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Investigation of the Acoustics Performance of the University's Lecture Rooms by using Economical and Feasible Design Improvement Strategies

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ABSTRACT

Students encounter difficulties in speech comprehension because of unfavorable classroom acoustics conditions, which subsequently affect their cognitive development and academic performance. Therefore, optimal listening conditions are required to ensure that listeners perceive and recognize speech effectively. This invites numerous studies to explore plausible acoustic interventions and treatments as an initiative to remediate the issue. Thus, this study seeks to a) identify the actual acoustic conditions in two (2) classrooms in the Faculty of Built Environment, Universiti Malaysia Sarawak, and b) establish economical acoustic design strategies for future improvements. This quantitative study embarks on on-site acoustic measurements to evaluate the reverberation time and background noise level of the selected classrooms. The data from the on-site measurement is applied for 3D model verification for the simulation process. The establishment of plausible design treatment alternatives is further analyzed through simulation using ODEON software. The simulation process yielded the effects of a) material surface treatment and b) sound field amplification systems on several acoustic parameters. The findings reveal that the surface treatment using low-cost material and the installation of sound field amplification significantly enhanced the classroom acoustic quality and are feasible to be implemented for future improvements.

1.0 INTRODUCTION

Conducive classroom surroundings are essential to facilitate effective teaching and learning processes. A conducive learning environment is influenced by a variety of environmental factors, including lighting, thermal comfort, and indoor air quality; but the most important factor has always been acoustic conditions (Palau & Mogas Recalde, 2019). Most of the teaching and learning practices involve auditory learning, which requires students to use their sense of hearing effectively to articulate the information delivered by the teachers. According to the American Speech-Language-Hearing Association (2005) and Rosenberg et al. (1999), approximately 45-70% of the student's time spent in classrooms involves speech comprehension. Classrooms

with poor acoustic quality degrade students' learning attainments, which involve reading and listening, especially for young children. Students of younger age groups have yet to develop auditory sensitivity to formant and voice onset times compared to adults (Astolfi et al., 2019). According to Cediel and Neira (2014) in a poor acoustic environment, teachers are susceptible to vocal dysfunction due to an involuntarily increased voice level (Lombard effect). Therefore, to improve students' learning development and teachers' well-being, good acoustic quality in a classroom is required.

Referring to classroom acoustics guidelines established by American National Standards Institute (2010) and Building bulletin 93 (2015), a classroom with optimal acoustics performance must achieve reverberation time of less than 0.8 seconds and background noise not exceeding 35dB(A). However, due to language differences, the criteria for other acoustical factors in each country vary significantly. The acoustic requirements in Chile, Norway, Denmark, and other countries, particularly for reverberation time, are set at 0.6 seconds. Meanwhile, 0.8 seconds of reverberation time has been adopted as the benchmark for Germany, France, Italy, and China (Park & Haan, 2021). In some countries like South Africa and India, a standard guideline for classroom reverberation time has yet to be established (Van Reenen & Karusseit, 2017) (Gupta, 2015) and this includes Malaysia.

Several acoustic parameters require serious attention while designing a classroom. The main four prominent factors to be acknowledged for classroom acoustic design are reverberation time (RT) (Sarlati et al., 2014) background noise (Mogas et al., 2021) and Speech Transmission Index (STI) (Escobar & Morillas, 2015). According to Picard and Bradley (2001), and Nijs and Rychtarikova (2011), speech quality in classrooms has been reported to deteriorate when reverberation times exceed 0.5 or 0.6 seconds. This condition is due to the masking effect of late reflections on the direct and early sound produced and consequently degrades speech intelligibility.

Speech intelligibility refers to the effectiveness of speech communication measured. This is measured through the percentage of word comprehension. The prediction of speech intelligibility of the listeners in a classroom can be quantified by using STI. The STI value varied from "0" to "1" and represented by the quality rating scale from "bad", "poor", "fair", "good", and "excellent". It was found that the STI value is directly influenced by the reverberation time, signal-to-noise ratio (SNR) (Houtgast, 1980) and excessive noise level (Peng & Wu, 2018).

Excessive amount of ambient noise levels is more concerning than improper room acoustic quality (Bradley & Sato, 2008). Most of the background noise in a classroom comes from outdoor activities, learning activities inside the classroom, and electrical appliances inside and outside the classroom. According to a study conducted by Haron et al. (2021), the ambient noise level in a school classroom in Malaysia surpassed 70 dBA as a result of heavy traffic during peak hours. Classrooms equipped with open louvre windows facilitate the easy dissipation of traffic noise into the classrooms. Hodgson et al. (1999) found that the noise level recorded in unoccupied and occupied classrooms was between 39-42 dB and 40-45 dB respectively. The value depicts that the acoustic conditions of the classrooms were affected by the noise generated by the ventilation system (Mydlarz et al., 2013). As a result of the ventilation system's operation, both STI and SNR values were reduced (Longoni et al., 2017).

The acoustic quality of a particular space is influenced by a few factors namely, the surface material, background noise, room volume, and so forth. According to previous studies, the selection of surface material plays a significant role in producing an ideal acoustic quality in a classroom. Using materials with higher reflective properties will create excessive sound reflection and thus more reverberant conditions. According to