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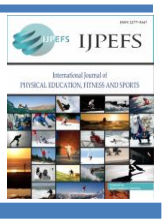

Solving the Acoustic Issue in Physical Education Settings

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Stu Ryan [a, *] and **Daniel Swartz** [b]

[a] Department of Teacher Education and Educational Leadership, University of West Florida, 11000 University Pkwy, Pensacola, Florida 32514, USA
[b] Exercise Science Department, Southern Connecticut State University, 501 Crescent Street-Pelz 002, New Haven, CT 06515, USA
[*] Corresponding Author: Ph: 850-474-2597; Email: sryan@uwf.edu

Abstract: The audibility of teachers and peers is an essential factor in determining the academic performance of school children. However, acoustic conditions in physical education settings are less than optimal and have been viewed as "hostile listening environments" that undermine the learning of children in school. While typical classroom teachers are faced with many voice concerns, gymnasiums with poor acoustics, covered areas, and outdoor teaching environments can be more challenging to the voices of physical education teachers. They often rely on shouting instructions over noises and hope their students will hear and understand. This article reviews current acoustic research in classrooms and in physical education settings and future actions designed to improve sound issues and their related policies.

Key Words: Acoustics, Sound, Policy, sports

1 Introduction

There is an extensive and systematic research agenda dedicated to acoustic issues in classroom settings while the theoretical and experimental research in the broad interdisciplinary subject of sound has been active for over 100 years. However, regardless of the distinguished efforts of numerous journals and thousands of empirical research articles, the discipline of physical education has rarely been the topic of acoustic research. For example, The Journal Language, Speech, and Hearing Services in Schools which is considered a leader in the area of school acoustic issues has published over 1000 articles on school based settings. A search of articles related to the discipline of physical education reveals a dismal total of one research study. Although research has revealed that typical classrooms may be acoustically challenging [1-4], the acoustic conditions in physical education settings are clearly more challenging than in the typical classroom and have been viewed as "hostile listening environments" [5]. Physical education teachers normally teach in a different environment than the "typical" classroom, however, that environment is their classroom. To date, researchers in physical education have little empirical research on the way acoustics affect physical education teachers and student behavior. A review of recent limited research into acoustic issues in physical education settings has revealed a troubling pattern that effects teachers and students alike [6-10]. Understanding the fundamentals of acoustics and germane literature may support future physical educator research and help solve acoustic problems that effects student learning.

2 Acoustics Fundamentals

In physical education settings, communication is transmitted from teacher to students through a mixture of direct and reflected sound. Direct sound travels outward from the teacher and becomes reflected sound after it has struck one or more objects or surfaces in a room and this reflected sound is known as reverberation. Reverberation is the continual process of sound reflecting off walls, floors, ceilings and anything solid (Smaldino, 2011) [11]. The energy from reverberation is lost by absorption at

each reflection and does not continue endlessly (Boothroyd, 2006) [12]. The sound from reverberation tends to fall off swiftly at first but then more slowly as time progresses. A reflective sound is frequently called an echo due to the distinct delay in the arrival of the sound back to the listener (Finitzo-Hieber, 1988) [13].

The level of direct sound falls by 6 dB for every doubling of distance from the talker (Boothroyd, 2006 [12]. If a teacher's speech level is 72 dB, this level will drop to 66dB at two feet, 60dB at four feet, 54 dB at eight feet, and at 8 feet from the speaker, there would be a 25% loss in speech level. A student's location in a gymnasium establishes the specific combination of direct and reflected sound a student hears. The distance between the teacher and students decides the amount of acoustical energy in a direct and reflective sound wave reaching the students. Gymnasiums and other physical education settings have different sizes and volumes, this distance would on average be much greater than the typical classroom and have less energy. Speech energy the students receive through direct and reflected sound waves is more intense than when only direct sound waves reach the listener. Therefore, sound energy in an environment with some amount of reflection or reverberation could increase the sound level. However, high levels of reflection can have an undesirable effect on speech understanding. A gymnasium is a difficult listening environment due to its size (increased distance leading to decreased sound levels) and its reflective surfaces resulting in lengthy reverberation times that can reduce speech understanding. Furthermore, a physical education teacher teaching outside can only rely on direct sound resulting in decreased speech levels.

Background noise is another significant factor that impacts the quality of a gymnasium's acoustics and is defined as any sound that is separate from the speech of the talker [14]. High levels of background noise may have an undesirable effect on the students including poor speech understanding, listener distraction, and fatigue while fatigue and even vocal abuse may affect the talker [14].

Determining the sources of noise in physical education settings helps to recognize the complex issues of acoustics. Sources of noise within a classroom may include students talking, chairs or desks scraping the floor, scuffling of shoes, air conditioning and heating systems. Noise outside of the classroom, but inside of the school may include hallway traffic, other classrooms, the cafeteria, and the gymnasium. Physical education settings are often subjected to lawn maintenance, road traffic, area construction, airplanes, school air conditioners, other physical education classes, recess classes, and wind. These sources of noise along with the size of class, student noise, voice level of teacher, possible reverberation, and varying distance of teacher to student during feedback/instruction may account for poor acoustic settings [10].

3 Classroom Acoustic Research

The primary modes of communication in the educational setting are speaking and listening, with it being estimated that children spend 45-75% of their time in the classroom comprehending their teacher's and classmates' speech [15, 16 and the audibility of teachers and peers is a critical factor in determining the academic performance of school children [17]. Listening activities may include paying attention to the teacher and peers during instruction, music, videos, and also in regular conversations. An acceptable listening environment in schools is important to cognitive, social, speech, and language development [18]. With so much of the student's day spent in listening activities, the acoustic properties of the school should be an essential consideration of the school environment. However, acoustic conditions in most classrooms are less than perfect [3] and undercut the learning of children in school [19]. Studies show that children from classrooms with poor acoustics are less productive in the workforce, have lower literacy and numeracy skills and tend to be in lower paid jobs than those from classrooms with good acoustics [4, 20]. Also, students who are listening and learning in a non-native language, have attention disorders, learning disabilities, and other auditory disorders make up a considerable proportion of U.S. classrooms, also require less noise than other children [21-23].

Therefore, it is important that the classroom acoustic environment is designed to allow children to accurately understand what their teacher and the children in their group are saying [24-26].

Noise in classrooms often surpasses recommended levels, potentially making it difficult for children to understand what is being said [27]. High classroom noise levels on day-to-day school activities may be substantial and fairly broad in scope [28, 29]. In Crandell's (1991) study of 32 unoccupied classrooms, the average noise level was measured at 50 dBA [30]. Painter and Frank (1999) reported noise levels ranging from 37 to 42 dB (A) in unoccupied infant and toddler classrooms [31]. Unoccupied classrooms in Ohio produced noise level ranging from 32 to 67 dB (A) [32]. The noisiest classrooms in the Knecht et al. study were those with noisy heating, ventilation and air-conditioning unit running.

However, most of the classrooms were noisy even when the air-conditioning systems were turned off. Past research of acoustical conditions in unoccupied classroom settings for the hearing impaired suggest that appropriate levels of noise are seldom achieved [32, 33]. Noise levels in occupied elementary classrooms are normally 10 dB higher than the unoccupied levels ranging from about 52 to 62 dB (A) [34]. Noise levels in occupied preschool classrooms in child care centers can range from 66 to 94 dB(A) [35] while noise levels in occupied infant and toddler classrooms in child care centers range from 58 to 68 dB(A) [36].

4 Physical Education Acoustic Research

Noise levels in elementary, middle, and high school physical education settings have been reported to have higher than recommended levels. Ryan & Mendel (2010) [5] compared noise levels in physical education setting to the American Speech-Language-Hearing Association (ASHA) guidelines and the American National Standards Institute (ANSI) standards for acoustics in educational settings. Only one of the physical education settings exhibited noise levels within the recommended ASHA criteria of 40 dBA and none of the settings met the standards set by ANSI [27]. Jurak et al., (2015) had similar results with eighty-six per cent of the sport halls having poor or merely satisfactory speech intelligibility [6]. Gymnasiums often have large heating and cooling systems as well as fluorescent lighting that contribute to the overall noise level [37], and they typically have poor sound quality [38]. Jiang (1997) conducted a series of sound measurements found that gymnasiums were as noisy as factories, and elementary school gymnasiums produced average sound measurements as high as 94.4 dB SPL, which is equivalent to the sound produced by a jack hammer [39, 40]. The National Institute for Occupational Safety and Health (NIOSH) research indicates that even at the general industry action level of 85 dBA, one in eight workers will sustain an occupational hearing loss great enough to cause hearing loss [41].

Signal-to-noise ratios in elementary, middle, and high school physical education settings were also compared to the ASHA guidelines and ANSI standards [10]. The difference between what the teacher is saying (signal) and the noise level in the classroom is generally called the signal-to-noise ratio (SNR). The results indicate that a large majority of the physical education settings investigated exhibit SNR levels lower than recommended levels established by ASHA and ANSI.

Based on these findings, SNRs in physical education settings are likely detrimental to student learning [42].

Physical education teachers often have to use their voices at great distances [43] which have been shown to cause substantial voice problems [44]. A survey by Ryan, Rotunda, Song, & Maina, (2012) [9] was administered to K-12 physical education teachers addressing three aspects of voice issues: consequences, strategies for prevention, and potential risk factors. The results indicated a strong prevalence and impact of voice problems for almost all physical education teachers surveyed regardless of grade level taught, age, or gender. These findings are consistent with a few minor studies of physical education teachers which also found high levels of voice strain, adverse effects on job performance and attendance [44-46].

5 Acoustic Policy

Several studies have been conducted to document the damaging effects of excessive classroom noise [28, 30, 34, 47-50]. As a result of many of these studies, in 1995 the American Speech-Language-Hearing Association (ASHA) published "Position Statement and Guidelines for Acoustics in Educational Settings," that called for background noise levels in classrooms not to exceed 30 dBA. This specification was reaffirmed in 2010 when the American National Standards Institute (ANSI) published "ANSI S12.60-2010 Acoustical Performance Criteria, Design Requirements and Guidelines for Schools" [51], that, based on room size, recommends that background noise level not to exceed 35 dBA. However, ANSI describes large areas including gymnasiums as "ancillary learning spaces" and recommends that the maximum background noise level in those locations not to exceed 40 dBA. Typical classrooms are labeled as "core learning spaces" where the primary functions are teaching and learning and where good speech communication is critical to a student's academic achievement [51]. Physical education has established national standards, developmentally appropriate and inappropriate practices, and is recognized as a subject area that is vital to the development of the whole child [52-53]. To label the primary educational functions of physical educators as "informal" is devaluing the health, fitness and well-being of physical education students and enhancing the acoustical issues in physical education.

6 Conclusion and Future Actions

Regardless of the number of classroom studies and the position statement by the ASHA, the one area

that would benefit the most appears to be left out by researchers and the issue of poor acoustics in physical education settings is still disconcerting. However, the Acoustic Society of America (ASA) which oversees the development of acoustics standards for ANSI has recently established a committee of acoustics engineers, physical educators, and acoustics products representatives to write a new acoustic standard for physical education environments which will be separate from the classroom standard. The new physical education standard will give architects and school planners much needed acoustic guidelines which will improve the acoustics in all future construction. Current facilities with poor acoustics can use the new standard to justify improvements including modifying existing areas with acoustic carpeting, ceiling tiles, curtains, and sound absorption wall material which would help decrease noise levels. The new standard may not effect some of the outside noise, however, some noise can be modified to reduce their impact. For example, locating recess in areas void of physical education classes, scheduling other physical education classes so that distance between classes is considered, and coordinating lawn maintenance and physical education classes so teachers are not raising their voices over the engine noise. These modifications are likely to help decrease noise levels and may help with vocal fatigue.

The literature describes using a sound field amplification device as another strategy for improving student hearing which improves academic performance, speech recognition, learning, and increased self-esteem by children with normal hearing [54, 55]. A sound field amplification device or public address (PA) system normally consists of a small microphone and a FM transmitter worn by the teacher, an amplifier, a stationary FM receiver with one or more speakers. This type of equipment is already in use in many schools [2] and there is a developing body of research and information relating to the use and effectiveness of sound amplification in classrooms and in physical education settings [7, 8, 16, 55-57].

In the future, both ANSI, ASHA, and ASA need to seek cross-discipline research that includes physical education teachers. This type of collaboration would hopefully start the process needed to enhance understand methodologies and philosophies of all groups with the objective of improving acoustics in physical education settings. The typical settings of physical education classes will always be challenging and will enhance the problems associated with poor physical education acoustics. However, support from education administrators and acoustic associations will help determine the most appropriate, cost-effective procedures to increase the acoustic environment in existing and future physical education settings. This collaborative approach would be ideal to allow new schools to meet the new recommended guidelines so physical education students, can hear and learn at their maximum potential without endangering the voice of the teachers.

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