AN ASSESSMENT OF DIFFERENT SIZED OPEN PLAN AND ENCLOSED KINDERGARTEN CLASSROOM LISTENING ENVIRONMENTS

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Abstract

Open plan classrooms, where several class bases share the same space, have recently re-emerged in Australian primary schools. This paper compiled the results of three recent studies to compare both the acoustic parameters and speech perception test results in four different Kindergarten classrooms (an enclosed classroom with 25 students, a double classroom with 44 students, an untreated linear fully open plan triple classroom with 91 students, and a purpose-built semi-open plan K-6 classroom with 205 students) with the children's ratings about how well they could hear their teacher. Compiling these results allowed a regression analyses to be undertaken to establish the acoustic limits needed for children to rate they could hear their teacher 'well' (here defined as the 'hear well' criteria). Ambient noise levels, intrusive noise levels, and teacher's speech levels were recorded during different activities and room impulse responses were recorded for different teaching scenarios. From these recordings average noise levels, signal-to-noise ratios, speech transmission index scores, and reverberation times were calculated. These parameters were compared to the current Australian/New Zealand acoustic standards for classrooms (AS/NZS2107:2000), the acoustic recommendations in the literature for classrooms with 5-6-year-old children, and the derived 'hear well' criteria. The results revealed much higher intrusive noise levels in the two largest open plan classrooms (especially the untreated triple classroom), resulting in signal-to-noise ratios and speech transmission index scores to be well below the 'hear well' criteria. Results from the speech perception task also revealed poorer scores and slower response times in the triple open plan classroom compared to the other classrooms. Additionally, children's speech perception abilities decreased the further away they were seated from the teacher in the classrooms with higher noise levels resulting in scores outside the 'hear well' criteria. These results suggest students may have difficulty listening and learning in open plan classrooms and teachers are likely to strain their voice from needing to speak above a comfortable level to be heard. Additionally, the regression analysis results from the children's questionnaires confirmed that the acoustic recommendations suggested in the literature need to be met in order for the children to be able to hear their teacher 'well'. These results suggest that it may be beneficial for Australia to implement acoustic standards for unoccupied and occupied classrooms and have enforced

criteria for classroom designs to ensure they meet these standards so children are comfortable and able to learn effectively in every educational setting.

1. Introduction

Primary school is a child's first experience of formal learning. It is vital for preparing children for higher education and life through literacy, numeracy, and other diverse skills. The primary modes of communication in the educational setting are speaking and listening, with children spending on average 45-60% of their time at school comprehending speech [1]. They therefore need to be able to discriminate the speech sounds they hear from the vast variety of other distracting noises present in the classroom. Interfering background noises include outside noise (e.g. traffic and construction work), intruding noises from adjacent rooms and corridors (e.g. talking and movement), and noise 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. The use of sound reflecting building materials adds reverberation to both the background noise and the speech signal which results in masking and distortion of the speech signal, reducing speech intelligibility [2], [3].

Child generated noise is the major noise source found in classrooms [4]. Noise levels in the younger classes tend to be highest [5] and this is also the age group most affected [6]. High noise levels adversely affect speech perception, cognition, concentration, and the psychoeducational and psychosocial achievement of the child [2], [3], [7], [8]. Furthermore, it is not only the students who suffer from poor classroom acoustics. Studies have shown 80% of teachers experience vocal fatigue from constantly needing to raise their voice above a comfortable level which puts them at high risk of vocal abuse and pathological voice conditions [9], [10]. Noise also raises blood pressure and stress levels, as well as causing headaches and 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 classroom noise levels for both teachers and students. Many countries including Australia have acoustic standards for classrooms [13]. However, these are not enforced and are only for unoccupied classrooms. While there are suggestions in the literature about the maximum noise levels and minimum SNRs and speech transmission index scores (STIs) needed for children to hear their teacher in occupied classrooms (e.g. [2], [14], [15]), these are rarely achieved [8]. This raises the question of whether these recommendations are too conservative. Additionally, 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 spaces which can have up to 200 children sharing the same area. Open plan classrooms are seen to benefit children by using a more child-centred teaching approach that focuses on group work and a wide range of activities [16]. They are also thought to benefit teachers as they promote the sharing of skills, ideas, and experiences, allow for team-teaching, joint planning and organisation, and facilitate a more cooperative and supportive atmosphere [16]. However, because of this increase in student numbers and different classes doing different activities, these classrooms are subject to high noise levels [7]. These are likely to be particularly distracting when one class is trying to engage in critical listening activities and there is noise coming from the other classes which that teacher cannot control. Therefore, it is timely to re-assess the acoustic recommendations in the literature for occupied classrooms (see also [17]), compare these to the acoustics of different types of open plan/enclosed classrooms (here taken from Mealings et al. [18]), evaluate how these acoustics affect children's speech perception [19], and provide evidence that Australia (and other countries) should enforce acoustic standards and recommendations for classroom design.

Therefore, the purpose of this study was to:

1) Derive the occupied noise level, SNR, and STI required for children to be able to hear their teacher well (see also [17]), and compare these to the current recommendations in the literature.
2) Derive the score on the Mealings, Demuth, Dillon, and Buchholz (MDDB) Classroom Speech Perception Test [20] corresponding to children rating they can hear their teacher well (see also [17]).

3) Compare the average noise levels, SNRs, STIs, and MDDB speech perception scores calculated in the different types of classrooms by Mealings et al. [18], [19], with those needed for children to hear their teacher well.

2. Method

2.1 Participants

Four Kindergarten classrooms were chosen for the studies by Mealings et al. [17]–[19] to represent the different sized classrooms found in Sydney (see Figure 1). The enclosed classroom (25 students) was 8x9 m with a ceiling height of 3 m. It had 3 solid brick walls and a closed concertina wall and shared store room with the adjacent Kindergarten class. The double classroom (44 students) was 15x9 m with plasterboard walls, a triangular ceiling ranging 2.8-4.2 m in height and 2 m distance between class bases. The fully open plan triple classroom (91 students) was 37x11 m with plasterboard walls, an acoustically tiled ceiling with a height of 3.3 m, and approximately 6 m between each class base. No other acoustic treatment was evident. The purpose-built K-6 ‘21st century learning space’ (205 students) was 32x27 m, had a ceiling height of 3.2-6.0 m, and approximately 7 m between open class bases. The Kindergarten children in this classroom were located in the corner (i.e. the most acoustically sheltered location) in a semi-open plan style with 3 cm pin boards on the walls and soft furnishings for absorption. All classrooms were carpeted. Table 1 shows the demographics of the children who participated in Mealings et al.’s [17]–[19] studies (with parental consent).

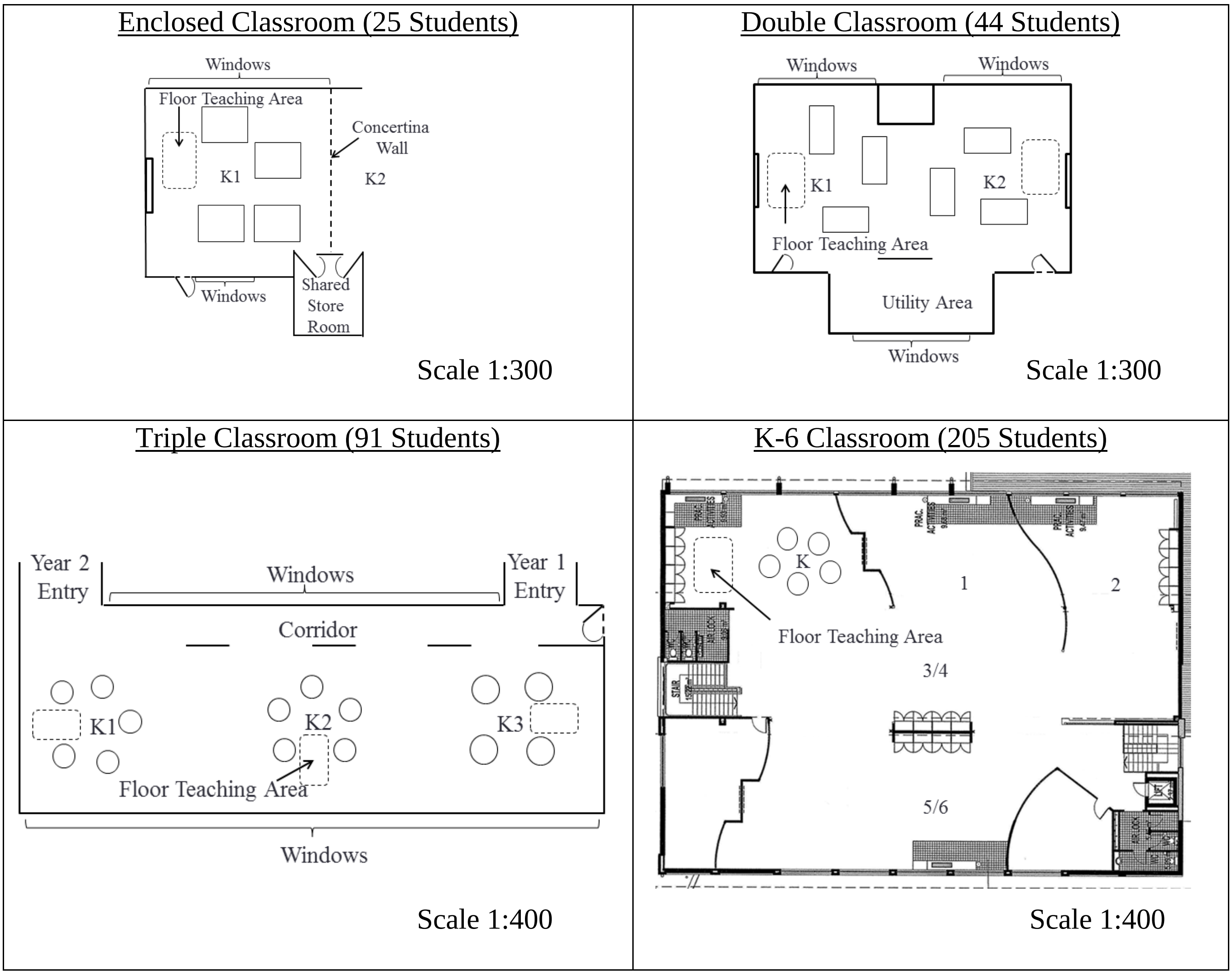

Figure 1. Floor plans of participating classrooms

Table 1. Demographics of Kindergarten children who participated in the study

Classroom	Number of participants	Number of males/females	Age range and mean (years;months)	Number who have ESL
Enclosed	24	14M; 10F	5;1-6;3 *M* = 5;6	13
Double	23	12M; 11F	5;1-6;3 *M* = 5;5	0
Triple	25	11M; 14F	5;1-6;3 *M* = 5;6	12
K-6	23	13M; 10F	4;11-6;1 *M* = 5;7	4

2.2 Procedure

2.2.1 Children's questionnaires (from [17])

The children's questionnaires were based on those used in similar studies with a similar age group [21], [22]. Each child was individually taken aside from the class to fill in the questionnaire with the researcher. Each child was asked how well they could hear their teacher when all classes were quiet, when adjacent classes were working at their tables, and when adjacent classes were doing group work and moving around using a five point Likert scale (1 = not at all, 2 = not very well, 3 = ok, 4 = well, and 5 = very well) represented as a smiley face scale [21].

2.2.2 Acoustic measures (from [18])

2.2.2.1 Noise recordings: Noise recordings were taken with Adobe Audition software a sample rate of 44.1 kHz on a standard PC using RME Hammerfall HDSP 9632 internal soundcard inclusive expansion boards and three ½" omnidirectional condenser microphones (calibrated in diffuse speech-shaped noise using a B&K 2250 sound level meter) on 1 m high stands at the front, middle, and back of the floor teaching area of each classroom (see Figure 1). Each recording was 2-10 min long depending on the activity. These recordings were used to calculate the unoccupied ambient noise levels, the intrusive noise levels from the other classes during quiet activities, and the intrusive noise levels from the other classes during noisy activities. Unoccupied ambient noise recordings were taken inside the vacated classrooms after school. This measured the internal and external noise (e.g. air conditioning units and road traffic). The intrusive noise from adjacent occupied classes was recorded when the main class base was empty and the other class bases were engaged in quiet activities (e.g. whole class teaching) and when the other class bases were engaged in noisy activities (e.g. group work). Each recording was listened to and any artefacts (such as children touching or directly speaking into the microphone) were removed.

2.2.2.2 Room impulse responses and reverberation time: Room impulse responses (RIRs) were measured in the main class base of each classroom with 30 s long logarithmic sweeps using a Tannoy VX8 loudspeaker connected to a Yamaha AX-350 hifi stereo amplifier and three ½" calibrated omnidirectional microphones. These were used to calculate unoccupied reverberation times, STIs, and to predict the teacher's voice levels inside the classrooms. The loudspeaker at a height of 1.2 m (representing teacher sitting on a chair in front of students which was their typical teaching style) 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 at the front, middle, and back seating locations in front of the loudspeaker. The unoccupied reverberation time (T30) was derived from the measured RIRs according to ISO 3382-2 [23] using Odeon and MATLAB software. The T30 was first derived in octave bands and then averaged across the bands with centre frequencies of 500, 1000, and 2000 Hz. The broadband T30 was finally averaged across the three applied microphone locations for each scenario.

2.2.2.3 Calculation of teachers' average speech levels: The teachers' speech was recorded during whole class teaching using an omnidirectional DPA dual-ear lapel microphone placed approximately 3 cm from the teacher's mouth. Recordings were made using Adobe Audition software and were convolved with the measured RIRs to estimate speech levels for each scenario at three listening positions. Speech levels were predicted by using concatenated and equally long speech samples from all teachers as the input signal to remove voice level differences between teachers. The equipment and signal processing was calibrated by comparison to a similar recoding performed in an anechoic chamber at the National Acoustic Laboratories, Australian Hearing Hub. Twelve talkers were recorded using the DPA dual-ear lapel microphone and a calibrated B&K 4134 microphone which was placed 2 m in front of the talkers and attached to a B&K 2610 measurement amplifier. The corresponding (anechoic) RIR was measured by replacing the talkers with the same Tannoy VX8 loudspeaker system used for the classroom measurements. The calibration filters were derived by comparing the spectra (and RMS levels) of the direct speech recording at 2 m distance with the corresponding RIR-based simulation. These were then applied to the speech recordings and RIR measurements.

2.2.2.4 Calculation of signal-to-noise ratios: Average SNRs were calculated using the average teacher's speech levels (in dBA) at the front, middle, and back of the floor teaching seating area (as described in Section 2.2.2.3) and the average noise levels (in dBA) recorded in the same areas as described in Section 2.2.2.1. SNRs were calculated using unoccupied ambient noise, intrusive noise when the other classes were engaged in quiet activities, and intrusive noise when the other classes were engaged in noisy activities.

2.2.2.5 Calculation of speech transmission index scores: The STI provides a guide to how intelligible speech is in a room by measuring the reduction in fidelity introduced into the speech transmission channel from the source to the receiver, caused by both reverberation and noise [5]. The STI is represented on a scale from 0 to 1, with 0 representing no speech to be understood and 1 representing all speech to be understood. STIs were calculated at the front, middle, and back of the floor teaching area using the RIRs and noise recordings of unoccupied ambient noise, intrusive noise when the other classes were engaged in quiet activities, and intrusive noise when the other classes were engaged in noisy activities, using the AARAE MATLAB Toolbox [24].

2.2.3 Classroom speech perception test (from [19], [20])

The children in each classroom participated in the Mealings, Demuth, Dillon, and Buchholz (MDDB) Classroom Speech Perception Test [20]. This is an online four-picture choice minimal pair word discrimination task. The children sat on the floor in front of an interactive whiteboard and heard sentences presented from a loudspeaker and matched with pictures for four possible endings (e.g. *Sally likes the [bee, bead, beam, bean]*). The children selected the picture they heard via a personal response system which recorded both their accuracy and response time (measured from the onset of the stimulus). The task was completed live in each classroom while the other classes in the area engaged in quiet versus noisy activities. Note only twenty-two children from the triple classroom were included in this part of the study as one child was absent and two children were excluded as they did not finish the task. For the enclosed classroom, one child only scored 8% in the quiet condition so was excluded from the analysis as they failed to demonstrate an ability to understand and complete the task.

3. Results

3.1 Reverberation times (see also [18])

The recommended reverberation time for primary school classrooms is < 0.4-0.5 s [13]. As reported in Mealings et al. [18], the enclosed classroom was the only classroom within this limit with a reverberation time of 0.50 s. The reverberation times of the double, triple, and K-6 classrooms were 0.60, 0.70, and 0.58 respectively.

3.2 Acoustic limits required for children to be able to hear their teacher well (see also [17])

The average noise levels, SNRs, STIs [18], and MDDB speech perception scores [19] for each scenario were matched with the children's average rating of how well they could hear their teacher for that scenario in each classroom [17]. That is, the average unoccupied ambient noise levels were paired with the 'all classes quiet' ratings, the average intrusive noise levels during quiet activities were paired with the 'other classes working at their tables' ratings, and the average intrusive noise levels during noisy activities were paired with the 'other classes doing group work with movement' ratings. Four regression analyses were conducted to calculate the regression line which can be used to estimate the acoustic measurement needed to achieve a given hearing rating (see also [17]).

The first simple linear regression was calculated to predict the noise level based on the children's hearing rating. A significant regression equation was found ($F(1,10) = 8.53$, $p = .015$), with $R^2 = 0.46$. The noise level (dBA) = -6.94(the mean hearing rating) + 73.65.

The second simple linear regression was calculated to predict the SNR based on the children's hearing rating. A significant regression equation was found ($F(1,10) = 7.60$, $p = .020$), with $R^2 = 0.66$. The SNR (dB) = 7.18(the mean hearing rating) – 14.22.

The third simple linear regression was calculated to predict the STI based on the children's hearing rating. A significant regression equation was found ($F(1,10) = 9.07$, $p = .013$), with $R^2 = .69$. The STI = 0.1363(the mean hearing rating) + 0.2011.

The fourth simple linear regression was calculated to predict the MDDB speech perception score based on the children's hearing rating. A significant regression equation was found ($F(1,6) = 18.42$, $p = .005$), with $R^2 = .97$. The MDDB speech perception score (as a percent) = 9.98(the mean hearing rating) + 30.92.

The estimate of what noise level/SNR/STI/MDDB score is needed to get a rating of 4 (which corresponds to a child rating they can hear their teacher 'well' – we call this the 'hear well' criteria) is shown in Table 2. Notice there was a close match between our 'hear well' values and those recommended in the literature.

Table 2. Measured values for acoustic parameters that correspond to a child hearing their teacher well compared to those recommended in the literature

Parameter	Regression line	'Hear well' criteria	Recommended value
Occupied noise level	y = -6.94x + 73.65	< 45.9 dBA	< 50 dBA [14]
SNR	y = 7.18x – 14.22	> +14.5 dB	> +15 dB [2]
STI	y = 0.1363x + 0.2011	> 0.75	> 0.75 (for 6-year-olds) [15]
MDDB speech perception score	y = 9.98x + 30.92	> 71%	

3.3 Comparison of the 'hear well' criteria to the classroom acoustic measures from [18]

The noise levels, SNRs, and STIs calculated in each of the classrooms by Mealings et al. [18] were compared to the 'hear well' criteria from Table 2 (see Table 3). The enclosed, double, and triple classrooms were all within the 'hear well' criteria when the classes were unoccupied, but the measurements in the K-6 classroom were just outside of the noise level and SNR criteria, most likely due to noise from the heating and ventilation system. However, when the adjacent class(es) were occupied and engaged even in only quiet activities, only the enclosed classroom achieved the desired acoustics across the whole floor teaching area. While the average noise level in the double classroom was right on the 'hear well' criterion, only the children seated at the front of the class (i.e. closest to their teacher) experienced the desired SNR and STI. Most concerning, however, was the noise levels in the triple and K-6 classrooms. These were well outside of the 'hear well' criterion even when the other classes engaged in only quiet activities. This resulted in poor SNRs and STIs in both classrooms. Furthermore, these acoustic parameters were even worse for the triple classroom when the other classes engaged in noisy activates, with the children up the back (i.e. furthest away from their teacher) experiencing an SNR of -6 dB. This means a teacher would have to raise their voice 20.5 dBA above their comfortable speaking level to achieve the 'hear well' +14.5 dB SNR. Constant speaking at this level is likely to result in vocal health problems. When the class adjacent to the enclosed classroom was engaged in noisy activities, the average noise levels measured in the enclosed classroom fell just outside the 'hear well' criterion (most likely because of the open shared store room). Only the children up the front experienced SNRs and STIs within the 'hear well' criteria. In the double classroom, the 'hear well' criterion was only achieved for the STI measurement for children seated up the front.

Nonetheless, the conditions in the enclosed and double classrooms were still much more favourable than the noise levels, SNRs, and STIs measured in the triple and K-6 classrooms.

Table 3. Average noise levels, SNRs, and STIs measured in the classrooms by Mealings et al. [18] for children seated at the front, middle, and back of the class while the adjacent class(es) were unoccupied, engaged in quiet activities, and engaged in noisy activities

	Classroom	**Unoccupied**			**Quiet activities**			**Noisy activities**		
		Front	**Mid**	**Back**	**Front**	**Mid**	**Back**	**Front**	**Mid**	**Back**
Noise level (dBA)	Enclosed	41.8			43.1			48.8*		
	Double	36.7			46.0*			50.3*		
	Triple	36.0			57.5*			62.1*		
	K-6	46.3*			60.5*			60.5*		
SNRs (dB)	Enclosed	19.0	18.5	17.4	19.3	18.8	17.7	14.3*	13.8*	12.7*
	Double	29.1	24.7	22.8	17.5	13.1*	11.1*	13.3*	8.8*	6.9*
	Triple	27.7	23.8	20.8	5.5*	1.7*	-1.3*	0.8*	-3.1*	-6.1*
	K-6	13.0*	12.8*	11.5*	-0.2*	-0.3*	-1.7*	-0.2*	-0.3*	-1.7*
STIs	Enclosed	0.89	0.84	0.83	0.88	0.82	0.81	0.77	0.72*	0.70*
	Double	0.87	0.82	0.80	0.82	0.75	0.69*	0.77	0.67*	0.60*
	Triple	0.96	0.92	0.89	0.65*	0.53*	0.43*	0.52*	0.40*	0.30*
	K-6	0.85	0.84	0.85	0.47*	0.45*	0.44*	0.47*	0.45*	0.44*

Note. * indicates acoustic conditions that are outside of the ‘hear well’ criterion.

3.4 Comparison of the ‘hear well’ criteria with the speech perception test scores from [19]

The children’s MDDB speech perception scores when the adjacent class(es) were engaged in quiet versus noisy activities from Mealings et al. [19] were compared to the ‘hear well’ criterion in Table 2. As discussed in Mealings et al. [19], the children’s scores stayed fairly consistent front to back for the enclosed and double classroom when the other classes were engaged in quiet activities. This resulted in the average scores of the children being above the 71% ‘hear well’ criterion across the classroom. The children seated up the front in the triple and K-6 classrooms also achieved scores within the criterion. However, because these larger classrooms had higher noise levels, the children’s scores decreased the further away they were seated from the loudspeaker. As a result, the children seated in the middle and back regions of the floor teaching area had average scores below the 71% ‘hear well’ criterion.

When the adjacent class(es) were engaged in noisy activities, the children seated up the front achieved the 71% ‘hear well’ criterion in the enclosed, double, and K-6 classrooms. However, these scores dropped to 55-65% for the children seated in the middle and back regions. The classroom of most concern, however, was the triple classroom which had the highest noise levels. While the children seated right at the front achieved an average score of 72%, the children right at the back only scored 25% (i.e. chance level). As discussed in Mealings et al. [19], the children’s average score was significantly poorer than the average scores of the children in the other three classrooms. These children also had significantly slower response times compared to the children in the enclosed and K-6 classroom.

4. Discussion

The aim of this study was to determine the noise level, SNR, STI, and MDDB Classroom Speech Perception Test [20] score required for children to be able to hear their teacher well, and compare these to the current recommendations in the literature and those measured in four different sized open plan/enclosed classrooms by Mealings et al. [18], [19].

As shown in Table 2, there was a close match between our ‘hear well’ criteria and those recommended in the literature, reinforcing the importance of meeting these recommendations to ensure adequate speech perception in the classroom. However, the results from the classroom acoustic measurements revealed that these conditions are often not met, especially in open plan classrooms.

The enclosed classroom was mostly within the 'hear well' criteria, but crept just outside of it in the middle and back seating positions when the adjacent class was engaged in noisy activities. This is probably due to the sound transmission through the shared store room. Therefore, it is likely that the acoustics measurements would have been within the criteria if the shared store room door was closed.

For the double classroom, the 'hear well' criteria were only met for children seated up the front when the adjacent class was occupied and engaged in either quiet or noisy activities. This is most likely because there was only 2 m separating the classes so the noise would have been particularly distracting. This shows the importance of gathering children close to the teacher and ensuring there is as much separation between groups as possible.

The most noticeable difference in the acoustics, however, was when the class size increased from a double to triple classroom. While the triple classroom met the 'hear well' criteria when the adjacent classes were unoccupied, when they became occupied there was a large increase in the noise levels resulting in poor SNRs, STIs, and MDDB speech perception scores and response times, even when the adjacent classes were engaged in only quiet activities. When the adjacent classes engaged in noisy activities, the acoustic conditions were very poor, especially for children seated towards the back. This is likely to have a significant detrimental effect on the children's education.

The K-6 classroom also failed to meet the 'hear well' criteria. Interestingly, however, the noise levels were more consistent in this classroom, and did not reach the intensity of those in the triple classroom. The children also performed surprisingly well on the speech perception task. This is most likely because the classroom was purpose-built as open plan so it had some acoustic treatment, large separation between classes (hence the intrusive noise would be less intelligible), and the Kindergarten class was located in the corner (a more acoustically sheltered location) in a semi-open plan style (i.e. only one open wall). This contrasts to the triple classroom where the original walls between the three classrooms had been knocked down to make it fully open plan and no other acoustic modifications had been installed. These results show the benefit of acoustically treating classrooms to minimise the effect of noise.

Overall, the results of this study demonstrate the importance of having recommendations for *occupied* classrooms as this reflects the actual listening environment. These recommendations are particularly important when considering the appropriateness of open plan classrooms. The results of this study suggest that open plan classrooms with three or more class bases are unlikely to provide appropriate listening environments for critical listening activities. This is because the ingress of noise from the other classes sharing the space is likely to affect the children's speech perception accuracy and processing speed, and also result in teachers experiencing vocal health problems from needing to speak above a comfortable level to be heard. If open plan classrooms are desired, they should be acoustically built as *flexible* learning spaces. That is, they should have operable walls that can stay open for group work and other activities that benefit from an open plan space, but can be closed for critical listening activities. They should also be designed in a semi-open plan style and have at least 6.5 m between class bases where there is an open wall [7]. Additionally, teachers should try to coordinate activities across classes to minimise noise from disrupting the other classes in the area [15].

As this study only involved four classrooms, future research is needed with a large sample of classrooms to assess exactly what classroom types and acoustic treatments are required to meet our 'hear well' criteria and the acoustic recommendations in the literature. Additionally, research is needed to assess what classroom environments are appropriate for children with attention deficits, hearing impairments, language delays, auditory processing disorders, and English as a second language (ESL), as these children are now more commonly integrated into mainstream classrooms and reported to be even more affected by poor acoustics [11], [25].

5. Conclusions

The findings of this study provide further evidence for the importance of having optimal listening conditions in Kindergarten classrooms to enhance children's access to new concepts. The results suggest that classrooms that are unable to control the ingress of noise from nearby classes do not provide appropriate learning environments for critical listening activities with young children due to the adverse effects of this noise on children's speech perception. In this study, this applied to the triple and K-6 classrooms, and to a lesser extent the double classroom. Future research is needed, however, to assess exactly what classroom types are the most suitable learning spaces for children at different ages and also for those who have special educational needs such as attention deficits, hearing impairments, language delays, auditory processing disorders, and ESL. It is essential for this research to be conducted in a wide range of open plan and enclosed classrooms to assess which designs and acoustic treatments are appropriate for different numbers of students and/or class bases in an area, in order to meet the recommended reverberation times and *occupied* noise levels to ensure adequate speech perception in the learning environment. Once this research has been conducted it may be beneficial for Australia (and other countries) to implement recommendations or restrictions for classroom design and acoustic conditions so speech perception is not compromised in educational settings.

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