

CAAM: A Novel Classroom Acoustics Assessment Model for Enhancing Learning Quality (Case Study: KAU)

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Abstract. In this paper, a new classroom acoustics assessment model (CAAM) 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 KAU decision makers to take effective decisions on classroom acoustics treatment issues. It also provides KAU higher authorities the suitable guidelines that help for determine 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

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. The quality and efficiency of this kinds of communications, and hence, quality of learning and teaching environment is measured by the acoustics conditions of the classrooms [1]. 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 [2].

Building classroom with good acoustics is one of the important design considerations for new classrooms. Achieving this from the beginning is a straight forward solution of the Acoustics problems that may be found inside classroom; however existing classrooms acoustics treatment is the only way to overcome the existing classrooms acoustics problems that affect the sound intelligibility inside classroom and consequently affect the learning quality and learning outcomes. The aim of the present research project is to develop a classroom acoustics treatment model that 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 KAU university classrooms.

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 we have to be considered into our proposed model.

The relationship between a well acoustically designed classroom and improvement of scholastic achievement showed that the presence of excessive background noise levels or reverberation in classrooms has a negative impact on academic achievement and the educational process as a whole [2]. It is shown in [4] that, the main reason of acoustics problems existing in classrooms 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. The work in [3] 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) [5, 6]. 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 on learning and students' behavior, and these results are registered in numerous studies [7]. In [8], the different aspects that affect the acoustics quality of classrooms were studied. It showed that location, construction, position or layout of the 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. Subjective assessment in [9] showed that both students and teachers perceive noise in the classroom and they are bothered by it. 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.

Speech intelligibility usually interfered with the excessive noise and reverberation inside classrooms. This cause result in reducing understanding and therefore reduced student learning and teaching quality. In many classrooms, the speech intelligibility rating is 75% or less [10]. Which means that, in speech intelligibility tests, listeners with normal hearing can understand only 75% of the words read from a list. Imagine reading a textbook with every fourth word missing, and being expected to understand the material and be tested on it. Sounds ridiculous are exactly the situation facing students every day in their classrooms.

The work explained in this paper proposes a classroom acoustics assessment model for enhancing learning quality. The effective weights of all the above acoustics class-

rooms criteria will be taken into consideration in the model proposed in this paper, as explained in next sections.

3 The CAAM proposed Model

Fig. 1 shows the components of the proposed CAAM model. It consists of five main criteria that affect the learning process and related to classrooms acoustical properties. These criteria are developed according to a previous study in [11]. Each criterion is described by set of alternatives. Twenty eight alternatives are suggested for education at KAU University. Three levels of hierarchy are constructed, the first level is the goal of decision model, the second level of hierarchy represents the proposed criteria that contribute to the goal achievement, and the last level of hierarchy represents the proposed alternatives that contribute to each of these criteria. Following is a description of each of these criteria.

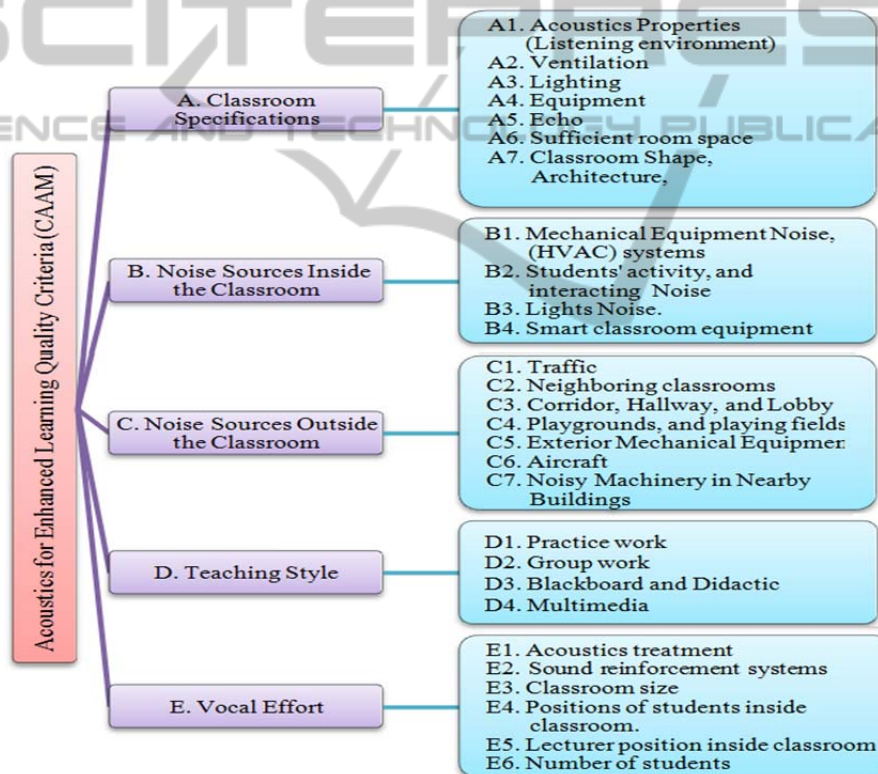


Fig. 1. The Proposed CAAM Model.

3.1 Classroom Specifications

It's one of the main criteria that affect the education quality. According to our proposed model this criterion includes seven alternatives named A1 to A7 defined as shown in Fig. 1. Maintaining a good classroom design requires an intensive study for various classroom specification related to education process. University classrooms that are used for scheduled classes are not limited in their use for a particular subject or discipline. Classrooms include general purposes, lecturing classroom, auditoriums, seminar room, and computer labs [12]. There are numerous factors affect the sound level in classroom, and hence the sound intelligibility. These include the Adequacy of space, Lighting, acoustics properties, ventilation, existing equipment inside the classroom, where the classroom is placed relative to other interior spaces in the building. For each type, different standard and specifications are required, as follows:

- *Acoustic Properties*, such as design of walls and ceilings to evenly distribute sound through the classroom, walls and ceiling acoustical treatment. Preserve reverberation time within standard ranges according to the volume of the classroom. And, to keep ambient noise level less than 35 decibels when measured with the A-scale of a sound level meter [12].
- *Lightening*, as stated in [13], "Successful lighting in a teaching environment should consider the quality, energy efficiency and flexibility of light necessary for a room – not just the quantity of light. Students and instructor should be supported with the appropriate luminance level but it should also be the right kind of light". Although low light levels inside classroom is a problem, too much lighting is also a problem; too much light can cause difficulties like glare, reflection, eye strain, etc. Lighting should be designed in accordance with the Illuminating Engineering Society's and the National Electrical Code's recommendations.
- *Equipment* and facilities, each classroom must be minimally-equipped with a data projector, projection screen, teacher's desktop computer, permanent network connection for students' computers/laptops [13].
- *Ventilation*, classroom designs must achieve certain level of comfort and effectiveness that will promote optimum conditions for study, listening, reading, and interaction [13]. Poor ventilation causes students to feel drowsy and not alert. Proper air flow and ventilation while keep quiet operation of mechanical systems in classrooms is an important factor [14].
- *Classroom Space*, if classroom is too small seating capacity will be reduced. Insufficient classroom space with narrow aisles, too small seats and work surfaces, too closed seats are uncomfortable and unacceptable design. Classroom must be designed to have a good sight lines and efficient seating layouts.
- *Classroom Architecture*, shape and style, where the building is situated; the size and shape of the room; its placement relative to other interior spaces; sound reflections inside classroom; the number, type, and location of sound sources, and the strength of the sounds they produce. All of these are important factors that affect the learning process and its quality.

To meet the optimum acoustical quality a careful attention is required to all of the above factors and specifications, as will be explained in the proposed model.

3.2 Noise Sources inside the Classroom

This criterion includes four alternatives named B1 to B4 defined as shown in Fig. 1. In order to reduce classroom internal noise, classrooms should be isolated from building mechanical systems, elevators, restrooms, vending areas, and other noise generating areas. Heating ventilation and Air condition (HVAC) system are one of the major sources of noise inside classrooms. That explain why HVAC system requires careful design, competent installation and balancing, and regular maintenance [14]. Many factors influence the classroom acoustical design; these include air handlers or fans, velocity of air inside the classroom, size and acoustical treatment of ducts, returns, and diffusers. Another source of noise inside classroom is the students themselves; side discussions, students' activities and interacting increase the noise levels inside classrooms. Noise generated for lighting equipment and other equipment and facilities existing in modern classrooms must be also considered. This criterion describes sources of noise generated within the classroom. Alternatives of this criterion includes HVAC system, noise generated form students' activity and interacting, lights noise, and noise generated from smart classroom equipment.

3.3 Noise Sources outside the Classroom

This criterion includes seven alternatives named C1 to C7 defined as shown in Fig. 1. In order to keep the ambient noise level inside classrooms within acceptable range classrooms should be separated from noise generating activities outside the classroom. Sound buffers must be used to reduce external noise, insulating walls, doors and windows could be used to increase the sound transmission class (STC) rating. This will reduce the noise level inside classrooms and will separate classrooms from noisy areas such as streets, parking lots, students gathering area, housing areas, recreation sites, and athletic fields [14]. This criterion describes sources of noise from outside the classroom. Alternatives of this criterion include traffic noise, noise from neighboring classrooms, noise coming from corridors, hallways and lobbies, noise from surrounding playgrounds, any noise comes from exterior mechanical equipment, aircraft noise, and noise generated from noisy machinery in nearby buildings.

3.4 Teaching Style

This criterion includes four alternatives named D1 to D4 defined as shown in Fig. 1. Achieving increased effectiveness, efficiency and the enhancement of student learning is the main goal of all universities. The quality of teaching and learning is totally depends on the teaching methods and styles used. "Teaching and learning styles are the behaviors or actions that teachers and learners exhibit in the learning exchange". Teaching behaviors reflect the beliefs and values that teachers hold about the learner's role in the exchange. This criterion considers factors related to teaching methods and strategies and how these factors may affect the learning process. Here, alternatives include practice work, group work and teaching using blackboard and didactic method, and using multimedia techniques to deliver course materials. These alternatives provide different ways of the communication between lecturers and students that of

course affect the learning outcomes. It must be noticed that these alternatives also affect the noise levels measured inside classroom by different values.

3.5 Vocal Effort

This criterion includes six alternatives named E1 to E6 defined as shown in Fig. 1. Vocal effort can be defined as the quantity that ordinary speakers vary when they adapt their speech to the demands of an increased or decreased communication distance. The communication distance in the previous definition is the distance between listener and the speaker. Vocal effect also varies if the classroom has noisy conditions. A change in speech mode from whispering to shouting will result due to the Variation in vocal effort. If the acoustics design of classroom is poor, or the distance between the lecturer and the students is increased, lecturer needs to speak with a raised voice level; this may be happened for long periods of time, causing lecturer's vocal strain. Sound reinforcement systems, lecturer's location inside the classroom with respect to students, and the number of students inside the classroom affect the amount of variation in vocal effort. Vocal effort criterion considers alternatives that may cause this to happen. Alternatives include classroom renovation and acoustics treatment, using sound reinforcement systems, Location selected by lecturers as their usual position inside the classroom with respect to students' position, and the effect of the number of students inside the classroom.

4 The CAAM Model Evaluation

Survey questionnaires are developed to collect information about current situation of classroom acoustics design at KAU. These questionnaires are adapted from a previous work in [14]. Two questionnaire are designed, one for students and the other for faculty members and expertise. Different colleges at KAU have different classroom sizes with different acoustics classroom designs. The two questionnaires are developed, reviewed and updated with the assistance of KAU architectural design engineers and acoustics expert consultants. Based on the results from these surveys, the main criteria and alternatives of the proposed model are identified. Then, the architecture hierarchy process (AHP) [15], is used as a tool for assessment of the weights of the model criteria and their priority. Table1 shows the main criteria pairwise comparison matrix produced using the AHP method. Based on the data collected from questionnaires, a group of five main criteria with a total of 28 alternatives are identified, for enhancing service education quality at KAU. Results in Table1 show the main five criteria, including:

- Classroom Specifications (A),*
- Noise sources inside the classroom (B),*
- Noise sources outside the classroom (C),*
- Teaching Style (D) and Vocal Effort (E).*

They are ranked with 26%, 23%, 21%, 17%, and 13% due to their importance levels, respectively. The analyses of these criteria are explained in details next sections.

Table 1. QAAM Main Criteria Pairwise Comparison Matrix.

	A	B	C	D	E	Weights
A	1.00	1.00	1.00	2.00	3.00	26 %
B	1.00	1.00	1.00	2.00	2.00	23 %
C	1.00	1.00	1.00	1.00	2.00	21 %
D	0.50	0.50	1.00	1.00	2.00	17 %
E	0.33	0.50	0.50	0.50	1.00	13 %

5 Results and Discussions

Based on the data collected from section 4 above, Table 2 summarizes the results of CAAM model criteria and the weights of their 28 alternatives, produced by analyzing the pairwise matrices ;using AHP method; for the five main model criteria.

Table 2. Proposed Standards and criteria of CAAM.

#	CAAM Criteria	Alternatives	Weights related to main criteria	Weights related to CAAM	Average Weights
A.	Classroom Specifications (26%)	A1. Acoustics Properties (Listening environment)	25%	6.50%	3.71%
		A2. Ventilation	18%	4.68%	
		A3. Lighting	16%	4.16%	
		A4. Equipment	13%	3.38%	
		A5. Echo	12%	3.12%	
		A6. Sufficient room space	8%	2.08%	
		A7. Classroom Shape, Architecture, and Style	8%	2.08%	
B.	Noise Sources Inside the Classroom (23%)	B1. Mechanical Equipment Noise, (HVAC) systems	33%	7.59%	5.75%
		B2. Students' activity, and interacting Noise	25%	5.75%	
		B3. Lights Noise	22%	5.06%	
		B4. Smart Classroom Equipment	20%	4.60%	
C.	Noise Sources Outside the Classroom (21%)	C1. Traffic	20%	4.20%	3.00%
		C2. Neighboring classrooms	18%	3.78%	
		C3. Corridor, Hallway, and Lobby	16%	3.36%	
		C4. Playgrounds, and playing fields	14%	2.94%	
		C5. Exterior Mechanical Equipment	12%	2.52%	
		C6. Aircraft	11%	2.31%	
		C7. Noisy Machinery in Nearby Buildings	9%	1.89%	
D.	Teaching Style (17%)	D1. Practice work	30%	5.10%	4.25%
		D2. Group work	25%	4.25%	
		D3. Blackboard and Didactic	25%	4.25%	
		D4. Multimedia	20%	3.40%	
E.	Vocal Effort (13%)	E1. Acoustics treatment	22%	2.86%	2.17%
		E2. Sound reinforcement systems	18%	2.34%	
		E3. Classroom size	17%	2.21%	
		E4. Positions of students inside classroom.	16%	2.08%	
		E5. Lecturer position inside classroom	14%	1.82%	
		E6. Number of students	13%	1.69%	

5.1 Room Specification (A)

Seven criteria are used to characterize related room specifications. Both faculty members and students were asked to give the importance rating of various criteria of their classroom. Results are shown in Table 2, where the acoustics properties (listening environment) of the surveyed classrooms were the most important criteria. It can affect classroom specifications with a 25% importance level. The second important criterion for this criterion is the ventilation, with 18% importance level. Lighting is the third important criterion that can affect room specifications in model with 16% importance level. Equipment inside the classroom comes in the fourth rank with 13% importance level. Echo, sufficient classroom space, and classroom shape, architecture and style have 12%, 8%, and 8% importance level, respectively. Further details of these ratings in relation to the model design are given in Table 2.

5.2 Noise Sources inside the Classroom (B)

Students and faculty members surveyed reported that noise generated within the classroom is a big problem that affects the learning process. They have reported that most of the noise exiting inside the classroom is from the Mechanical Equipment (HVAC) systems, and the importance level of this criterion is 33% with respect to this criterion. The second source of noise is the students' activity and interaction with an importance level of 25%. Noise coming from lights inside classroom affects the noise inside the classroom with 22% importance level. Smart classroom equipment like computers, projectors, keyboards, printers etc. were also identified as common source of noise generated within new classrooms with an importance level of 20%. Further details of weights of these criteria related to the model design are given in Table 2.

5.3 Noise Sources outside the Classroom (C)

Another important factor that affects the learning quality inside classroom is noise that comes from outside the classroom. Students and faculty members surveyed reported problems with noise generated outside the classroom e.g. from traffic, neighboring classrooms, corridors, hallway, lobby, playgrounds and playing fields, exterior mechanical equipment, aircraft, and noise generated from machinery in nearby buildings. Noise from traffic and from other classrooms were the most frequently reported external noise problems with an importance level of 20% and 18% respectively. Noise from corridors, hallway and lobby has importance level of 16% with respect to other sources of noise from outside classroom. Noise from playgrounds and playing fields, exterior mechanical equipment, aircraft, and noise generated from machinery in nearby buildings were rate 14%, 12%, 11%, and 9% respectively.

5.4 Teaching Style (D)

One of the key criteria found and has been highlighted by both students and faculty members in this survey were the teaching style. Traditional lecturing style is no long-

er the dominant style in teaching nowadays. Results showed that practice work has 30% importance level in teaching style for the time being. And, group work has an equal importance level as blackboard and Didactic teaching style with a value of 25%. While new technologies and multimedia used in teaching these days has an importance level of 20%.

5.5 Vocal Effort (E)

In our survey faculty members rated the criteria of acoustics treatment as the most important criterion that may affect the Criteria of Vocal effort with a 22% importance level. They also rated the sound reinforcement systems criterion with a value of 18% importance level. The classroom size was reported to affect vocal effort with a percentage of 17%. Positions of students inside classroom criterion and lecturer position inside classroom criterion were rated as 16% and 14% respectively. Finally the number of students has been evaluated to 13% importance level in terms of its importance in influencing the vocal effort.

All weights related to each criterion are shown in Table2. An overall ranking for criteria's weights related to the CAAM Model is shown in Fig. 2. It shows that B1 "the noise from the Mechanical Equipment systems" has the highest noise effect in the classroom.

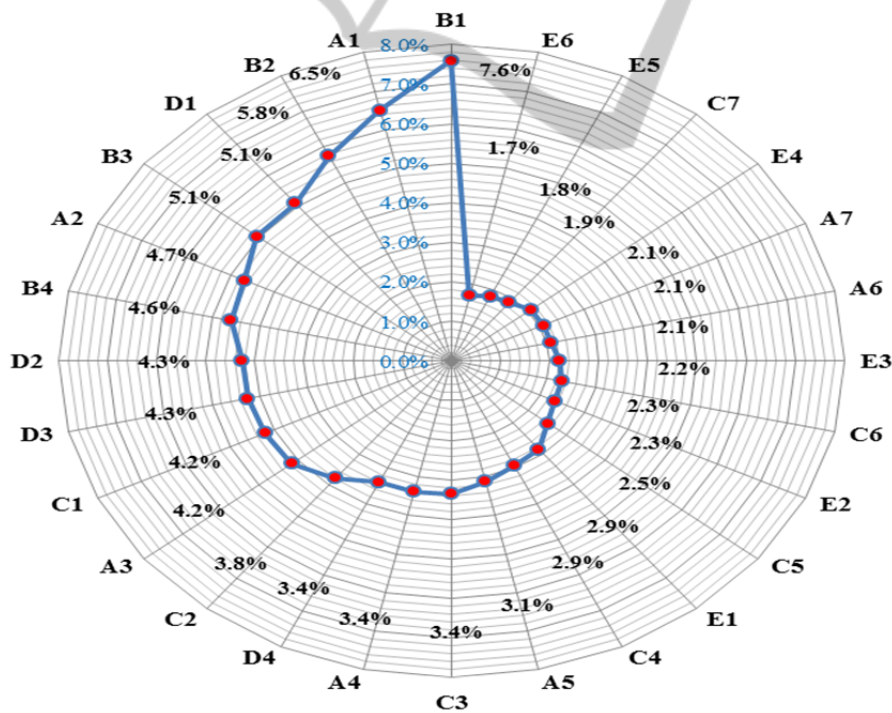


Fig. 2. Ranking of all alternatives' weight related to the CAAM Model.

6 Conclusions

Achieving good acoustics design must be considered at the early stages of new classroom design. Renovating existing classrooms through acoustics treatment will help improve learning quality and enhance the overall education process by enhancing speech intelligibility. The work in this paper proposed an acoustics classroom model for enhancing learning quality. It can help acoustics design engineers, architects, and infrastructure decision makers to do a better first step estimate and do a well-focused study about acoustical problems at KAU classrooms. This will help to take accurate decisions and to manage the treatment phase in a proper way. The priority and weights of the model criteria along with their alternatives were identified using the views of students, staff, education consultants, and expertise using a developed questionnaire, and the AHP methodology. This model can also be generally used for other universities and schools as well. The proposed model adds important dimensions and recommendations that have to be taken into considerations in advance before starting the classroom renovation and acoustical treatment process.

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