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Assessment model of classroom acoustics criteria for enhancing speech intelligibility and learning quality

Ayman I. Madbouly [a,b,*], Amin Y. Noaman [c], Abdul Hamid M. Ragab [c], Ahmed M. Khedra [c], Ayman G. Fayoumi [c]

[a] Research and Consultancy Dept., Deanship of Admission and Registration, King Abdulaziz University, Jeddah, Saudi Arabia
[b] Building Physics and Environment Research Institute, Housing and Building National Research Center, Cairo, Egypt
[c] Faculty of Computing and Information Technology, King Abdulaziz University, Jeddah, Saudi Arabia

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ABSTRACT

In this paper, a new classroom acoustics assessment model (CAAM) based on analytic hierarchy process (AHP) for enhancing speech intelligibility and learning quality is proposed. The model is based on five main criteria that affect the learning process and related to classrooms acoustical properties. These include classroom specifications, noise sources inside and outside the classroom, teaching style, and vocal effort. The priority and weights of these major criteria along with their alternatives are identified using the views of students, staff, education consultants, and expertise by using a developed questionnaire, and the AHP methodology. This model can be considered as a helpful framework enabling universities decision makers to take effective decisions on classroom acoustics treatment issues. It also provides colleges' higher authorities the suitable guidelines that help for determining necessary requirements that help to raise the quality and efficiency of the educational environment; in order to reach an excellent learning environment; and hence increasing students learning outcomes.

1. Introduction

Higher Education Institutions (HEIs) might engage with the goal of sustainable development [15]. In addition, the developing management education for sustainability is a complex challenge for existing HEIs [22], hence education for all citizens is essential to all modern societies. Usually, formal education is conducted in classrooms, where the learning process involves intensive verbal communication between students and teachers and among students.

Higher education like other industries is obligated to provide services and meet certain sets of standards and needs [9]. This is beside the quality and efficiency of this kind of communications, and hence, quality of learning and teaching environment is measured by the acoustics conditions of the classrooms [24]. Mak and Wang [26] reported that acoustics could be defined as the generation, transmission, and reception of energy in the form of vibrational waves in matter. Pääkkönen et al. [28] said that the acoustics of educational places should support learning through the promotion of the needed sound spreading and preventing unwelcome noise. The existence of high levels of noise in the classroom will affect the learning and teaching environment for both students and teachers, and will make students tired prematurely, and consume their cognitive abilities that can be used better employed in paying more attention to and understanding the content of their classes [20,36,41]. Building classroom with good acoustics is one of the important design considerations for new classrooms. Achieving this from the beginning is a straightforward solution to the acoustics problems that may be found inside the classroom; however, existing classrooms acoustics treatment is the only way to overcome the existing classrooms acoustics problems that affect the sound intelligibility inside the classroom and consequently affect the learning quality and learning outcomes. The aim is to develop a classroom acoustics treatment model. This model can be used by architectures, acoustics design engineers, and by infrastructure decision makers in an early stage of classroom acoustics treatment process to get better objective judgment about the criteria that could be managed and treated to achieve the acoustical conditions of universities classrooms, for enhancing learning quality, as will be explained in next sections.

* Corresponding author at: Research and Consultancy Dept., Deanship of Admission and Registration, King Abdulaziz University, Jeddah, Saudi Arabia.
E-mail addresses: amadbouly@kau.edu.sa, amadbouly@yahoo.com (A.I. Madbouly), anoaman@kau.edu.sa (A.Y. Noaman), aragab@kau.edu.as (A.H.M. Ragab), ahmedkhedra@kau.edu.sa (A.M. Khedra), afayoumi@kau.edu.sa (A.G. Fayoumi).

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The rest of the paper as follows: a review of literature is explained in Section 2, speech intelligibility and learning quality is explained in Section 3, the proposed CAAM model in Section 4. The Instruments used and model evaluation is explained in details in Section 5. The CAAM model analysis and results, and model's weights comparison and recommendations are explained in Sections 6 and 7, respectively. Findings and discussions, followed by the conclusion are explained in Sections 8 and 9, respectively. Then, Appendix (A) shows the items used for classroom acoustics survey using questionnaire. Appendix (B) shows how AHP was used for computing the ratings for each decision alternative for each quality criterion of the CAAM Model. Appendix (C) shows the detailed description of samples size used and the respondents' percentage for students, faculties and experts in each college.

2. Review of literature

In this section, we explain how the classrooms noise can affect the students learning process, and how we can avoid that. We also discuss the effective acoustics classrooms criteria that have to be considered in our proposed model.

Scannell et al. [37] reported that several studies have proven that, the acoustics are particularly important to students' learning and well-being especially in university classrooms and lecture halls. Shield et al. [40] stressed that there is a relationship between good acoustic design and good scholastic achievement, so we have to, optimize acoustic conditions for teaching and learning to improve scholastic achievement. Moreover, Kristiansen et al. [21] highlighted the significance of the optimal acoustical environment in school classrooms for learning and teaching.

There is no doubt that several factors led to the deterioration of environmental acoustics inside classrooms, especially with the evolution in the modern era. In the past, classrooms were quiet, pleasant and enjoyable [38]. In Bistafa and Bradley [6], a modern classroom study showed that modern classrooms have a relatively higher level of noise and more reverberation time values. As shown in Bistafa and Bradley [6], the lack of resources or funds is not the main reason for the existence of such acoustics problems existing in classrooms. But, the main reason is the lack of awareness and understanding of the problem by the professionals involved in teaching or in classroom design and the inability to find suitable solutions [6]. The work in Seep et al. [38] stated that the best way to solve acoustics problems is to avoid them in the design phase. Many researches proved negative impacts and effects of noise and the lack of clarity of talk and the lack of speech intelligibility not only on the efficiency of learning and the quality of teaching but also on the well-being of students and teachers.

Students are impaired by background noise and teachers suffer from raising their voice level to compensate high level of background noise and increase the signal to noise ratio (SNR) [12,18]. On the other hand, if the classroom acoustics were well designed and the acoustical properties inside the classroom were improved this will result in an improvement of learning and students' behaviour, and these results are registered in numerous studies [16,47]. The influence of acoustical adaptation on classroom's acoustical environment was studied [48]. It showed that acoustical adaptation in the classroom changed the values of acoustical parameters into the desired range. In addition, it showed that not only the amount of absorption plays a role, but also its placement is essential. The research [11], evaluated the effect of installation and use of sound field systems on the learning process and teaching in classrooms. It indicated that after installation of the sound system the student's understanding was improved. However, there are no much academic achievements shown. There was no much benefit from using the sound system in this regard. It noted that the classroom acoustics is an important factor that influencing the effectiveness of the sound field systems, and the classroom with poor acoustics benefited from the installation of such sound systems. Classrooms with good acoustics have no benefits from this installation. Adding such sound systems will increase the speech to noise ratio in classrooms with poor acoustics design.

Noise from the HVAC system contributes significantly to the background sound levels in a classroom or other learning space. Heating, ventilation, and air conditioning (HVAC) systems are an essential component of modern classrooms. However, HVAC systems are the most significant contributors to the background sound levels in a classroom or other learning spaces. To achieve the required acoustical standard of the classroom a standard HVAC system should be installed. Trane [43] showed that acoustical standard could be met using standard HVAC equipment without greatly increasing installed cost. It showed that meeting the acoustics requirements require good selection, design, and application practices. Classrooms acoustic quality assessment and the perception of teachers and students about the acoustic quality of the school environment have been studied in Zannin et al. [49], where the different aspects that affect the acoustics quality of classrooms were studied. It showed that location, construction, position or layout of the schools' recreational areas are important aspects that may affect speech intelligibility and the learning process in classrooms even if we have a well acoustically designed classroom.

In a subjective assessment [4] showed that both students and teachers perceive noise in the classroom and they are bothered by it. Moreover, they conducted a subjective and objective assessment of acoustical and overall environmental quality in classrooms. The study was carried out on fifty-one different classrooms, some were acoustically renovated. Measurements were carried on eight classrooms that represented the different types of classrooms in the subjective survey. This subject questionnaire included items on the overall environmental quality in classrooms and their aspects like acoustics design, thermal, visual quality and indoor air as well. It was found that the acoustics and visual quality inside the classroom have the greatest influence on the students' learning efficiency. The students were not satisfied with the quality of ventilation and heating in their classrooms, and acoustical conditions as well. As a result, a bad judgment of the overall quality was concluded. The effective weights of all the above acoustics classrooms criteria will be taken into consideration in the model proposed in this paper, as explained in next sections.

3. Speech intelligibility and learning quality

Airey and Mackenzie [1], defined speech intelligibility as, "the process whereby a person can clearly hear what is being said and fully understand the context of the spoken word". It describes the quality of the signal the listener receives; this quality is mainly dependent on the Direct-Reverberant-Ratio (influenced by the Reverberation Time) and the Signal-to-Noise-Ratio (influenced by the sources sound level, background noise and distance from the source to receiver), as shown in Fig. 1. The Reverberation Time is in its turn dependent on the absorbing qualities and dimensions of the materials in the room [10]. Some researches on this topic have been done in [5,19,42]. They concluded that the teacher voice level and the distance from the teacher to the student had a significant influence on the SI. These factors that affect speech intelligibility will be investigated in details while describing our proposed model, aiming to achieve better students learning quality. Speech intelligibility is usually interfered with by the excessive noise and reverberation inside classrooms. The measurement data analysis shows a positive correlation between internal ambient noise