A cost benefit analysis of providing a 'sound' environment in educational facilities

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ABSTRACT

Speech and aural interaction is very important in the teaching and learning process, and as such, good acoustic design is essential to facilitate effective learning. Critical issues in acoustic design revolve around reverberation control, isolation of noise into learning spaces and control of extraneous noise sources, including noise from building services and traffic noise ingress. The Association of Australian Acoustical Consultants (AAAC) Guideline for Educational Facilities Acoustics (2010) provides the first Australia wide guide to providing a good acoustic environment in educational facilities. Often good acoustic design can be compromised by the high cost of construction. An analysis of the cost versus acoustic benefit of the guideline is considered to aid in building better educational facilities and better educational outcomes.

INTRODUCTION

The benefit of providing a good acoustic environment in the classroom is widely acknowledged to be very important in facilitating the teaching and learning process. Poor room acoustics can lead to poor speech intelligibility resulting in poor communication and teacher fatigue. This then affects maintenance of discipline and cooperation, and student motivation and engagement in the learning process.

Good acoustic design is typically encouraged for educational facilities. However, this can be compromised by the initial higher cost of construction and a lack of understanding of the potential long-term effects poor acoustics may have.

While the qualitative benefits of good classroom acoustics are broadly understood, this paper seeks to quantify the long-term impacts of poor classroom acoustics. This is done by assessing classroom acoustics and the resultant initial higher cost of construction against longer-term economic outcomes.

SKILLS AND WORKFORCE OUTCOMES

In considering the cost versus acoustics benefit for classroom acoustics, the long-term effect on individuals and the workforce is assessed.

Participation and productivity in the workforce is strongly influenced by the level of education and skill of an individual (Australian Government, 2007). Participation and productivity are also both linked to wages.

Improving the literacy and numeracy skills of students, particularly at younger ages, is considered to be an important way to develop the skills necessary for people to work and to function in society at later years in their lives (DPC, 2007).

This was backed up by Shomos (2010) who showed a statistically significant effect of literacy and numeracy skills on both labour force participation and hourly wages.

Thus, from a policy perspective, if people's literacy and numeracy skills can be improved, then they will tend to achieve better labour market outcomes.

OUTCOMES OF POOR ACOUSTICS

The work by Shield & Dockrell (2008) showed that:

> chronic exposure to both external and internal noise has a detrimental impact upon the academic performance and attainments of primary school children. The study suggests for external noise of individual events that have the most impact while background noise in the classroom also has a significant negative effect.

They concluded that to minimise the impact of noise in a school environment, there are two important factors that need to be considered. First, the siting of the building such that external noise ingress into classrooms is minimised and second, the background noise levels in classrooms should be minimised. Both these factors will ensure a good teaching and learning environment.

Regression analysis showed that of the schools surveyed, those where the occupied background noise levels (L_{90}) exceed 50 dB(A) the students failed to meet government targets for literacy and numeracy.

It has also been shown that individuals with more education (more years) have higher literacy and numeracy skills (Shomos, 2012). As such, increasing time in the education system (especially during secondary schooling) will result in a higher skill level. Providing a good acoustic environment should be a constant for all schools to provide best and equal opportunity for all students.

DESIGN CRITERIA

There are several sources design criteria that can be used to guide the good acoustic design of schools and other educational facilities.

Some of these guidelines that are commonly used in Australia include:

- Department for Education and Skills Building Bulletin 93 *Acoustic Design of Schools—A Design Guide* (2003) (UK)

- ANSI/ASA S12.60-2010 *Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools Part 1: Permanent Schools* (USA)
- Association of Australian Acoustical Consultants (AAAC) Guideline for Educational Facilities Acoustics (2010) (Australia)
- Australian/New Zealand Standard 2107:2000 *Acoustics—Recommended design sound levels and reverberation times for building interiors*, which does not consider acoustic separation between spaces.

For the purposes of this paper we will focus on typical classrooms. All these standards provide roughly the same design criteria for classrooms.

The design criteria used for this assessment will be based on the AAAC criteria as the only current comprehensive Australian design guide to the acoustic design of educational facilities. For classrooms the AAAC criteria are:

- A mid-frequency (500 – 1000 Hz) reverberation time of 0.4 – 0.6 seconds
- Noise isolation to adjacent classrooms of $D_{nt,W}$ 45 dB, which is taken to be equivalent to an R_W 50 partition
- Internal noise level L_{eq} of 35 dB(A).

CLASSROOM DESIGN

The base construction for a classroom without any particular consideration to acoustics is taken to be:

- Carpet floors
- Plasterboard walls and ceiling
- Partition construction—1x13 mm plasterboard on both sides of 64 mm steel studs with insulation.

To achieve compliance with the reverberation and noise isolation requirements of AAAC guidelines, an appropriate construction is:

- Carpet floors
- Plasterboard walls
- Acoustic tiled ceiling with NRC 0.5
- Wall construction—2x13mm fire rated plasterboard on both sides of 64 mm studs with insulation

A summary of the mid-frequency reverberation time and the wall rating of the base case and an acoustic treated case is presented in Table 1. The mid-frequency reverberation time is based on a 8 x 10 x 2.7 m classroom.

Table 1 Summary of acoustic parameters of the base and acoustically designed classroom

	Mid-frequency Reverberation time	*R_W rating of partitions*
Base	0.8 – 1.3 seconds	R_W 40
Acoustic	0.4 – 0.6 seconds	R_W 50

Internal noise levels in unoccupied spaces can be affected by:

- internal noise transfer from adjacent spaces
- services noise, specially from mechanical services
- external noise ingress

The resultant internal noise level is then also affected by the reverberation time within the space.

COST OF CONSTRUCTION

For an 8 x 10 m classroom with the finishes (floor, ceiling and walls) as outlined above, the estimated cost total cost is $9,487 for the base classroom and $15,492 for the acoustically treated classroom. This is a 63% increase over the base construction cost to ensure good classroom acoustics.

The rates used to calculate the construction costs are based upon projects in the Adelaide CBD/Metropolitan area and are current as at Second Quarter 2012.

For a typical classroom size of 24 students, this equates to a cost per student of $395 for the base classroom and $649 for the acoustically treated classroom. This can be taken to be the total cost per student for their entire schooling period. This results in a cost difference of $254 per child to ensure good classroom acoustics.

CLASSROOM NOISE LEVELS

As mentioned previously, Shield & Dockrell (2008) have identified that an occupied noise level of around L_{90} 50 dB(A) corresponds to a target literacy and numeracy level.

Figure 1 shows the effect of reverberation time on the internal L_{Aeq} and L_{A90} noise levels within an occupied classroom. These levels are based on measured levels (Canning & James, 2012).

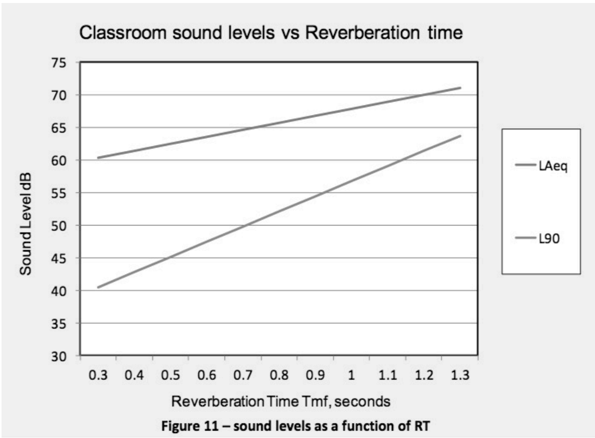

Figure 1 Sound Levels as a function of RT. Source: Canning & James, 2012

The difference in internal noise levels between the base case and AAAC case can be derived using Figure 1 and the reverberation times in Table 1. For a reverberation time of 0.4 – 0.6 seconds, the average L_{90} classroom noise level is 45 dB(A) and for a reverberation time of 0.8 – 1.3 seconds the average L_{90} classroom noise level is 58 dB(A).

Based on this we can assume an average a 13 dB difference in the occupied noise levels between the two spaces.

This also shows that for an acoustically designed classroom (with a reverberation time of 0.4 – 0.6 seconds), the occupied level is within L_{90} 50 dB(A), which is identified to correspond to the target literacy and numeracy level.

AFFECT ON SKILL LEVELS

Shield & Dockrell (2008) have undertaken a linear regression analysis to estimate the effect internal noise levels has on skill level. Figure 2 shows a scatter plot illustrating the relationship between the L_{A90} of an occupied classroom and the average KS2 score. The KS2 test is a UK Year 6 school test for English, mathematics and science.

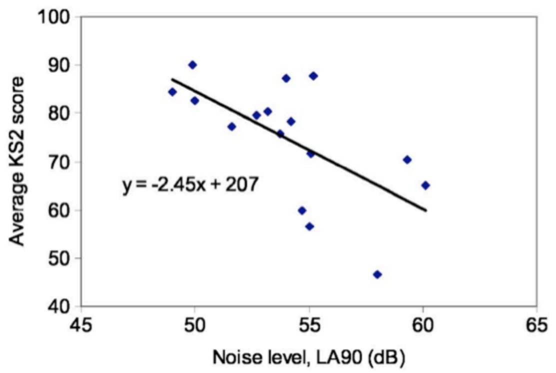

Figure 2 Scatter diagram illustrating relationship between occupied classroom L_{A90} and average KS2 scores. Source: Shield & Dockrell, 2008

Based on this assessment and the difference in L_{A90} noise levels in the base room and acoustic room, there is potentially an average 33 % decrease in performance for an untreated (base) classroom.

COSTS OF NOISE

The hourly wage rate for different literacy and numeracy skill levels is shown in Table 2 (Shomos, 2010). These wage rates are based on the Australian Adult Literacy and Lifeskills survey (2006).

Table 2 Wage rate (dollars per hour in main job, 25 – 64 year old), by average skill level

	Males	*Females*	*Total*
Level 1	22.13	16.87	19.69
Level 2	24.69	30.71	26.63
Level 3	30.21	26.54	26.82
Level 4/5	36.64	27.51	32.23

Level 1 is the lowest literacy level and 4/5 are the highest two levels. Level 3 is regarded by the survey developers as the 'minimum required for individuals to meet the complex demands of everyday life and work in the emerging knowledge-based economy' (Shomos, 2010).

For the purposes of this assessment we have assumed that the Level 3 skill level equates to that achieved in an acoustically treated classroom. The literacy levels are based on a range of scores for each level and a 33 % decrease from the Level 3 skill test scores will result in a Level 1 skill level (Shomos, 2010).

Based on the hourly wage rate in Table 2, this equates to an overall loss in salary (over a 39 year working period) of $549,466.

On this basis, for an initial outlay of an additional $254 per child during their schooling period this could result in a life salary loss of $549,466.

The exact figures calculated here should be used with caution. They are only to be viewed as an indication of the potential economic effect that poor classroom acoustics may have on an individual. There are many other extraneous factors that will affect a persons income, such as innate learning ability, experience, health, self-motivation etc. that are not affected by classroom acoustics. This assessment only demonstrates that identical students with identical teachers and curriculum could have different skill levels and thus different salaries if one benefited from an acoustically treated classroom.

SUMMARY

A summary of the potential impacts of classroom acoustics is shown in Figure 3.

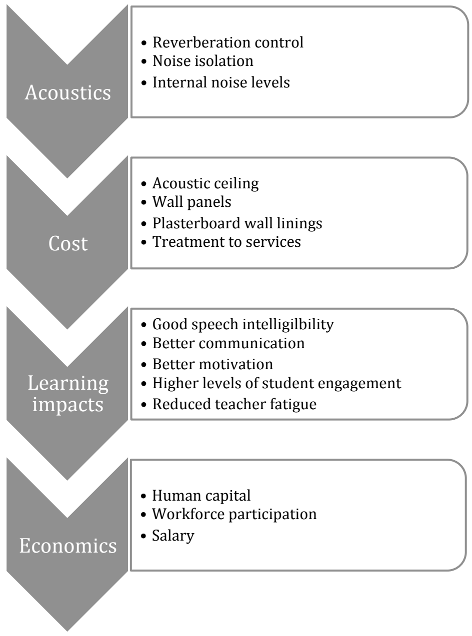

Figure 3 Impacts of Classroom Acoustics

CONCLUSIONS

Poor classroom acoustics are known to negatively impact on the learning and teaching process. This paper has shown that this impact may lead to a lower skill level compared to an individual who benefited from an acoustically treated classroom. A lower skill level can then result in a diminished earning capacity and salary.

This paper demonstrates that the ongoing effects of poor classroom acoustics can cause significant economic loss to an individual. The cost of providing a quality acoustic environment is not significant compared to the potential ongoing economic loss suffered by a student.

A good acoustic environment within educational facilities should not be compromised by the initial higher cost of construction as this is far outweighed by the immediate and long-term benefits to students.

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