Acoustic impact on collaborative teaching and learning activities in open learning spaces

AUTHORS:
Colin Campbell[a)]
Saint-Gobain Ecophon AB, Sweden
Holger Brokmann[b)]
Saint-Gobain Ecophon gmbh, Germany
Jeroen Vugts[c)]
LBP|SIGHT, Netherlands
Esther van Oorschot-Slaat[d)]
LBP|SIGHT, Netherlands

ABSTRACT 1466:

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 centered 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.

[a)] email: colin.campbell@ecophon.se
[b)] email: holger.brokmann@ecophon.de
[c)] email: J.Vugts@lbpsight.nl
[d)] email: E.vanOorschot-Slaat@lbpsight.nl

1. INTRODUCTION AND BACKGROUND

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. 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. PEDAGOGY, LEARNING SPACES RESEARCH AND ACOUSTIC CONTEXT

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). This is broadly to encourage greater student engagement in their own learning process and encourage collaborative[27] learning. To motivate students to learn how to learn for themselves and to be more active, taking more responsibility for their own learning. Where the teacher is more of a facilitator or coach in a shift towards activity based learning. However, elements of the traditional approach, the three Rs[12]: **r**eading, w**r**iting & a**r**ithmetic are often highlighted as missing regarding these pedagogic changes which can create divisive or polarised debates around learning and more often than not around learning spaces. 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) spaces 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.

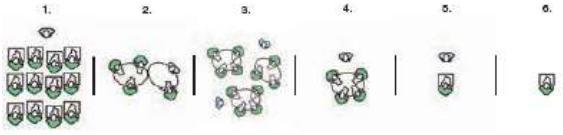


Figure 1. Teaching style typologies Dovey & Fisher, 2014.

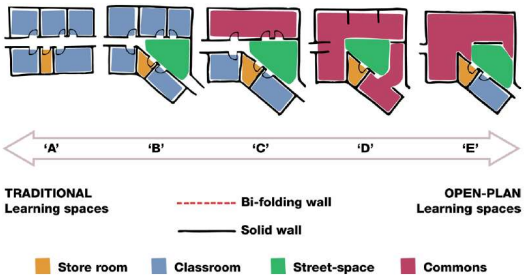


Figure 2. Dovey & Fisher's learning space typologies (2014), adapted by Soccio & Cleveland, 2015 adapted by Bradbeer et al, (under review).

In figure 2. it is understood that any move from space A towards E requires a move from teacher-centric approaches to student-centric approaches in order for the activities and spaces to function. This means the teacher involvement changes to be more of a facilitator where students take more responsibility in their learning, allowing teachers to release some control. This is a delicate balance and requires an appropriate and clearly understood culture and leadership approach in the school. Interestingly, the 2000 school ILETC survey[26] in New Zealand and Australia found traditional spaces and teacher led approaches still highly prevalent. The report[26] found that 58% were utilizing Type A - Traditional closed classrooms off a corridor and 36% of learning activities were teacher centric and didactic approaches.

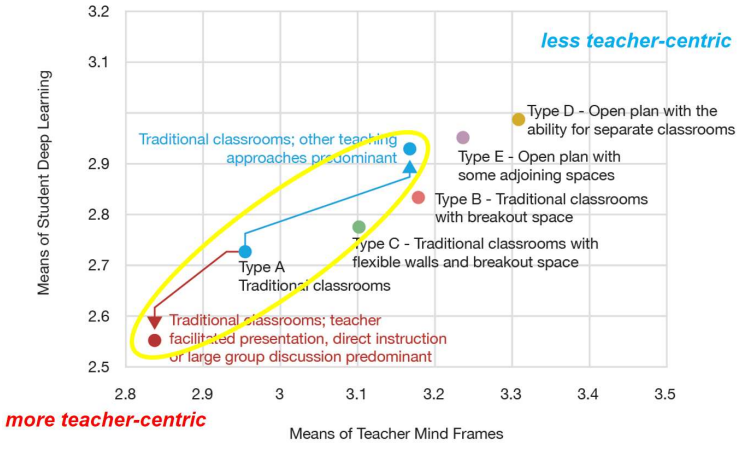


Figure 3: Adapted from the ILETC Report[26] with additional text and yellow ellipse highlighting the differences found.

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). These findings are very similar to those of the Essex Study[6] where improved acoustics had a similar effect, allowing more diversified teaching approaches in cellular classrooms.

2.3 Acoustic context around priorities for learning activities

Increasingly, teaching and learning activities based around collaboration are going to be more speech communication intensive. Moreover, it is also important to highlight that a collaborative[27] approach, encouraging engagement and participation means that speech communication is now much more complicated than in the past. No longer 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 sessions. This is a much more complex acoustic dynamic compared to a teacher led session like a lecture[1]. Accordingly, the acoustic design needs to move from a theoretical room acoustics only approach to one which incorporates the influence of the users in their learning spaces. Taking an end user focused activity based acoustic design approach is likely to deliver a suitable acoustic learning environment. Where the design process is primarily centred around the teaching and learning activities, and the appropriate acoustic control and measures can be included and understood from the outset.

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 Openness of spaces.

Taking on board the above comments, we wanted 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 in the acoustic context, to effectively support comfortable and effective speech communication activities for all teachers and students. In addition, and in the bigger picture, 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 was recently highlighted by the OECD[18] as a profession where in many countries, is undergoing clear challenges. 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. This means learning spaces are likely to have a higher background buzz which needs to be controlled to minimise the buildup of sound which leads to the tendency for people to raise their voices (Lombard Effect[19]) involuntarily. This means

their voices compete with each other to be heard above the buzz or ambient background noise, thus causing an increasingly unpleasant and uncomfortable noise breeds noise situation. 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 45 dB including ventilation and 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 It is important to understand some of the fundamental design issues around transparency[24] or openness between learning zones as there are two clear conflicts which often go unresolved. A physical openness is desirable for the visual transparency of behaviour in assisting more passive management and proactive interventions around everyday situations or enabling individuals to be given support in a learning space without involving or disturbing other 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, breaking up large spaces into physical zones with large objects like cupboard stores or toilet facilities can help to reduce the spread of sound. Balancing enough physical transparency whilst reducing the direct spread of sound with movable furniture and partitions to reflect or diffuse the sound paths can help. However, the uses for movable objects need to be understood and managed in order not misused as barricades and back tracking towards trying rebuild traditional separated and cellular learning spaces. This can then result in potential flexible spaces which try to accommodate everything actually becoming unsuitable for anything specific and being viewed very negatively. This is totally understandable if it is due to unwanted and disturbing sound spreading into and disturbing adjacent zones and learning activities.

4. CASE STUDY: "WERKPLAATS BILTHOVEN, NETHERLANDS – NEW EXTENSION PRIMARY YEARS SCHOOL.

4.1 Case study overview, design and use – the new extension in focus is a "typologies[17] of space" C/D layout.

A preceding Euronoise2018 paper focused on the existing De Werkplaats primary years building (5-8 years) which has a more traditional type B/C layout[17] give an understanding around the school's development and use of their learning spaces (see figure 5 & 9). The existing building utilizes sliding doors allowing spreading out to the break-out street spaces. According to the former head teacher, this means that before the children occupy the more open new extension[30] which is the focus of this paper, they are already used to spreading out to a variety of learning activities in spaces outside the traditional classroom. They are used to starting lessons in the traditional classroom, then moving out to the street space when the door is open. Perhaps most importantly, this means they understand how to behave and respect student doing different activities in the adjoining learning zones. The head teacher referred to this transition in class spaces with sliding doors as an acclimatisation process (Figures 5,6 & 7) for the students and is believed to be a contributory success factor of the new extension.

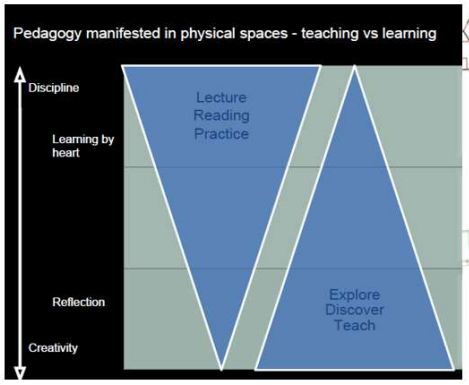


Figure 4: Loop[14].

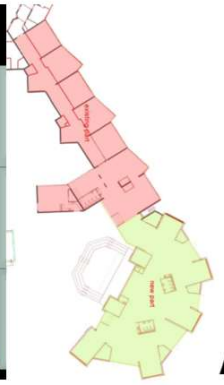


Figure 5: School layout.

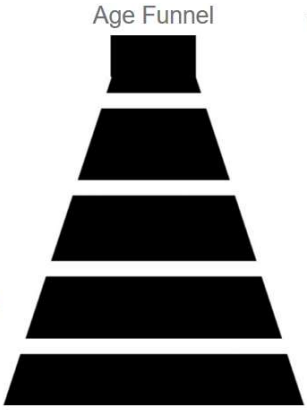


Figure 6: Age funnel.

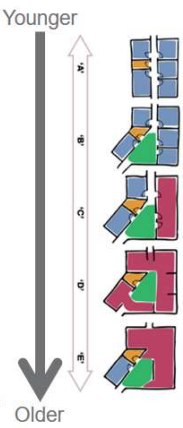


Figure 7: From Figure 2[17].

The head teacher (2011-17) Jeroen Goes described the school organizational approach of both the existing and new extension as follows: "It's not a concept but a culture" This approach goes back to the Founder from 1926 Kees Boeke[29]. The full name - De Werkplaats Kindergemeenschap means "The Workplace children's community". From the outset there was a different approach, instead of teachers and students they describe the organization as workers and coworkers and employees built around a team ethos. There are around 600 students in the kindergarten and primary schools with children 4-12 years old. The new extension which is focused on in this study is quite open plan compared to the existing more traditional building for the younger children (5-8 years). The traditional building has been described as a step and transition towards the more open learning spaces of the new extension with doors between classrooms and sliding doors to the adjacent informal street spaces which are often kept open. So the classes are quite free to move around, and as they do, they learn how to behave and respect neighbouring learning spaces without disrupting or distracting them. In addition, although the new extension is quite open, it has however a carefully zoned where the students (9-12 years) and teachers are working together. Based on the leadership and culture, there is an activity based approach and the education is delivered in teams and class domains / zones. The core primary learning domains where the teacher addresses the class are out of the line of sight and sound of the adjacent classes. The classes start in the primary areas with any whole class instruction and then spread into the secondary learning spaces between the primary learning domains. Despite this extension being a more open-plan lay-out, the users of the school are very satisfied with the acoustics and they say it fits better with the school's philosophy around a learning workplace community. Due to its ongoing success it is interesting to understand more about the acoustic environment in the school, in terms of sound attenuation between different learning domains in the building.

Werkplaats new extension	**Details**
Age of students	**9-12 years**
Number of students	**300**
Overall m2	**1000m2**
M2 / student	**3.5m2**
Type of space[17] layout	**C/D**

Figure 8: Table info for Werkplaats extension.

Figure 9: Overall school layout existing building & new extension. The new extension is marked in green above and has a more open-plan lay-out than the traditional existing building in pink.

Figure 10: shows the secondary learning spaces.

Figure 11: shows the secondary space in between two primary domains.

Figure 12: shows an extended 180degree image of the much of the whole learning space including four primary domains.

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 (S2). The resulting averaged sound pressure levels were measured from the S2 position in a primary learning domain to various nearby learning spaces. The sound measurement objectives were to give a better understanding of the school acoustic conditions in terms of sound attenuation and acoustic privacy (potential distraction & disruption to learning). The measurements were made according to ISO 3382-3 acoustic standards[23] for open plan spaces using a steady state reference sound source. The spatial decay of sound source indicates the decrease of speech / noise from the source position to other positions over an increasing distance and indirectly around physical barriers e.g. walls and furniture. (Figure 14). The acoustic report[22] data in Figure 15 below, gives an insight into the sound level reduction achieved in, and between the primary class domains, the nearby secondary class areas and adjacent primary domains.

4.2 Acoustic measurements made to investigate how the sound propagates from a typical primary class domain to secondary areas and adjacent class domains.

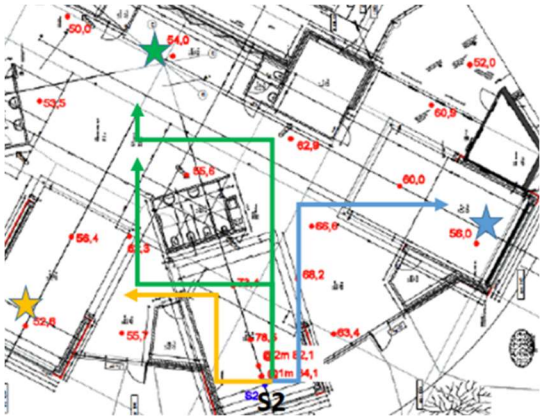
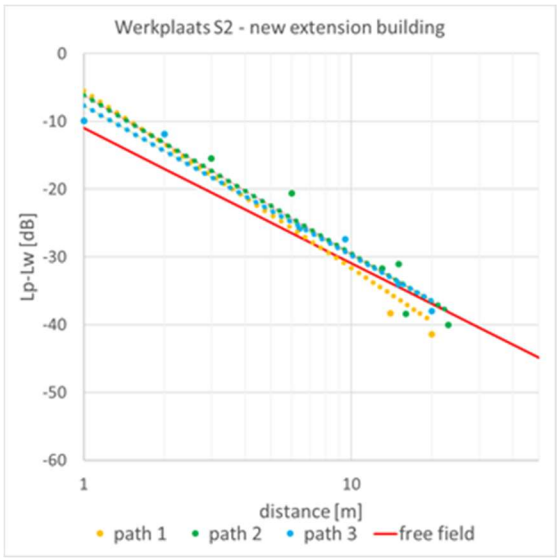


Figure 13: 3 d architectural model of new extension. **Figure 14:** Sound attenuation - the decay of sound pressure levels between source-receiver configurations. The indicative measured sound paths 1 (yellow), 2 (green) & 3 (blue), from position S2 in the new extension.

Measurement results from source position S2 a primary class domain in the new extension are shown in Figure 15. 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]. Figure 14 shows the sound propagation measurement paths between a primary class domain and the surrounding learning spaces. Figure 16 shows the typical sound attenuation in an open plan office which is much less effective as the line of sight and sound are generally more with less physical sound barriers.



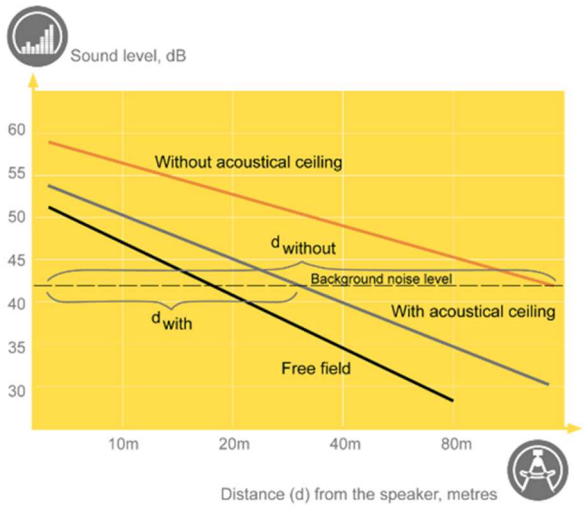


Fig 15: Sound paths 1-3 vs free field. **Fig 16: Office open space with & without acoustical ceiling vs free field.**

Figure 7: Measured sound pressure levels (LAeq) - 3 indicated sound paths from S2 source:
1. Indicative yellow sound path into an adjacent primary class domain.
2. Indicative blue sound path into another adjacent primary class domain.
3. Indicative green sound path into an adjacent seconday common learning zone.

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

The measured values below are shown and compared with relevant acoustic regulations[21] where appropriate for open-plan schools. They describe the 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. As found before[24] there is likely

to be a correlation between the decrease in sound propagation with a beneficial increase in speech intelligibility (STI). See summary STI data in Figure 18 below.

LBP Sight previous acoustic data typical spaces	Werkplaats
Sound decay between teaching domains	>20dB
Recommended decay between adjacent activities	20dB
Overall background noise	<45dB
Speech intelligibility in own primary domain	>0.6 (STI)
Speech intelligibility in own secondary domain	>0.45 (STI)
Speech intel. to other domain / circulation	<0.20 (STI)
Reverberation time	<0.5s

Figure 18: Table overview of acoustic measurements (values averaged) at Werkplaats (by LBP Sight) & appropriate recommended guideline.

5 DISCUSSION AND CONCLUSIONS

Based on the acoustic measurements and testimonial input from the head teacher, class teachers, the architect and the acoustician, we have a better understanding about how the new extension at the DeWerkplaats primary school works. How it supports the teaching and learning activities carried out there and is now working closer towards its original philosophy around a community based and collaborative workplace.
The sound reduction between the class domains is much greater than you would expect in a typical open plan office, as show in Figure 15 & 16 which helps to put some context and emphasis the difference in these types of spaces. However, comparisons with open-plan offices should be made with caution as educational open spaces should have much better control of sound propagation between spaces. This is due to; higher people to space ratios which will give a higher background ambient noise aligned with increased speech communication collaboration throughout the building. More over learning space layout should avoid potential direct sound lines following the sightlines which are there for transparency.
In the new extension we can see the effective level of sound attenuation achieved between the key learning spaces. From the class domains, there is an initial sound reduction of around 10dB as the domain opens into adjacent secondary zones. Then due to the indirect sound and sight lines around walls and furniture screens a sound reduction of 15dB was achieved in the adjacent secondary spaces potentially used by the same class. Then a sound reduction of 20-25dB was measured in the adjacent primary domains used by a different class.
Finally, a beneficial sound reduction of around 30dB was achieved to the central street-space. Combining these sound level reductions with the minimum background noise level of around 45dB supports why in general speech is not disturbing the adjacent class domains which also corresponds to the different speech intelligibility values previously measured. Overall the sound attenuation in the new open-plan extension is almost as effective as the existing traditional layout when it's sliding doors open and both surpass the recommended standards for sound attenuation between spaces in schools with an open plan layout. However, it was noted by the head teacher that part of the success of the more open space for children aged 9-12yr old, is perhaps down to an age acclimitisation process (see Figure 6) during their time in the existing more traditional semi-open space, for the 5-8yr old, in advance of occupying the more open extension. From being used to starting classes behind a closed sliding door they use the street spaces while respecting the adjacent classroom activities etc. 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 a more dramatic sound level drop due to more pronounced zoning via overlapping partitions replacing doors and acting as very effective sound traps. Again as has been found in DeWerkplaats, effectively designed spaces attenuating much of the

unwanted noise have increased privacy and minimised distractions and disturbance beyond initial expectations and are perceived very positively by the users.
Hans Kloosterman a teacher said “The idea was to use every possible square metre without wasting any space for corridors. Each corner is designed for a certain activity, for example for arts and crafts we go to the studio. Children who are easily distracted go to a quiet area of the building. Having the children move around this way saves having to adapt classrooms. The children I teach are no longer “mine” but “ours”. The teachers help each other and there’s a much better sense of community now” referring to team teaching. Careful attention by the architect Kees Willens to minimize parallel walls and offset the chances of sightlines and sound lines combining to potentially distract and disturb if unchecked.

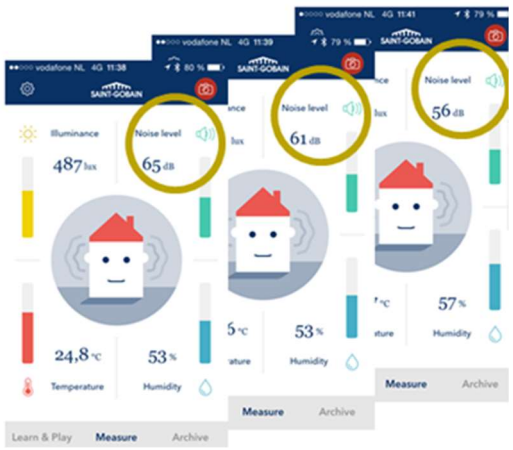


Figure 19: Sound levels recorded[31].

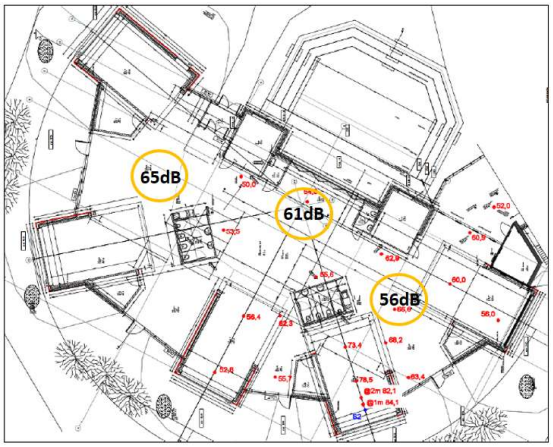


Figure 20: Shows around where the sounds were recorded.

Interestingly during a tour with the head teacher and while walking through the different class domains in the open learning spaces, he identified the different activity zones and what behaviour and noise is expected for them to work. We experienced the areas starting in active practical sessions then becoming quieter and more focused. We also saw a corresponding drop in the sound levels (MC350 App[31]) which backed up what we experienced (see Figure 19 & 20). Figure 20 shows the average sound levels in three different areas, where the head teacher explained the three different activities being carried out. We perceived the learning activities to become progressively quieter as we moved through the learning spaces which was in line with this. The sound levels dropped around 5 dB as we moved between the different activity zones and although the first area was around 65dB it felt in keeping with the practical collaborative session going on. As we moved to the other zones we were not conscious of any disturbing noise from the other areas and perhaps this was due to the natural buzz in the immediate spaces. In general, the atmosphere was calm and comfortable and the different noise levels of the learning activities was expected and managed accordingly. On some occasions the ambient noise can become too much for individuals and alternative methods are used, for example it was noted that ear defenders were available for all students. The head teacher explained that headphones for music or ear defenders are only used temporarily, for calming or reducing noise. Any music selected to be appropriate ambient or natural sounds Over the past 5 years the Werkplaats learning spaces have functioned very effectively with few problems. One issue worth noting is around the team teaching approach which is in operation in all spaces. Teachers need to collaborate more closely with their surrounding teachers and they work and support each other either directly or indirectly all the time. It is vital that there is a harmony in the team dynamic for this to work. The voice of a more loudly spoken teacher can disturb adjacent spaces and interfere with other learning activities. This was found to be the case, where the voice was reflecting off a wall in an unseen sound line and around a corner into an adjacent space. The issue was solved with more

wall panels. See Figure 21 & 22. However, more extravert teachers can take up more space with their class without realizing whilst more introvert teachers may be inclined to withdraw, so although more research is needed here, it should part of the organizational set up discussion.

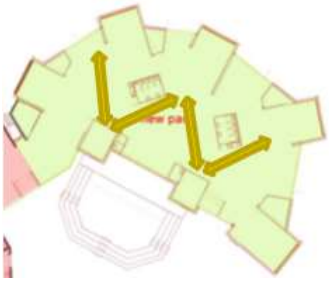


Figure 21: arrows show unwanted sound reflections.

Figure 22: additional wall absorber which eliminated the disturbance.

Figure 21 shows the approximate invisible sound line paths which are sound reflections disturbing adjacent spaces. Figure 22 shows where wall absorbers were placed to take away these sound reflections which created noise disturbance between the adjacent spaces.
There is a simple yet effective activity based design approach in action here which is supported effectively by the acoustically separated class domain zoning. From an acoustic perspective the high performing Class A absorbing ceiling and wall absorbers, accompanied by a vast array of furniture and offset walls has given an effective and comfortable sound environment. Effectively separated zones in a comparatively open layout and supporting whole class instruction, group work whilst avoiding the potential Lombard Effect[19.] It also supports a diverse range of learning activities in the adjacent secondary spaces without unduly distracting or disturbing the adjacent class domains. Relating to the typologies of space A-E[17] referenced earlier, this relatively open-plan C/D type of space relies on proactive collaborative teaching and learning approaches which respect the adjacent learning activities. The teachers don't seem to have any issues managing the learning activity noise. In fact, some commented on transparency and team teaching approaches as beneficial for better student engagement.
It should also be noted that there is a clear culture of how the students and teachers should behave and work through collaboration. The leadership and team teaching appears to reinforce this on a constant basis almost as an unconscious but integral aspect of the school. The head teacher was very positive about the activity based approach here and how with the support of the architect and acoustician developing and activity based acoustic design approach it is possible to support many different activities in quite open but carefully designed learning spaces.
Finally, and crucially, understanding the significance of good acoustics cannot be underestimated regarding the key building design influencers. The project architect Kees Willems summarises the importance of acoustics in this type of school project: "If the acoustics aren't right, the whole concept fails" The most important physical condition for success is good acoustics. Without good acoustics you end up with an unhealthy building".

This case study will hopefully be useful for further development and to inform future design guidance for new schools or extensions, particularly with reference to the existing and adjoining semi-open plan school covered in a Euronoise2018 paper which compliments this more open-plan approach in the schools' development. Hopefully there may also be a way to inspire the architecture design process to think about sound and sight lines and where they might be connected, even if it is only rule of thumb thinking.

References:

1. M. Oberdoster; G. Tiesler. Modern School Acoustics – On teaching styles, room acoustics, teachers' health and pupil behaviour. 2006
2. Lyberg Ålhander V, Summary of the Project 'Speakers' Comfort': Teachers' Voice use in Teaching Environments. IBPC 2015 Turin.
3. Børn & Unge 01/2008, Study into noise exposure in Educational buildings - Hearing damage and Det Nationale Forskningscenter for Arbejdsmiljø, Denmark.
4. Ljung, R., Israelsson, K. & Hygge, S. (2013). Speech Intelligibility and Recall of Spoken Material Heard at Different Signal-to-noise Ratios and the Role Played by Working Memory Capacity. Applied Cognitive Psychology, 27 (2), 198-203.
5. B. M. Shield, J. E. Dockrell, "The effects of classroom and environmental noise on children's academic performance ICBEN 2008
6. D.Canning, A. James. The Essex Study –Optimised Classroom Acoustics for All. 2012.
7. Canning, D - Evidence defining good acoustics for pupils with hearing difficulties (2010).
8. A. ROBINSON; L.ROSE MUNRO, New generation learning environments: creating good acoustic environments - policy to implementation Internoise 2014 Melbourne.
9. Oseland,N.& Hodsman,P (2015) Planning for Psychoacoustics: A Psychological Approach to Resolving Office Noise Distraction.
10. Anne Knock https://anneknock.com/2017/03/04/how-open-learning-space-can-work-for-introverts-extroverts-ambiverts-d-a-r-e/
11. The Four Cs http://www.p21.org/our-work/4cs-research-series
12. The Three Rs https://en.wikipedia.org/wiki/The_three_Rs
13. (Fisher and Frey, 2008) The gradual release of responsibility model.
14. M. Guldbaek Broens,Teacher collaboration & physical space. How teachers divide & share an open learning space through their practices. 2016
15. ILETC http://www.iletc.com.au/
16. Dovey and Fisher, Teaching style typologies 2014, adapted by Bradbeer et al, (under review)
17. Dovey and Fisher, Learning space typologies 2014, adapted by Soccio & Cleveland, 2015
18. A.Schleider OECD Directorate,Education conference 2016.
19. J. Whitlock, G. Dodd, "Classroom Acoustics – Controlling the Cafe Effect… is the Lombard Effect the key?" ACOUSTICS 2006, New Zealand
20. E. E. Greenland, B. M. Shield, A survey of acoustic conditions in semi-open plan classrooms in the United Kingdom. ASA Journal 2011.
21. Møller Petersen, C. Rasmussen, B. Acoustic design of open plan schools and comparison of requirements. (2012)
22. The Werkplaats Bilthoven (NL) acoustic measurements Report - Acoustic Bulletin DeWerkplaats article 2018 http://www.acousticbulletin.com/wp-content/uploads/2018/05/werkplaats-bilthoven-nl-acoustic-measurements.pdf
23. ISO 3382 – 3: Acoustics – Measurements of room acoustic parameters – Part 3: Open plan offices
24. J.Vugts, E.van Oorschot-Slaat, C. Campbell, H. Brokmann, Effective open learning landscapes and the well-being of teachers and students. ICBEN 2017.
25. A. Wood, A School's Lived Architecture: the politics and ethics of flexible learning spaces. Philosophy Education and Social Research Institute, Manchester Metropolitan University January, 2017.
26. ILETC Tech Report 1. http://www.iletc.com.au/wp-content/uploads/2017/07/TechnicalReport_Web.pdf
27. EUN Partnership Collaborative Learning, CO-LAB Final Evaluation and Recommendations Report IBE, January 2018.
28. Sound environment in open plan learning spaces https://www.ains.fi/
29. Kees Boeke - wikipedia https://en.wikipedia.org/wiki/Kees_Boeke
30. DeWerkplaats film with English subtitles http://www.ecophon.com/en/about-ecophon/ECO-magazine/education-articles/2016/de-werkplaats/
31. MC350 APP measuring sound from an uncalibrated iphone microphone, however useful for comparative purposes in context.