Acoustic impact on effective teaching and learning activities in open learning spaces.

Abstract:

The Importance of good acoustics is being increasingly recognised; Studies have shown that teacher and student working environments, associated behaviour and management are related to acoustic quality, especially regarding inclusion.
There is also an ongoing pedagogic evolution worldwide, around innovative learning environments. Involving supporting teacher change, highlighting changes from traditional teacher lead to student centred learning activities, to encourage teacher and student collaboration and engagement. This change; traditional to diversified teaching often leads to high noise levels, which has proven to increase stress and reduction of concentration.
To provide the acoustic conditions supporting effective teaching and learning requires control of sound levels, speech intelligibility, speech privacy between spaces and control of indoor ambient noise.
Good practice European examples are referenced which support these evolving pedagogic approaches. Assessing specifically their acoustic data and the relevant acoustic parameters and regulations.
In general, the open learning spaces are perceived as noisy. We believe that in order to create effective open learning spaces, an activity based acoustic design approach is needed so future learning environments can make the necessary considerations to support sustainable learning outcomes, health and well-being of all occupants.

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1. Background and Introduction

1.1 Noise is a problem in learning environments

It has been well documented that noise has a detrimental effect in educational environments. Studies have shown teacher ill-health[1], vocal disorders[2] and hearing damage[3] are prevalent in educational premises. Students' health concentration[4], cognitive load[4], performance[5] and behaviour[6] are all affected. Sound and noise have an impact on the effectiveness of teaching tasks and styles[1], and teaching work load /stress[1]. Room acoustics has an impact on subjective and objective noise[6] and the associated behaviour[6] in learning and working environments including students with additional learning needs[7,8]. These negative impacts as a result of noise have been documented in mostly traditional classroom settings. It is however widely acknowledged that semi-open and open learning landscapes described here as Innovative Learning Environments[26] (ILEs) have even greater noise issues[25] due to the nature of sound spreading from one teaching / learning space to another and the disruptive consequences associated with this.

1.2 Importance and benefits of good acoustics

We have clear evidence around how to solve traditional cellular classroom acoustics[6] which can reduce the impact of the problems with noise already mentioned. In addition, this includes providing the right conditions for those students who are sensitive listeners[7] with additional learning needs; hearing and visually impaired, dyslexic, students with ADHD, autism, learning difficulties and non-native speakers. Optimising a traditional classroom for the inclusion[6,7] of students with additional needs is straightforward and has been shown to benefit all students and teachers in their teaching and learning activities with positive benefits in attitude and behaviour. While this level of acoustic control is straightforward in a classroom it is however much more complicated in a more open setting due to the risk of inappropriate activities combined with unsuitable acoustic conditions potentially causing unnecessary distraction and disruption. Serious consideration is

required for inclusion[8] and perhaps further consideration for accommodating teacher and student personality[9,10] differences (introvert, extrovert) and maturity differences.

2. 2.1 Pedagogic changes and spaces required

Pedagogic changes have been evolving with a general shift from teaching to learning: the traditional teacher centred class is believed to be limited nowadays and is moving towards a more student centred learning approach. There are many pedagogic reasons behind this. Often cited is a focus on the four Cs[11] approach. (Communication, Collaboration, Creativity and Critical Thinking). Some of the most common reasons concern encouraging greater student engagement in their own learning process and encouraging collaborative[27] learning. To allow the students to learn how to learn for themselves and to be more active, taking more responsibility for their own learning has led to a shift towards activity based learning where the teacher is more of a facilitator or coach. However, the traditional approach, the three Rs[12]: **r**eading, w**r**iting and a**r**ithmetic are often highlighted as missing regarding these changes which can create divisive or polarised debates around learning and more often than not around learning spaces also. The Gradual Release Model[13] overview clearly separates the move from teacher responsibility towards student responsibility which is indicative of the ongoing teacher vs student changes. A development on this combining levels of control indicates the pedagogy manifested in physical spaces[14], by Mie Guldbaek Broens of LOOP.bz.

2.2 Innovative Learning Environment (ILE) research

An important ongoing project addressing this complex issue is the Australian Research Council Linkage Project, "Innovative Learning Environments and Teacher Change" – ILETC[15] project, which will bring together multiple PhD studies centred around teaching approaches and the use of innovative learning environments. The ILETC project is working with teaching style typologies[16], (see Figure 1) and learning space typologies[17] (see Figure 2) as a baseline for teaching and learning activities and the associated learning spaces.

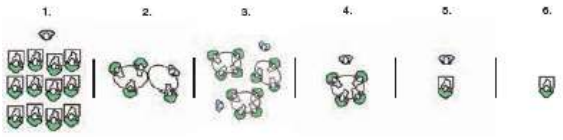

Figure 1. Teaching style typologies Dovey and Fisher, 2014.

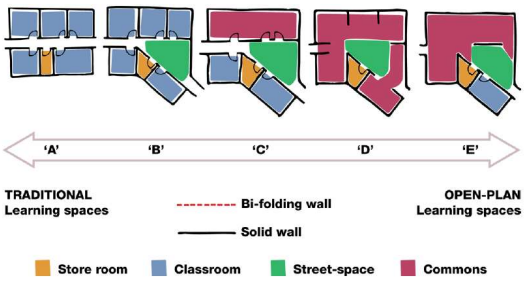

Figure 2. Dovey and Fisher's learning space typologies (2014), adapted by Soccio & Cleveland, 2015 adapted by Bradbeer et al, (under review).

In figure 2. it is understood that any move from space A towards E requires a general shift from teacher-centric approaches to student-centric approaches in order for the activities and spaces to work properly. This does not mean the teacher is no longer involved, however it means the teacher acts more as a facilitator where students take more responsibility in their learning which in turn allows teachers to release control. This is a delicate balance and requires an appropriate and clearly understood culture and leadership approach in the school. Interestingly, the ILETC survey[26] of over 2000 schools in New Zealand and Australia found perhaps more traditional spaces and teacher led approaches still highly prevalent. REF ILETC Report No1[26] findings were that 58% were utilizing Type A - Traditional closed classrooms entered by a corridor and 36% of the learning activities were teacher facilitated presentation, direct instruction or large group discussion.

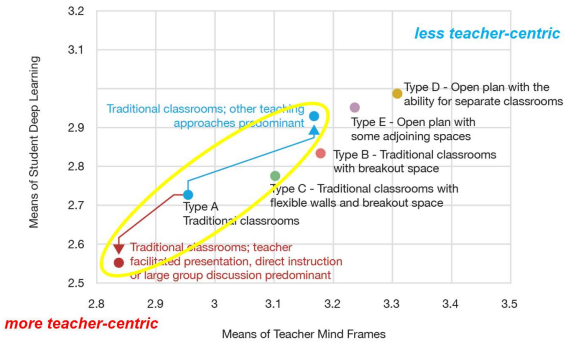

Figure 3: Adapted from the ILETC Report[26] with additional text and yellow ellipse highlighting more desirable approaches around being more or less teacher or student-centric.

Overall, the ILETC study has set out that more desirable teacher mind frames and more behaviour associated with deeper learning are linked with less teacher-centric classroom dynamics. Interestingly there is a considerable variance in Type A cellular classroom outcomes when the more or less teacher-centric approaches are compared (see Figure 3 above). This may be of great but perhaps undervalued importance or unexplored to date and will be looked into in the featured case study.

2.3 Understanding the value of informal and in-between social street spaces for the majority of schools.

The street spaces as illustrated in green and circled in yellow below in Figure 4 are utilised in the case study featured and may play a key role in the potential development of non ILEs. First of all, the majority of schools around the world are similar to a traditional type A format (see figure 2) which are likely to have any development limited to only refurbishment or minor remodeling over their lifespan. However, this does not mean they cannot develop, as there is an opportunity to utilize teaching resources and learning spaces better via the existing corridor / street spaces which can have quite far reaching consequences. This opportunity to vary teaching and learning activities becomes more apparent as explored by Bodil Bøjer[29]. It can transform static formal teaching in cellular spaces into more dynamic teaching and learning approaches by utilizing expanded informal street spaces. As illustrated in the green areas below in Figures 4-6.

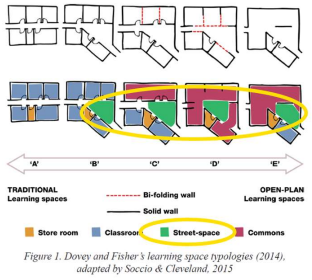

Figure 4: ILETC typologies of space[17]

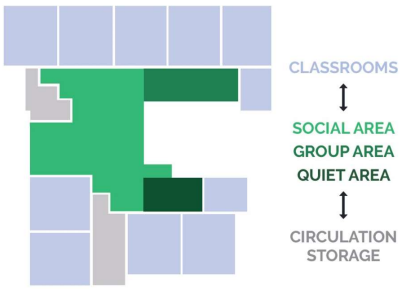

Figure 5: Street space adaption of spaces[29]

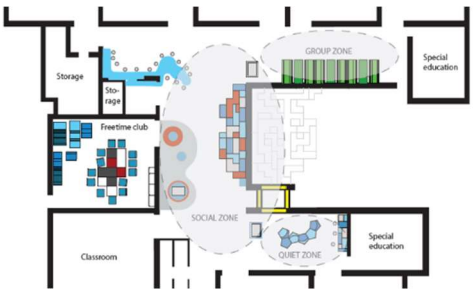

Figure 6: Street spaces and specific activity zones[29]

Figure 4: "Street spaces" as illustrated by Dovey and Fisher, Learning space typologies 2014, adapted by Soccio & Cleveland, 2015[17] highlighted in yellow ellipses. Figure 5 & 6: Adaption of corridors to informal multi-purpose street spaces - Bodil Bøjer Ind Phd.[29]

Increasingly, teaching and learning activities around collaboration are speech communication intensive. Not only a monologue with a teacher speaking and students listening but a dialogue with and between the students, who are actively encouraged to participate in shared discussions and collaborative[27] sessions. This is a much more complex acoustic dynamic to that of a traditional teacher led session like a lecture[1] for example.

3. What is needed for an understanding of ILEs in the context of the featured case study; 3.1 learning activities, 3.2 acoustic conditions, 3.3 spaces.

With the introductory comments in mind, we want to explore and understand more about an ILE we have tracked and visited on numerous occasions which works as a successfully functioning teaching and learning environment.

3.1 An activity based acoustic design approach is helpful in order to create a good learning environment, to assess which teaching and learning activities should be prioritized. To help inform how the spaces should be designed to effectively support these (particularly speech communication) activities for all teachers and students. Teaching as a resource is of high importance as is leadership to support and enable teachers and students to work in ILEs which are sustainable in the long-term. This cannot be underestimated, as teaching as a profession is, in many countries, undergoing clear challenges[18]. This includes staff retention and recruitment, workload and teacher well-being.

3.2 Speech communication for both teacher and student collaboration should be optimized to be clear and intelligible over short distances within class zones. However, beyond class zones speech is perceived as noise and should be kept to a minimum, to reduce the spread of sound causing general disturbance between different learning spaces. This means a specific need to balance good speech intelligibility locally, whereas in contrast over distance, poor intelligibility giving speech privacy between learning zones as demonstrated effectively in a previous school case study[24]. Balancing openness with privacy is similar in some ways to an open plan office, however it is also worth noting a significant occupancy difference. The space ratio (Student/m^2), is likely to be denser and more interactive with speech communication than in a typical office where workers may also interact less and operate on a sub 50% typical occupancy rate. So in learning spaces with a higher and more interactive occupancy there is always likely to be a background buzz which needs to be controlled as sound / noise increases there is a tendency for people to raise their voices (Lombard Effect[19]) involuntarily. This means they compete with each other to be heard above the ambient background noise, thus causing a noise breeds noise situation which is increasingly unpleasant and uncomfortable. More over the chances of the learning environment being as quiet in reality[28] as an office are rare or unlikely, so adaption of any office acoustic approaches like sound masking should be done with caution as they may be potentially counter-productive. The indoor ambient sound level was circa 35 dB (A), although this might be higher at times with ventilation and overhead projectors but recommended[20] to be 30-35 dB Laeq so there is likely to be a degree of ambient masking existing already.

3.3 Transparency[24] or openness between learning spaces can create a few issues. A physical openness is desirable for the visual transparency of behaviour and management around everyday situations which can support more passive and proactive interventions or support to individuals without involving or disturbing many students. However, if there is a line of sight which is also a physical line of sound, there is potential for spreading disturbing noise over distance. In addition to high performance sound absorbing surfaces, having movable sliding doors / walls and furniture dividers instead of solid walls can maintain enough physical transparency whilst reducing the direct spread of sound by being reflected or diffused away from the line of sight. However, these movable objects need to be managed and understood in order not to prevent spaces ending up as flexible spaces trying to accommodate everything and actually unfortunately unsuitable for anything specific. This may be due to unwanted and disturbing sound spreading or reflecting into adjacent spaces which if unchecked are likely to disturb an adjacent class or learning activity.

4. Case study 'Werkplaats Bilthoven, the Netherlands' existing primary years school.

4.1 Case study 'Werkplaats Bilthoven, the Netherlands' overview, design and use – the existing school in focus is a typologies[17] of Space B, C/D layout.

While there is a new extension of the primary school building which has a fully open plan layout in which pupils (9-12 years) and teachers are working together, this paper focuses on the existing part of the building. This has a more traditional classroom layout with children (5-8 years), but has doors between classrooms and sliding doors to the adjacent informal street spaces which are often kept open. So in practice, the existing part of the building can be regarded as a school with a semi-open plan lay-out. Despite this being an adaptable semi-open plan lay-out, the users of the school are very satisfied with the acoustics. For this reason, it is interesting to understand more about the acoustics in the school, in terms of sound attenuation between different spaces in the building. Therefore, measurements of the sound decay between several source and receiver positions were carried out. The existing part of the building (marked in pink below) has a more traditional classroom layout, however can expand into the neighbouring spaces via the large sliding doors into the adjacent circulation areas.

Figure 7: 'Werkplaats Bilthoven' (primary school) layout. Focus and measurement senarios in existing lower years school (5-8yrs) in pink.

Figure 8: shows the classroom and adjacent street spaces.

Figure 9: shows the classroom doors closed from the street space.

4.2 DeWerkplaats acoustic measurements and data (see full report[22])

The acoustic measurements were performed using a reference sound source (type Norsonic nor278). This source was placed in a classroom in the existing part of the building (S1). The resulting averaged sound pressure levels from the source to the multi-purpose street space and then the adjacent classroom were measured in several positions in a defined path to find out how the layout and sliding doors influence the spread of sound. The sound pressure level measurement objectives were to give a better understanding of the acoustic conditions in this school building in terms of sound attenuation and potential acoustic privacy. The measurements were made according to ISO 3382-3 acoustic standards[23] for open using a steady state reference sound source.

Sound attenuation - The decay of sound pressure levels between source-receiver configurations. The spatial decay of sound source gives an indication of the decrease of speech/noise from one position to other positions over increasing distance and indirectly around physical barriers e.g. sliding doors and walls. (Figures 11-13).

In the report[22] Table 1 below, the acoustic data[22] gives an insight into the sound level reduction achieved in, and between the class spaces and multi-purpose street space areas.

LBP Sight previous acoustic data typical spaces	Werkplaats

Sound decay between teaching domains	>20dB (A)
Overall background noise	<45dB (A)
Speech intelligibility in own domain	>0.60 (STI)
Speech intelligibility to other domain / circulation	<0.20 (STI)
Reverberation time	<0.5s

Table 1: Previous room acoustic measurements made at Werkplaats (by LBP Sight) with the values averaged.

4.3 Acoustic measurements were carried out with and without sliding doors opened between classrooms and circulation area as illustrated below.

Figure 10: The three sound propagation measurement paths made in the existing building as figures 11-13.

Source position S1 – Classroom existing part

The results of the measurements with the source in position S1 are shown in figures 11-13. As a result of the measured sound levels the sound propagation along the measurement path is derived. The results are compared with free field conditions (Lw-Lp (dB) relative the free field slope DLfs)[23]. Fig 2-4 show the sound propagation measurement paths between the two classrooms via the circulation multi-purpose space with the corresponding sliding doors both open and closed. The internal door between classrooms is closed at all times.

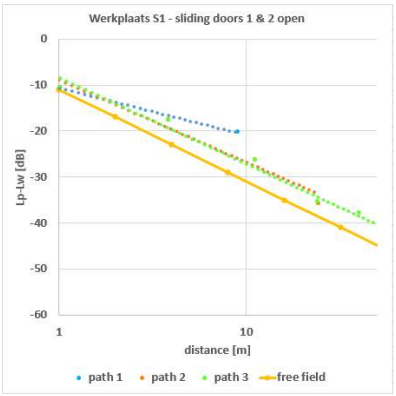

Figure 11: Sliding doors 1 & 2 open.

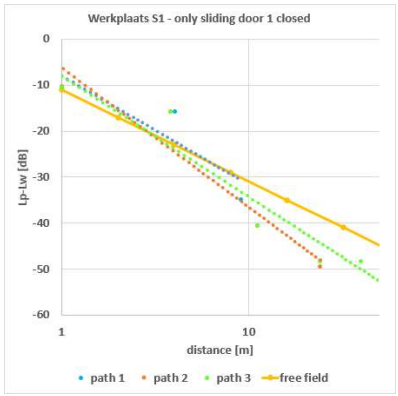

Figure 12: Only sliding door 1 closed.

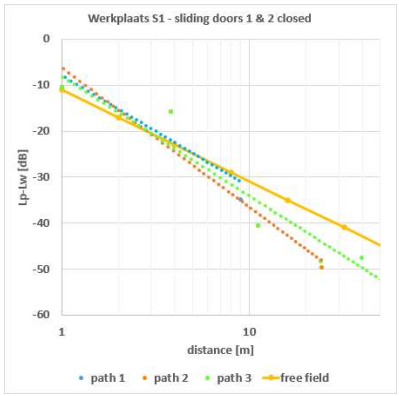

Figure 13: Sliding doors 1 & 2 closed.

Figure 11: Measurement configuration 1. Measured sound pressure levels (LAeq) as a result of the reference sound source in position S1, both sliding doors open to the street space and adjacent calssroom.

Figure 12: Measurement configuration 2. Measured sound pressure levels (LAeq) as a result of the reference sound source in position S1. Sliding door 1 is closed (closer to the sound source) to the street space, sliding door 2 is open (further from the sound source) to the street space.

Figure 13: Measurement configuration 3. Measured sound pressure levels (LAeq) as a result of the reference sound source in position S1. Both sliding door 1 and door 2 are closed from the classrooms to the street space.

4.4 The acoustic measurements relative to acoustic standards for sound propagation / attenuation.

The measured values below are shown and compared with various acoustic regulations[21] for open plan schools. They describe three scenarios measured and how the sound behaves in this learning environment which gives a representation of how the overall sound environment typically works in this case study.

Sound Source S1 Room1 & Room2 doors	To class street space	To adjacent class street space	To adjacent classroom
1. Rm1 door open & Rm2 door open	10dB	20-25dB	27-33dB
2. Rm1 door closed & Rm2 door open	23dB	30-35dB	38-42dB
3. Rm1 door closed & Rm2 door closed	23dB	30-35dB	37-43dB*
Recommended standard for sound attenuation	20dB		
Rec standard for sound insulation between rooms			40-45dB**
Rec standard for sound insulation for door sets		30-35dB	

Table 2: Measured values compared to various open plan school acoustic regulations[21] *Internal door reason for not achieving 40-45dB**.

Interesting aspects from the above measurements is that they give an insight into the sound level reduction in and between the class spaces and multi-purpose street spaces; over distance which is dependent on the high absorption materials and sliding doors. There is no improvement between figure 12 & 13 due to poor attenuation between the two classrooms around the door. The door is non-acoustic with small open keyhole allowing for some leakage which is enough to negate any potential sound level reduction between the two classrooms.

5 Discussion and conclusions

Based on the acoustic measurements and testimonial input from the headteacher, class teachers and an acoustician, we have a better understanding about how the existing primary years school works and how it supports the teaching and learning activities carried out there.

- The sound attenuation in the existing part of the school is about 25-30 dB between both classrooms with the sliding doors open. This is lower than recommended standards for sound insulation between classrooms, but higher than the recommended sound attenuation between spaces in schools with an open plan layout.

- With closed sliding doors a sound decay of circa 20 dB was measured towards the street space behind the sliding doors and at least 25 dB on greater distances. This is lower than recommended standards for sound insulation between classrooms and street spaces and the separating internal door should be upgraded to improve the drop in sound levels. It would be interesting in future to understand more about the sound attenuation in the new and more open extension with no sliding doors to close. However, it was noted by the head teacher that part of the success of the more open space for children aged 9-12yrs is perhaps down to an acclimitisation process during their time in the semi-open space, for the 5-8yrs before they move on to the more open space. The classes in the semi-open space start with the sliding door closed and can gradually adapt to using the street spaces while respecting the adjacent classroom activities etc.

- If compared with guidelines for acoustic design of schools[21] partitions between adjacent activity areas in open plan bases schools should achieve at least 20 dB sound attenuation. Furthermore the recommended sound insulation DnT;w between classrooms should be 45-50 dB or DnT;A = 43 dB.

Looking at the sound reduction from the sound source to the street space and adjacent classroom (Lp-Lw (dB) relative to the freefield slope DLfs)[23] it is worth noting the findings from the Witzenhasuen case[24]. It has similar findings in the sound level drop which is likely to correlate with a corresponding drop in the speech intelligibility (STI) leading to increased privacy and minimum distractions and disturbance as perceived by the users.

There is a simple yet effective activity based design approach in action here which is supported effectively by the use of the sliding doors to the street space and the variety of furniture. From an acoustic perspective the high performing Class A absorbing ceiling accompanied by the layout has given an effective sound

environment. This supports whole class instruction, group work and avoids the potential Lombard Effect[19]. It also supports a diverse range of learning activities spreading out into the street space without unduly disturbing or distracting the adjacent classrooms.

Relating to the typologies of space A-E referenced earlier, these traditional semi-open spaces appear to support an ongoing transition from teacher-centric to more student-centric learning approaches. Teachers don't seem to have any issues managing the learning activity noise. In fact some commented on having more engagement with some students who were previously restricted in the classroom, thereafter being more productive when they could choose a space where they were more comfortable which improved their learning engagement and outcomes.

A further case study of the new extension would inform a fuller understanding of how and why these spaces are perceived and utilised so successfully. It should also be noted that there is a clear culture of how the students and teachers should work and collaborate. The leadership and team teaching appears to reinforce this on a constant basis almost as an unconscious but integral aspect of the school. This case study will hopefully be useful for further development and inform future design guidance for new design or remodeling of schools.

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