition Springer Science + Business Media, 2009.

[14] D.M. Egan, *Architectural Acoustics.* USA: McGraw-Hill, 1988.

[15] R. Pirn: On the Loudness of Music Rooms. Journal of the Acoustical Society of America 53, 301. 1973

[16] R. Patel: Architectural Acoustics A Guide to Integrated Thinking. London: RIBA Publishing, 2020.