



An investigation into the acoustics of an open plan compared to enclosed Kindergarten classroom

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ABSTRACT

Open plan classrooms, where several class bases share the same space, have recently re-emerged in Sydney primary schools. This case study examines the acoustics of a mid-range open plan Kindergarten classroom containing 91 students, compared to an enclosed classroom of 25 students. Ambient noise levels, intrusive noise levels, occupied background noise levels, and teacher's speech levels were recorded in both classrooms during different activities. Room impulse responses using logarithmic sweeps were also recorded in each classroom for different teaching scenarios. From these recordings, signal-to-noise ratios, speech transmission index scores, and reverberation times were calculated. The results revealed much higher intrusive noise levels in the open plan classroom, resulting in signal-to-noise ratios and speech transmission index scores to be well below those recommended in classrooms with students of this age. Reverberation time in the open plan classroom was also outside the recommended level. Additionally, occupied background noise levels in both classroom types were well above recommended levels. These results show the importance of further research into the noise levels of open plan classrooms to determine if they are suitable learning spaces for young students. The impacts of noise on speech perception, learning, and teacher's vocal health are discussed.

Keywords: Classroom acoustics, open plan classrooms I-INCE Classification of Subjects Number(s): 51.1.4; 63.3

1. INTRODUCTION

Primary school is a child's first experience of formal learning, preparing them for higher education and life through literacy, numeracy, and other diverse skills. As the primary modes of communication in the educational setting are speaking and listening, it is important that the acoustic environment be conducive for enhancing learning opportunities for young children. On average, children spend 45-60% of their time at school listening and comprehending, so they need to be able to discriminate the speech signal from the vast variety of other competing noises present in the classroom environment (1). Interfering background noises include external noises from outside the classroom (e.g. traffic and construction work), intruding noises from adjacent rooms and corridors (e.g. talking and movement), and internal noises from within the classroom (e.g. talking, movement, and air-conditioning unit and equipment noise). High noise levels result in poor signal-to-noise ratios (SNRs); a direct measurement of the intensity of the signal (e.g. the teacher's voice) compared to the background noise level. In addition, the use of sound reflecting building materials adds reverberation to both the background noise and the speech signal. The synergistic combination of noise and reverberation results in masking and distortion of the speech signal, reducing speech intelligibility (2,3).

Noise generated by other children is the major noise source found in classrooms (4). Noise levels are reported to be highest in the classrooms of the youngest children (5) which is also the age group

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worst affected (6). High noise levels adversely affect speech perception, cognition, concentration, and the psychoeducational and psychosocial achievement of the child (2,3,7,8). Children with hearing impairments, and/or those who have English as a second language, (ESL) are even more affected by poor classroom acoustics (5,7,9).

Furthermore, it is not only the students who suffer from poor classroom acoustics. While only 5% of the general population experience vocal fatigue, it is experienced by 80% of teachers, putting them at high risk of vocal abuse and pathological voice conditions from the need to constantly raise their voice above a comfortable level to be heard (10,11). Noise also raises blood pressure, increases stress levels, causes headaches, and results in fatigue (7,11,12). Teachers in classrooms with poor acoustics are more likely to have sick days off work and believe their job contributes to voice and throat problems (5). These adverse impacts indicate the importance of controlling noise levels for both teachers and students in the educational setting. However, several American studies have shown that classroom acoustic environments rarely report favourable listening conditions (8,13). While it is generally recommended that ambient background noise levels should not exceed 35 dBA, reverberation times (RTs) should be less than 0.4 s, and SNRs should be greater than +15 dB (5,7,14,15), many studies have shown that ambient background noise levels reach 60 dBA, SNRs are between -7 to +5 dB, and RTs range from 0.4 to 1.2 s (2,8,16). In occupied classrooms, student generated noise creates the highest noise levels measuring between 50-70 dBA (2,15). Particularly of concern is that despite noise levels already being excessive in traditional enclosed classrooms with 20-30 children, there is a current trend of replacing these enclosed classrooms with new open plan 'flexible learning spaces'. Open plan classrooms are perceived to be less authoritarian, more secure and 'home-like', and allow for a range of activities to be carried out facilitating group work and social development (17,18). These open plan classrooms can result in up to 200 children sharing the same area (19). Along with this increase in numbers, an increase in child-generated noise would be expected. Given there are no acoustic barriers between classes, these noise levels are likely to be particularly distracting when one class is trying to listen to their teacher while the other classes are engaged in noisy doing group work activities. A previous study in the UK showed that this intrusive noise (i.e. the noise from adjacent classes when the main class is empty/quiet) ranges from 47-62 dBA (20). Few studies, however, have compared the acoustics between open plan and enclosed classrooms, especially in regard to intrusive noise levels. Therefore, the aim of this case study was to compare the classroom acoustic variables (i.e. RTs, noise levels, SNRs, speech transmission index scores (STIs)) in an open plan compared to traditional enclosed Australian kindergarten classroom. It was hypothesised that, due to the larger room volume and increased number of students, the RTs and noise levels would be higher in the open plan classroom resulting in lower SNRs and STIs.

2. METHOD

2.1 Schools Involved

The participating open plan Sydney school consisted of 91 Kindergarten students grouped linearly into three classes (K1, K2, K3), with no barriers between them. The number of students in open plan classrooms in Sydney tends to range between 40-200 students divided into class bases of 20-30 children, hence this classroom represented a mid-range student and class base number. The room was 37 m by 11 m with a ceiling height of 3.3 m and approximately 6 m between each class base. The Year 1 and 2 classes were located off an adjacent corridor but had no doors/walls separating the spaces. The class area was carpeted but the corridor was a hard surface. Windows were located on both the front and back walls (Figure 1).

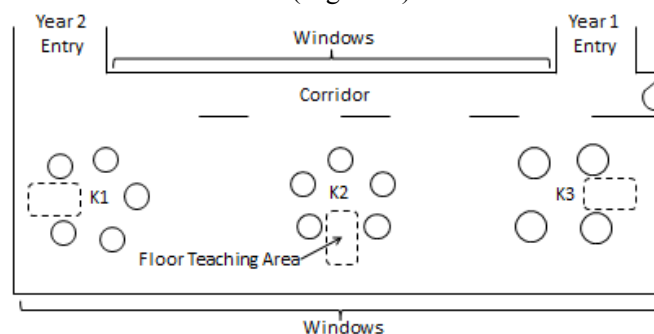


Figure 1 – Classroom floor plan of open plan Kindergarten classroom

The participating enclosed Sydney school consisted of 25 Kindergarten students in a classroom with 3 solid walls, a closed concertina wall and a shared store room with the adjacent Kindergarten class. The room was 8 m by 9 m with a ceiling height of 3 m. The class area was carpeted and windows were located on both side walls (Figure 2). Primary school classrooms with concertina walls and/or shared storerooms are typical of those found in the Sydney region.

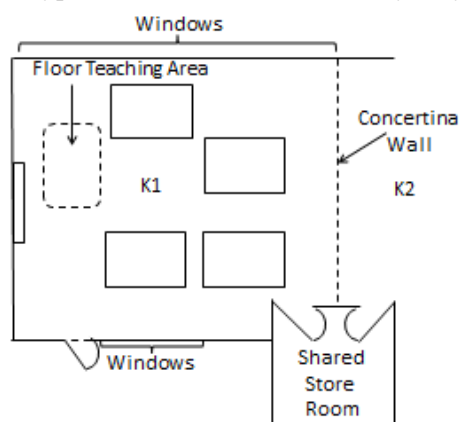


Figure 2 – Classroom floor plan of enclosed Kindergarten classroom

2.2 Procedure

2.2.1 Classroom Activities

Previous research shows that noise levels in classrooms are dependent on the activity that the students are engaged in (4,21). For our study we chose two different activities (one representing a quiet activity and the other a noisy activity) to record the noise levels in:

- 1) Whole class teaching: This critical listening activity involves the children sitting on the floor in front of their teacher. During this activity only one person is speaking at a time - either the teacher or a child giving an answer.
- 2) Group work: This activity involves the children sitting at tables or on the floor working together on tasks. It may also involve children moving around the classroom. During this activity many people are speaking at the same time.

The proportion of time spent in each of these activities from a survey of the Kindergarten teachers at the schools involved is shown in Table 1. These proportions are consistent with those found in previous studies (21).

Table 1 – Teachers' report of proportion of time spent in various classroom activities

Classroom type	Whole class teaching time (%)	Group work time (%)
Open plan	40	40
Enclosed	25	45

2.2.2 Equipment

The microphones used for the study included an omnidirectional DPA dual-ear lapel microphone and three ½" omnidirectional condenser microphones. The condenser microphones were used for both noise recordings as well as Room Impulse Response (RIR) measurements, and were calibrated in diffuse speech-shaped noise using a B&K 2250 sound level meter. The lapel microphone was used for recording the teacher's voice and calibrated as described in Section 2.2.5. The microphones were connected to a RME Quadmic 4-channel microphone preamplifier. A Tannoy VX8 concentric loudspeaker connected to a Yamaha AX-350 hifi stereo amplifier was used for measuring the RIRs. The computer was a standard PC using RME Hammerfall HDSP 9632 internal soundcard inclusive expansion boards. Adobe Audition software was used for the recordings and MATLAB software was used for the RIR measurements.

2.2.3 Noise recordings

Noise recordings for four different scenarios were made in the main class base so that levels could be calculated and compared to acoustical guidelines:

- 1) Ambient noise levels (ANL): This recording was taken inside the classroom after school when the classes were completely vacated. It measured the internal and external noise generated by, for example, air conditioning units and road traffic. The recommended ANL

for classrooms is < 35 dBA as shown in Table 2.

- 2) Intrusive noise levels during quiet activities (INL(Q)): This recording was taken when the main class base was empty and the other class bases were engaged in whole class teaching.
- 3) Intrusive noise levels during noisy activities (INL(N)): This recording was taken when the main class base was empty and the other class bases were engaged in group work.
- 4) Background noise levels (BNL): This recording was taken when the main class base was occupied and all class bases were engaged in group work. The recommended BNL (hence INL) for classrooms is < 50 dBA as shown in Table 2.

For each condition, three omnidirectional condenser microphones on stands at 1 m height were placed around the class area of the main class base. Adobe Audition software was used to record the noise levels at each microphone. Each recording was listened to and any artefacts (such as children touching or directly speaking into the microphone) were removed.

Table 2 – Recommended values for acoustic parameters in classrooms

Measurement	Recommended value	Reference
ANL	< 35 dBA	(22)
BNL, INL	< 50 dBA	(23)
SNR	$+ 15$ dBA	(2)
STI	> 0.75 (for 6-year-olds)	(21)
RT	$< 0.4-0.5$ s (unoccupied)	(22)

2.2.4 Room impulse responses and reverberation time

RIRs for three different teaching scenarios were measured in the main class base with 30 s long logarithmic sweeps using a Tannoy VX8 loudspeaker and three calibrated omnidirectional microphones. Based on these measurements, RTs and STIs were calculated and compared to the acoustical guidelines summarized in Table 2. The RIRs were also used to predict the teacher's voice levels inside the classrooms as further described in Section 2.2.5. RIRs were recorded for the following scenarios:

- 1) Whole class teaching: The loudspeaker at a height of 1.2 m (representing teacher sitting on a chair in front of students) was placed at the front of the class. Three microphones at an average height of 0.45 m (representing students sitting on the floor) were placed front to back in front of the loudspeaker.
- 2) Teacher addressing single table of students: The loudspeaker at a height of 1.5 m (representing teacher standing in front of students) was placed in front of the table. Three microphones at an average height of 0.7 m (representing students sitting on the chairs) were placed around the table.
- 3) Teacher addressing all tables and students: The loudspeaker at a height of 1.5 m (representing teacher standing in front of students) was placed at the front of the class. Three microphones at an average height of 0.7 m (representing students sitting on the chairs) were placed around different tables.

The unoccupied reverberation time (T30) was derived from the measured RIRs according to ISO 3382-2 (24) using the Odeon software. The T30 was first derived in octave bands and then averaged across the bands with centre frequencies of 500, 1000, and 2000 Hz. For each scenario the broadband RT was finally averaged across the three applied microphone locations. The recommended RT for classrooms is $< 0.4-0.5$ s as shown in Table 2.

2.2.5 Calculation of teacher's average speech levels

The teachers of the main class bases had their speech recorded during whole class teaching. An omnidirectional DPA dual-ear lapel microphone was placed approximately 3 cm from the teacher's mouth and recordings were made using Adobe Audition software. These recordings were then convolved with the measured RIRs for the three teaching scenarios (Section 2.2.4) to estimate speech levels for each scenario at three listening positions. To remove voice level differences between teachers, speech levels were predicted by using concatenated and equally long speech samples from all teachers as input signal. To provide accurate speech level estimates, the involved equipment and signal processing was calibrated by comparison to a similar recording performed in an anechoic chamber at the National Acoustic Laboratories, Australian Hearing Hub. Twelve talkers were recorded using the DPA lapel microphone as well as a calibrated B&K 4134 microphone

placed 2 m in front of the talkers and attached to a B&K 2610 measurement amplifier. Additionally the corresponding (anechoic) RIR was measured by replacing the talkers by the same Tannoy VX8 loudspeaker system used in the classroom measurements. By comparing the spectra (and RMS levels) of the direct speech recording at 2 m distance with the corresponding RIR-based simulation allowed the derivation of calibration filters that were then applied to the speech recordings and RIR measurements performed in the different teaching scenarios.

2.2.6 Calculation of SNRs

Average signal-to-noise ratios were derived for the different teaching scenarios between the teacher's speech level (in dBA) and the noise levels (also in dBA) described in Section 2.2.3. SNRs were calculated using the average teacher's speech levels at the front, middle, and back of the whole class teaching seating area (as described in Section 2.2.4) and the average noise levels recorded in the same areas and described in Section 2.2.3. SNRs were obtained for the three noise conditions that whole class teaching takes place in, i.e. ambient noise, intrusive noise when the other classes are engaged in quiet activities, and intrusive noise when the other classes are engaged in noisy activities. The recommended SNR for 6-year-olds is +15 dBA as shown in Table 2.

2.2.7 Calculation of STIs

The speech transmission index provides a guide to how intelligible speech is in a room by measuring the distortion introduced into the speech transmission channel from the source to the receiver, taking into account both reverberation and noise (5). The STI is represented on a scale from 0 to 1, with 0 indicating that no speech would be understood and 1 indicating that all speech would be understood. We calculated the STIs at the front, middle, and back of the whole class teaching seating area using the RIRs without noise (to demonstrate the effect of the room's reverberation alone), and with the three noise conditions described in Section 2.2.3. STIs were also calculated using the BNLs when the teacher was addressing a single table of students and when they were addressing the whole class doing group work at their tables. Recommended STIs are shown in Table 3 (5). It is important to note, however, that the STI was developed for adults. Given that children need more favourable listening situations, it is recommended that the STI should always be > 0.75 for 6-year-olds, as shown in Table 2 (21).

Table 3 – STI categories

STI value	Rating
0.000 – 0.300	Bad
0.301 – 0.450	Poor
0.451 – 0.599	Fair
0.600 – 0.749	Good
0.750 – 1.000	Excellent

3. RESULTS

3.1 Noise levels

The average noise levels for the four different scenarios described in Section 2.2.3 are shown in Figure 3. As previously stated, the recommended maximum INLs and BNL should be 50 dBA and the SNR for 6-year-olds should be +15 dBA (see Table 2). Note that although the ANLs are slightly higher than those recommended in Table 2, the enclosed classroom design keeps the INLs at an acceptable level. In contrast, for the open plan classroom, the recommended INLs are well exceeded. The BNLs, however, are well above recommended levels irrespective of the classroom design. These results show that the BNLs when all children are doing group activities can be problematic in both classroom types, but enclosed classrooms have the advantage during whole class teaching of minimizing the intrusive noise from other classes.

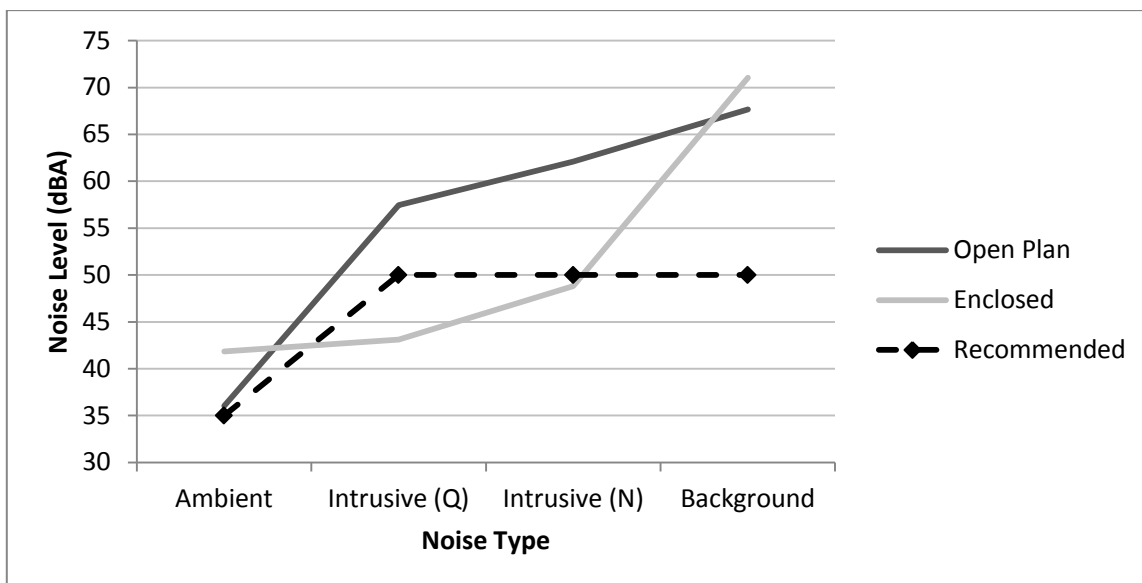


Figure 3 – Recorded noise levels during different scenarios for the open plan and enclosed classrooms

3.2 Reverberation Times

The average unoccupied RTs were calculated in each classroom as described in Section 2.2.4. For the open plan classroom, the mean RT was 0.7 s (*range* = 0.6-1 s, *SD* = 0.1). This is outside of the recommended RT of 0.4-0.5 s, but is not unusual of RTs found in previous studies of classroom acoustics (13). The mean RT for the enclosed classroom was 0.5 s, (*range* = 0, *SD* = 0) putting it within the upper limit of the recommended RTs (22).

3.3 Teacher’s average speech levels

The average speech levels for the teachers in both classrooms are summarized in Table 4. These were used to calculate the SNRs given in Section 3.4. These levels are consistent with the findings of Sato and Bradly (25).

Table 4 – Teacher’s speech levels for the open plan and enclosed classroom during different activities

Teaching scenario	Classroom type	Teacher’s speech level (dBA)						Child’s average distance (m)
		Front	Mid	Back	Mean	SD	Range	
Whole class teaching	Open Plan	62.0	58.2	55.2	58.5	3.5	55.2-62.0	2.5
	Enclosed	60.6	60.1	59.0	59.9	0.8	59.0-60.6	2.1
Teacher addressing single table	Open Plan	65.4	62.3	59.7	62.5	2.9	59.7-65.4	1.1
	Enclosed	61.3	64.1	59.0	61.5	2.6	59.0-64.1	1.4
Teacher addressing all tables	Open Plan	54.7	51.9	53.4	53.4	1.4	51.9-57.4	3.8
	Enclosed	56.2	56.8	52.2	55.1	2.5	52.2-56.8	3.8

3.4 SNRs

The measured SNRs during whole class teaching are summarized in Figure 4 for the three relevant noise conditions listed in Section 2.2.3. When the ambient noise in the room is the only noise source, SNRs meet the required criteria for both classroom designs. However, as soon as intrusive noise from other classes is introduced (even just from quiet activities), the SNRs dramatically drop well below the recommended level in the open plan classroom. This problem is further increased when the activities of the other classes changes to noisy group work activities, resulting in SNRs between +0.8 and -6.1 dBA in the open plan classroom. However, for the enclosed classroom, the SNRs stay above +15 dBA when the other classes are engaged in quiet activities, and only drops as far as +12.7 dBA (at the back of the room) when the other classes are engaged in noisy activities.

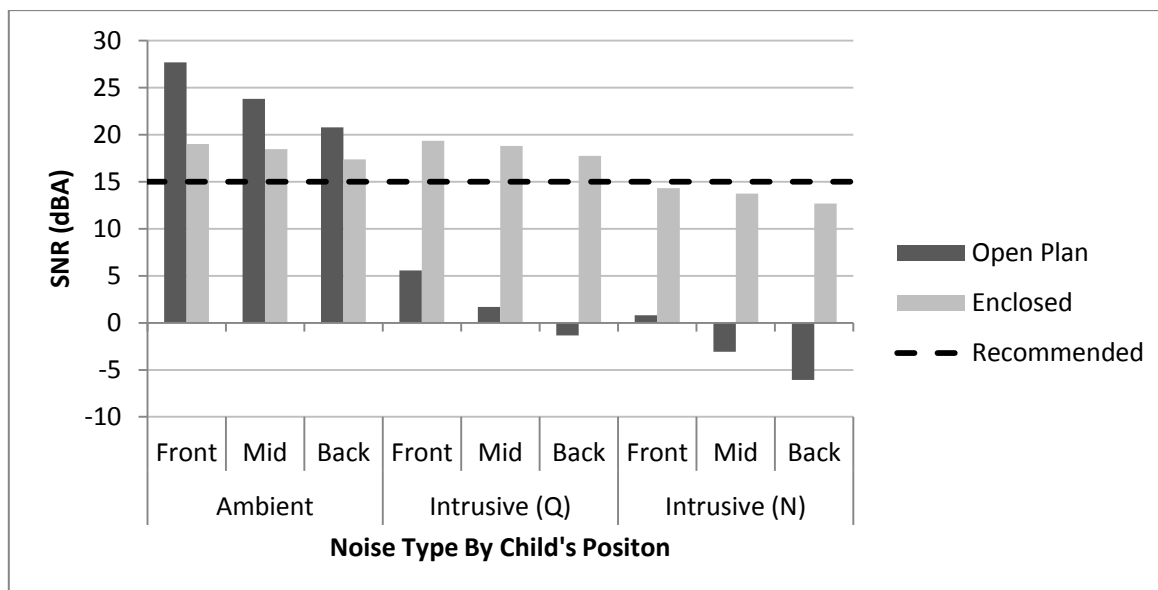


Figure 4 – SNRs by noise condition and child’s seating position for the open plan and enclosed classroom

The measured SNRs when all classes were doing group work activities are shown in Table 5. As seen in Figure 3, when all classes were engaged in group work activities, the BNLs for both the open plan and enclosed classroom increased to well above those recommended. Table 5 shows that if the teacher addresses their students using their usual teaching speech level during this activity, the SNRs are very poor, suggesting little speech would be understood. To achieve SNRs at the recommended level of +15 dBA, the teacher needs to raise their voice up to 31 dBA higher, which is equivalent to shouting (26). Constant talking at this level is highly likely to result in vocal health problems. Therefore it is not practical for teachers to address a whole table or tables, but only a single student provided they are in very close proximity.

Table 5 – Teacher’s speech parameters when addressing a single table of children and all tables of children engaged in group work for the open plan and enclosed classroom

Teacher addressing:	School	Teacher's usual speech level (dBA)	Average distance from child (m)	BNL	SNR	Required speech level (dBA)	Amount voice needs to be raised by (dBA)
Single table	Open Plan	62.5	1.1	67.7	-5.2	82.7*	20.2
	Enclosed	61.5	1.4	71.0	-9.6	86.0*	24.6
All tables	Open Plan	53.4	3.8	67.7	-14.3	82.7*	29.3
	Enclosed	55.1	3.8	71.0	-16.0	86.0*	31.0

Note: *Equivalent to shouting (26)

3.5 STIs

STIs were calculated for whole class teaching in both classrooms for no noise (which demonstrates the effect of room reverberation only) and the three other possible noise types that may be present during this critical listening activity (see Table 6). For the enclosed classroom, the STI stayed above the recommended score of 0.75 for 6-year-olds for nearly all noise types, and only just slipped below it (but was still in the “good” range) for the middle and back seating positions when the other classes were engaged in noisy activities. In contrast, the STI was only at the acceptable level for the open plan classroom when there was no noise or only ambient noise. As soon as intrusive noise was introduced, even just from quiet activities, only the children sitting at the front remained in the “good” range. When the other classes were engaged in noisy activities, the children seated at the back faced “bad” listening conditions, which is likely to have a major detrimental effect on their learning. The results of both the SNR and STI measurements strongly suggest that, at least, the tested open plan classroom is not appropriate for speech communication because of its high intrusive noise levels.

Table 6 – STIs for the open plan and enclosed classroom using different noise types

Noise type	Open plan classroom STIs			Enclosed classroom STIs		
	Front	Mid	Back	Front	Mid	Back
No noise	0.96	0.92	0.90	0.91	0.86	0.85
ANL	0.96	0.92	0.89	0.89	0.84	0.83
INL(Q)	0.65*	0.53**	0.43**	0.88	0.82	0.81
INL(N)	0.52**	0.40**	0.30**	0.77	0.72*	0.70*

Note: *Outside the “excellent” range (recommended for 6-year-olds)

**Outside the “good” range

4. DISCUSSION

The aim of this case study was to examine the acoustics of a mid-range open plan Kindergarten classroom containing 91 students, compared to an enclosed classroom of 25 students. Recordings of the teacher’s speech levels as well as Ambient Noise Levels (ANLs), Intrusive Noise Levels (INLs), Background Noise Levels (BNLs), and RIRs were made during different activities so SNRs, STIs, and RTs could be calculated and compared across classrooms. It was hypothesised that due to the larger room volume and increased number of students, the RTs and noise levels would be higher in the open plan classroom resulting in lower SNRs and STIs.

The major finding of this study was the differences in INLs for the open plan compared to enclosed classroom. INLs represent the noise heard from the other classes by the main class base while they are engaged in critical listening activities (i.e. while the class is quietly listening to instruction from their teacher). For the enclosed classroom, when the adjacent class was doing quiet activities, the noise levels and hence SNRs and STIs stayed within those levels recommended. Even when these activities changed to noisier group work activities, the levels were only just outside the recommended range. However, for the open plan classroom, when the adjacent classes were doing even only quiet activities, both the SNRs and STIs dropped dramatically to well below those recommended for this age group, particularly for those children sitting at the back of the class. These measures continued to drop when the other classes engaged in noisy group work activities, with the SNRs becoming negative. In this case, the STI score was only 0.3 for children seated at the back, representing “bad” listening conditions, compared to 0.7 (i.e. “good” listening conditions) for the same scenario in the enclosed classroom. This is likely to have a major detrimental effect on children’s learning in open plan classrooms as being able to hear their teacher clearly during critical listening activities is vital for learning new concepts. Therefore, the results of both the SNR and STI measurements strongly suggest that open plan classrooms of this size or larger are not appropriate for speech communication because of their high intrusive noise levels. These results clearly demonstrate the benefit of having acoustic barriers (i.e. enclosed walls) between classes to minimize the transmission of intrusive noise from adjacent classes. In addition, the difference between SNRs and STIs at the front and back of the teaching area indicates the importance of gathering children as close as possible to the teacher, or using sound field amplification systems in classrooms. Amplification systems, however, are not appropriate for open plan classrooms (where the SNR distance effect is even more apparent) because of their disturbance to other classes. This further suggests the shortcomings of this type of learning space.

It was interesting to note, however, that while there was a large difference in the INLs between the two classroom types, the combined BNLs were actually similar in both classrooms. We expected that because of the greater number of students and high INLs in the open plan classroom, the noise levels when all classes were engaged in group work activities would be higher than those in the enclosed classroom as a result of the Lombard effect (27). However, this was not the case, with the noise levels in the enclosed classroom also reaching well above those recommended. Although these levels were reached mainly during group work rather than during critical listening activities, these excessive noise levels evident in both classroom types are still a concern. This is not only because high noise levels increase stress and are thought to adversely affect both the psychoeducational and psychosocial achievement of the child (2,3,8,25), but also because of the effect they have on the teacher. During these activities it is common for the teacher to move around helping different groups. Therefore, to achieve the recommended +15 SNR and be heard, teachers need to raise their voice up to 31 dBA higher than their comfortable teaching voice. This requires teachers to speak at

82-86 dBA (at 1m distance) which is equivalent to shouting (26). This makes talking to more than a single child at a time very difficult. As group activities make up 40-45% of teaching activities, constant talking at this level is likely to result in vocal abuse and pathological voice conditions as well as increase the number of sick days taken due to voice and throat problems (5,10,11). Therefore, it is important that teachers try to control the noise levels in all classrooms, and be careful not to raise their voice regularly to get the children's attention. Clapping their hands or using a bell or other signal can be helpful alternatives to get the children's attention in these situations.

An analysis of the classroom ANLs revealed slightly higher levels than the recommended maximum of 35 dBA for the open plan classroom, and even more so for the enclosed classroom measuring 42 dBA. Nonetheless, the SNRs and STIs using this noise type still met the recommended levels for Kindergarten classes in both classroom styles. Hence, ambient noise from both internal and external sources, such as air-conditioning units or road traffic, were minimal enough to be unlikely to adversely affect children's speech perception abilities during whole class teaching. They may however contribute to higher BNLs during group work due to the Lombard effect, so it is still of interest to minimize these noise sources where possible.

In regard to RTs, the average unoccupied RT for the enclosed classroom was within the upper recommended limit of 0.5 s, but the average RT for the open plan classroom was outside it at 0.7 s. This was expected since the area of open plan classrooms is much bigger, leading to longer RTs (13). However, as the "no noise" STI calculations (which take into account the effect of reverberation only on speech transmission) were high for both classrooms, it is unlikely that the reverberation of either of these classrooms has a major effect on speech perception. Installation of sound-absorbing materials and reducing ceiling height however would still be beneficial to minimize RTs and help reduce the impact of noise (28).

The findings of our study provide further evidence for the importance of having optimal listening conditions in Kindergarten classrooms to enhance children's access to new concepts. Although this study only involves one open plan classroom and one enclosed classroom, these results strongly suggest that open plan classrooms are not appropriate for speech communication because of their high INLs. Hence, further investigation is needed to assess whether open plan classrooms are appropriate learning spaces for young children. As the layout, building materials, and number of students in classrooms varies widely, it is essential for future research to be conducted in a wide range of open plan and enclosed schools. It will also need to assess which designs are appropriate and what the maximum number of students in an area should be in order to meet the recommended RTs and noise levels to ensure adequate listening environments in the classroom.

5. CONCLUSIONS

This case study examined the acoustics of a mid-range open plan Kindergarten classroom containing 91 students, compared to an enclosed classroom of 25 students. The results revealed much higher INLs in the open plan classroom, resulting in SNRs and STIs to be well below those recommended in classrooms with students of this age. In contrast, the INLs and associated SNRs and STIs for the enclosed classroom remained largely within the recommended levels due to the acoustic barriers between the classes. However, unexpectedly the BNLs in both classroom types exceeded the recommended levels, requiring teachers to raise their voice well above their comfortable talking level. These results demonstrate the need to control noise levels in classrooms particularly during group work, by both teaching methods and acoustic treatment of the classrooms. Additionally, the high INLs and poor SNR and STI measurements found during critical listening periods (e.g. whole class teaching) in the open plan classroom strongly suggest that they are not appropriate learning spaces for young listeners. Future research into the noise levels of open plan classrooms is needed with a much larger group of classrooms to explore these issues further.

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