Applied Acoustics 89 (2015) 42–45

Contents lists available at ScienceDirect

Applied Acoustics

journal homepage: www.elsevier.com/locate/apacoust

Technical Note

# An investigation of acoustic treatment for children in a classroom of an elementary school

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ARTICLE INFO

*Article history:*
Received 8 July 2014
Received in revised form 26 August 2014
Accepted 4 September 2014

*Keywords:*
Elementary-school classroom
Objective acoustic parameter
Speech intelligibility
Questionnaire survey
Reverberation time
Noise

ABSTRACT

In this article, objective acoustic parameters and students' subjective responses were compared before and after an acoustic treatment in an elementary-school classroom. Acoustic treatment was done by installing sound absorption materials on the ceiling of the classroom for control of sound reverberation. The effects of reverberation time on children's speech recognition have also been investigated. Results show that (1) the objective acoustic parameters in the classroom were obviously improved; (2) the subjective loudness of different types of noise sources, that students experienced in the classroom, were reduced; and (3) the speech intelligibility was significantly improved in the classroom after the acoustic treatment.



## 1. Introduction

Multiple reflections of speech's sound by reflecting surfaces, such as walls, floors and windows, are occurred during teaching in classrooms. The receiving speech signals at students' ears will no longer be the original speech signals by the teachers, but it will be contaminated by reverberation as well as background noise. It is well known that reverberation is critical in children's verbal communication and learning [1–5]. Excessive reverberation smears the temporal properties of speech signals by the teacher and directly reduces the speech articulation in classrooms [3]. It may result in reduction of the students' comprehension in their lectures. Previous study showed that signal-to-noise ratio and reverberation time are two important factors affecting verbal communication between teachers and students in classrooms, especially for young children [6,7]. It is because children's auditory system and cognition have not been fully developed until 13–14 years old [4,5]. Acceptable acoustic environment for adults does not mean necessarily satisfying the needs of children. To achieve the same speech intelligibility scores as adults, children require higher SNR and less reverberation time in classrooms [4,5]. In the present study, acoustic ceiling system was installed in a primary school classroom to control reverberation. Objective acoustic parameters and the students' subjective responses were compared before and after the acoustic treatment in the classroom. In addition, the effect of various reverberation times on children's speech recognition was discussed.

## 2. Measurement setup

The classroom being tested is in rectangular shape with dimensions of 9.35 m in length and 7.90 m in width. The headroom is 3.70 m and 3.15 m before and after the acoustic treatment, respectively. The classroom layout has shown in Fig. 1. There are two blackboards on the front and back walls of the classroom, respectively. The floor is covered with ceramic tile. There are two large window areas on left and right walls. The walls are painted and plastered brick walls. The ceiling is smooth and painted concrete before the acoustic treatment. For the acoustic treatment, mineral-fiber acoustic ceiling tiles with 1.5 cm thickness were installed on the ceiling (Brand: Armstrong; Model: School Zone Smart; Specification: Noise reduction coefficient (NRC) > 0.60, Ceiling attenuation class (CAC) = 33 and Light reflectance (LR) = 0.85). Typical sound absorption coefficients of the ceiling tiles are shown in Table 1. There is 53-cm-height cavity above the ceiling tiles.

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http://dx.doi.org/10.1016/j.apacoust.2014.09.005
0003-682X/

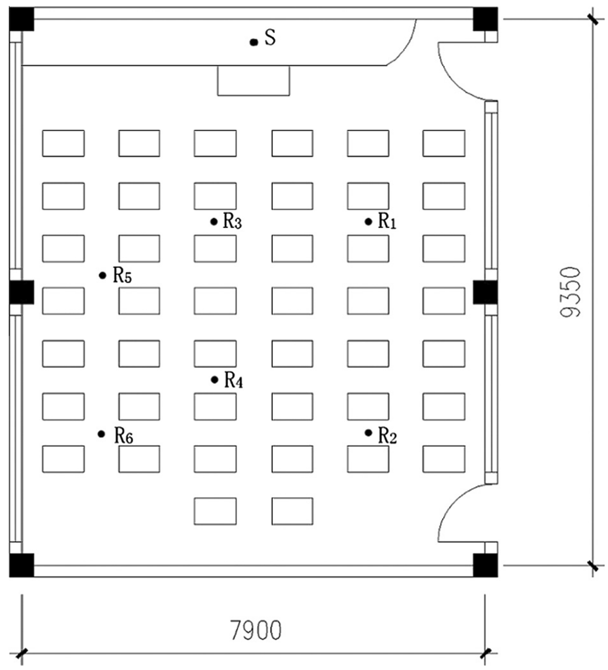


**Fig. 1.** Layout of classroom (S: source position; $R_1$–$R_6$: receiver positions).

**Table 1**
Sound absorption coefficient of ceiling tiles.

| Octave band/Hz | 125 | 250 | 500 | 1000 | 2000 | 4000 |
|---|---|---|---|---|---|---|
| Absorption coefficient | 0.39 | 0.48 | 0.61 | 0.76 | 0.71 | 0.46 |

## 3. Results and discussions

### 3.1. Comparison of objective acoustic parameters

To compare the changes of objective acoustic parameters before and after the acoustic treatment, room impulse responses between the source and six listening (receiving) positions in the classroom were measured using a sine sweep signal. A sound source (JBL-LSR6325P loudspeaker), that its directivity is similar to human mouth, was located at the center of the teaching platform in front of the classroom during the measurement. The loudspeaker was set 1.5 m above the floor and 0.5 m from the blackboard on the front wall. The receiving positions were located in the students' sitting area (i.e. listening positions). The receiving microphone was set 1.1 m above the floor. The arrangement for the sound source and receiving points shows in Fig. 1. Objective acoustic parameters, such as early decay time (EDT), reverberation time ($T_{30}$), clarity ($C_{50}$) and definition ($D_{50}$), were calculated from the measured room impulse responses at these listening positions. Comparison of the average values for objective acoustic parameters at the six listening positions before and after the acoustical treatment is shown in Fig. 2. It can be seen from Fig. 2 that the objective speech intelligibility parameters such as EDT, $T_{30}$, $D_{50}$, and $C_{50}$ were significantly improved after the acoustic treatment on the ceiling. EDT and $T_{30}$ at each octave band have been reduced by around 50% with the acoustic treatment. The $D_{50}$ at mid-frequencies (500–2000 Hz octave bands) were improved over 70% with the acoustic treatment. The $C_{50}$ at mid-frequencies (500–2000 Hz octave bands) were improved more than 70% and average over 6 dB with the acoustic treatment. The speech transmission indexes (STIs) were calculated from the room impulse responses without consideration of background noise. The STI values were 0.55 and 0.74 before and after acoustic treatment on the ceiling, respectively. The STI was improved by 0.19 (i.e. 35%) after the acoustic treatment on the ceiling. From the evaluation of objective acoustic parameter, the objective speech intelligibility should be obviously improved after the acoustic treatment in the classroom.

### 3.2. Questionnaire survey

Subjective evaluation of classroom's acoustic environment before and after the acoustic treatment has been performed through a student survey using questionnaires. The questions and results of the questionnaire survey were shown in Tables 2 and 3. Five-point scale (i.e. −2, −1, 0, 1, and 2) representing "much worse", "worse", "neutral", "improved", and "much improved", respectively, was used for the students to provide their feedbacks at each question. For example, −2, −1, 0, 1 and 2 are "much less clear", "less clear", "unchanged", "clearer" and "much clearer", respectively, in the Question 2. Forty-four students in grade 3 with age between 8 and 9 years old participated in this test. There were 23 male and 21 female students. It can be seen from Table 2 that most of the students felt reduction of echo (or reverberation) in the classroom with the acoustic treatment. The students also felt easier to concentrate on the lessons and clearer to hear the teacher's speech in the treated classroom compared to that before the ceiling's modification. Half of the students thought that noise in the classroom has been reduced during the lesson, while few subjects (9 students or 20.0%) felt the noise was increased. The noise perceptions in the classroom have been further analyzed, and students felt that the noise in the classroom from various sources was reduced after the acoustic treatment as shown in Table 3.

It is necessary to point out that the students may not be very familiar with the concept of echo during the survey for the Question 4 in Table 2. There are 19 students (43.2%) who thought that the echo in the classroom was unchanged or increased. However, 38 students (86%) in the classroom felt that they could listen to the teacher's speech more clearly in the treated classroom than that before the acoustic treatment.

Regarding the change of noise perception in the classroom, some students thought that the noise was reduced after the acoustic treatment in the classroom. Moreover, most of the students thought that the noise from the playground was reduced. It may be due to that door and window were basically open during the class. In addition, the classroom is located near to and higher than the playground. The noise from the playground can be partly absorbed by the absorptive ceiling before it reaches the students. Therefore, most of the students felt that the noise from the playground was decreased. The noise from streets outside the school is mainly traffic noise from highways. Half of the students thought that the traffic noise was also decreased. This can be explained by the similar reasons for the noise from the playground. Because of the sound absorption on the ceiling, the reflected fan noises from the ceiling to the students were also reduced in the classroom. For the students sitting below the fans, direct sound from the fans is dominant. The acoustic treatment on the ceiling cannot decrease the noise level at these positions; therefore, around half of the students thought that the fan noise was reduced.

The noise from the adjacent classes and corridors were mainly transmitted through the walls and windows. Also, noise from classmates around the subjects was dominated by direct sound. Sound absorption on the ceiling was ineffective to control these types of noise. However, these three types of noise were more unsteady or intermittent; therefore, some students still felt that these noises were reduced.