Effective open learning landscapes and the well-being of teachers and students

Jeroen Vugts[1], Esther van Oorschot-Slaat[2], Holger Brokmann[3], Colin Campbell[4]

[1] Ibpsight, Nieuwegein, Netherlands

[2] Ibpsight, Nieuwegein, Netherlands

[3] Saint-Gobain Ecophon, Lubeck, Germany

[4] Saint-Gobain Ecophon, Hyllinge, Sweden

Corresponding author's e-mail address: colin.campbell@ecophon.se

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 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.

A good practice European example is referenced and explored to investigate the practicalities of these evolving pedagogic approaches and spaces. Assessing specific acoustic data and the relevant acoustic parameters and regulations.

Effective open learning landscapes need to be planned with an activity based acoustic design so future learning environments can have the necessary considerations to support sustainable learning outcomes, health and well-being.

BACKGROUND AND INTRODUCTION

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 teaching 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 (ILEs) have even greater noise issues due to the nature of sound spreading from one teaching space to another and the disruptive consequences associated with this.

Importance and benefits of good acoustics

We have clear ideas and an understanding of how to solve good 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 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 unsuitable acoustic conditions. Serious consideration is required for inclusion[8] and perhaps further consideration for accommodating personality[9,10] differences (introvert, extrovert) and gender maturity differences.

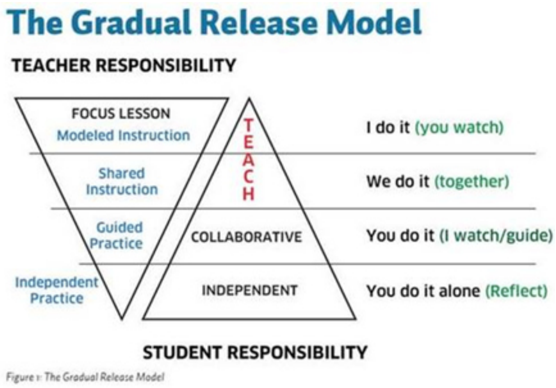
Pedagogic changes and spaces required

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. 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 criticised as missing which can create divisive or polarised debates around learning and more often than not around learning spaces also. (See Figure 1) The Gradual Release Model[13] with an overview of the teacher vs student changes and the development on this (see Figure 2) Pedagogy manifested in physical spaces[14].

An important 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 six PhD studies centered around teaching approaches and the use of innovative learning environments.

The ILETC project is working with teaching style typologies[16] ,(see Figure 3) and learning space typologies[17] (see Figure 4) as a baseline for teaching and learning activities and the associated learning spaces.



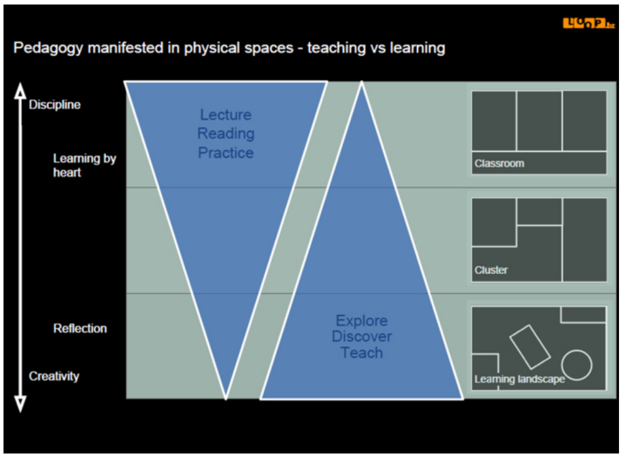
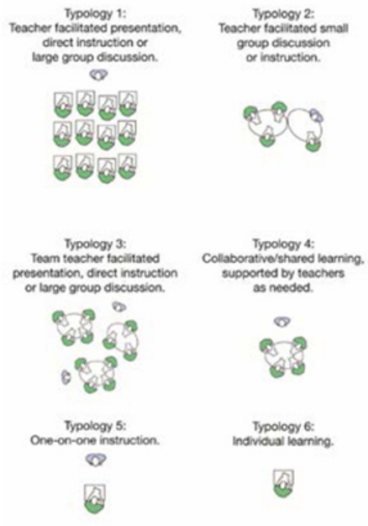


Figure 1: Gradual release model

Figure 2: Pedagogy manifested in physical spaces



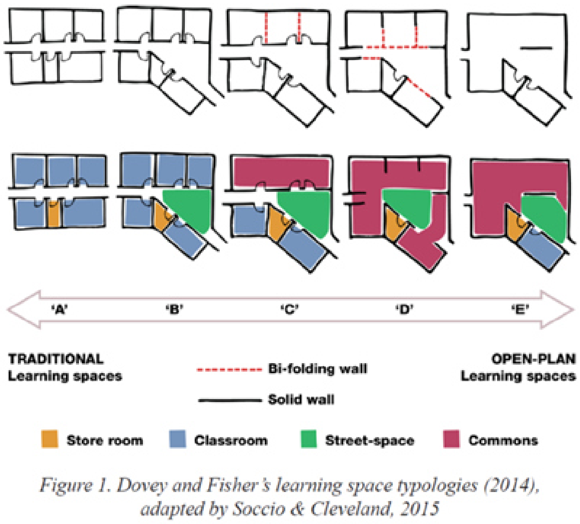


Figure 3.

Figure 4.

Figure 3: Teaching style typologies Dovey and Fisher, 2014, adapted by Bradbeer et al,(under review)

Figure 4: Dovey and Fisher's learning space typologies (2014), adapted by Soccio & Cleveland, 2015

Many of the teaching style activities are speech communication intensive, not only the teacher speaking and the students listening but also where the students are actively encouraged to speak in group discussions and collaborative shared sessions. The latter is a completely different acoustic dynamic to that of a traditional teacher lead session where it is predominately the teacher speaking and the students listening. It is also worth noting that the population of students in a learning space is likely to be more dense and interactive than in a typical office where people may interact less and which may run on a 50% occupancy rate. So the chances of the learning environment being as quiet as an office are unlikely, except in test or concentration sessions.

What is needed for ILEs; a) learning activities, b) spaces c) acoustic conditions

With the introductory comments in mind, we want to explore and understand more about a ILE which we have tracked and visited on numerous occasions which works as successfully functioning teaching and learning environments. Interestingly, the importance of a good acoustic environment was considered and valued from and early stage, resulting in few acoustic complaints.

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. Then 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, particularly bearing in mind that teaching as a profession is, in many countries, undergoing severe recruitment challenges. The teaching profession has some clear challenges[18] and as a profession, needs to be valued highly, to be financially and intellectually more attractive and to address issues around workload and teacher well-being.

Speech communication for both teacher and student speech collaboration and communication should be optimized to be clear and intelligible at short distances within class zones. However beyond class zones speech becomes noise and should be kept to a minimum, to reduce the spread of sound over distance causing general disturbance between different learning spaces. As sound / noise increases there is a tendency for people to raise their voices (Lombard Effect[19]) to compete with each other to be heard above the background noise, thus causing everyone to continue to raise their voices making the situation increasingly unpleasant and uncomfortable to be in. A certain amount of privacy is required, while the physical openness is desirable for transparency where behaviour can be managed more passively as situations can be handled and supported on an individual basis without involving all students.

Transparency or openness can create a few issues if there is a line of sight which is also a physical line of sound or disturbing noise over distance. Introducing glass dividers and partitions instead of solid walls increases the physical transparency and can reduce the direct spread of sound as it is reflected away from the line of sight. However the sound reflections created by additional glass should be carefully monitored and either cancelled out by a further wall absorber or furniture. This can help to reduce the potentially unwanted and disturbing sound reflections spreading into other adjacent spaces which if unchecked are likely to disturb a different class or learning activity. The Witzenhausen case study highlighted in this paper can help to inform key decision makers, as a first step in evaluation regarding a transition from traditional to more open learning spaces.

‘Berufliche Schulen Witzenhausen’ case study overview

The two-storey Upper Secondary of the ‘Berufliche Schulen Witzenhausen’ in Germany was completely renovated in 2011. It is now a semi-open plan layout which makes it an interesting school to study and understand more about the specific acoustic conditions for this ILE.

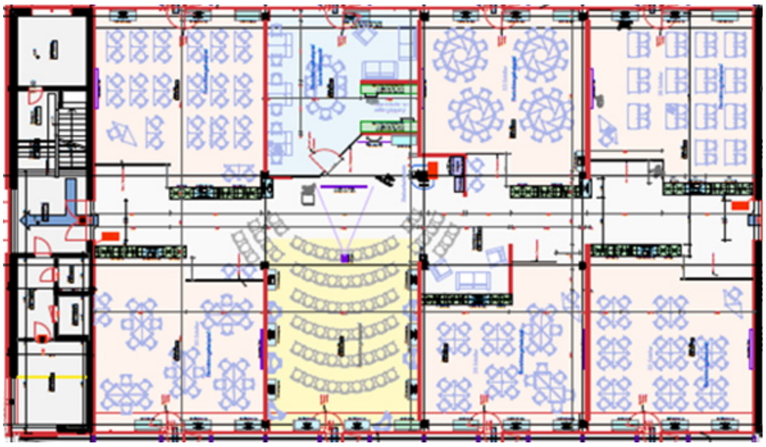


Figure 5: External view of school **Figure 6:** Plan drawing of 1st floor semi-open plan layout

This working example can provide some valuable information for steps towards workable and practical learning environment designs.

Before any drawings were made, the teachers were consulted and they asked for an open-plan environment where students and teachers could move around freely without the hindrance of closed doors. This placed extra high demands on the sound environment. All types of teaching and learning activities would have to function while students and teachers in other areas should not be disturbed. Design criteria meant prioritizing clear speech communication for teaching areas, whilst minimized sound spreading to other areas.

Although originally a traditional layout, the new remodeled learning environment can be described as a semi-open plan school. There are still partition walls or sound barriers between the classrooms and glazed walls between classrooms and circulation, corridor and break out spaces, however there are no doors between these different spaces. As a result of this all classrooms have offset openings between the partition walls and maintain an open physical connection with each other. Fully covering "Class A" sound absorbing ceilings and wall panels (covering around 25% of floor area) were proposed to limit sound propagation. In addition, to compensate for the absence of doors, the offset and overlapping glass partitions, cupboards and walls were integrated in the design. These full height partitions overlap, creating barriers and sound traps to reduce the spread of sound whilst maintaining a good level of visual transparency. In addition, to counter the potential unwanted sound reflections from the glass partitions, wall absorbers and furniture bookcases were set directly opposite the glass to limit sound build up and spreading between spaces.

The new environment represents a conscious step on a transition from the use of traditional closed learning spaces to a more open learning space. This is especially evident regarding the achievement of transparency of the class spaces while maintaining a well-designed level of acoustic control. Understanding how this design works can support other future school remodeling designs, particularly the transition towards more open zoned spaces. Teachers and students can work independently and additionally interact and collaborate with other class zones. Referring to the typologies of space (Figure 4) Witzenhausen is an example of a "Type A" with its existing teaching spaces, moving to a Type B/C in this remodelled building.

Consequently, despite the open plan layout, due to the thoughtful design the users of the school (teachers and students) are very satisfied with their learning environment including the acoustics during their teaching and learning activities. The open connection and transparency allow some flexibility and connectivity between the variety of activities and an increased awareness and respect in their behaviour has been observed. See head teacher comments later.

Open plan spaces require additional acoustic design criteria[20,21] as they are significantly more complex acoustic spaces. Intrusive noise arising from activities in adjacent class rooms and circulation spaces can increase the ambient indoor noise levels. If not properly controlled this noise can decrease speech intelligibility locally and cause increased potential disturbance, annoyance and distraction from the teaching and learning tasks[5,20]. Both floors of the building were identically designed with a central circulation area dissecting six classrooms with additional open multi-purpose learning areas and a staff-room present on each floor.

Witzenhausen acoustic measurements and data (see link to film and full Report[22])

Objectives - Room acoustic measurements were made to give a better understanding of the acoustic conditions in this school building in terms of reverberation, sound attenuation and acoustic privacy. The results will hopefully be useful for further development or design guidance for new design or remodelling of schools. The measurements were made according to ISO 3382-2&3 standards[22,25,26] on the 1st floor in furnished but unoccupied rooms, (see Figure 6).

Parameters - The following parameters were measured and compared to the most relevant standards and recommendations from previous research[22].

Reverberation Time (RT) The time it takes for a sound to decay by 60 dB(A).

Sound attenuation - The decay of sound pressure levels between source-receiver configurations (See figure 8). The spatial decay of sound pressure level gives an indication of the decrease of speech/noise from one position to other positions over increasing distance and indirectly around physical barriers.

The speech transmission index (STI) is a measure of speech transmission quality. The STI measures some physical characteristics of a transmission channel, such as a classroom or more open space. In ISO 3382-3[26] the STI is used to describe acoustic distraction and privacy. In accordance with IE 60268-16[22] (see Figure 7 below) for each source-receiver combination, the STI is determined from the measured impulse responses and adjusted for the influence of the background noise level (BNL).

STI-value	Qualification	Description
0,75 – 1,00	Excellent	High speech intelligibility, even for complex messages and unfamiliar words
0,60 – 0,75	Good	Good speech intelligibility, even for complex messages with familiar context
0,45 – 0,60	Fair	Good speech intelligibility for simple messages in familiar context
0,30 – 0,45	Poor	Poor speech intelligibility. useful for simple messages and familiar words.
0,00 – 0,30	Bad	No speech intelligibility, even for experienced listeners and simple messages

Figure 7: The definitions of STI values according to IEC 60286-16.

Speech clarity - C_{50} Comparing the early sound reflections vs the late sound reflections [23,24].

Absorption Area - calculated from the measured RT is 0.97 in Rm162 and 1.03 in Rm 167.

In the report table 1[22], the acoustic data[22] gives an insight into the sound level reduction in, and between the class spaces and multi-purpose open areas. The measured values are shown and compared with various acoustic regulations[22] for open plan schools. The examples below describe several different scenarios about how the sound behaves in this learning environment and is a representation of how the overall acoustic environment typically works.

S1 - Cluster of 4 classes and circulation spaces (measured from room 167 to neighbouring rooms 160,161,166). Below in Figure 8, we see the sound levels recorded at multiple receiver positions from the Source S1. Positions 1-32[22].

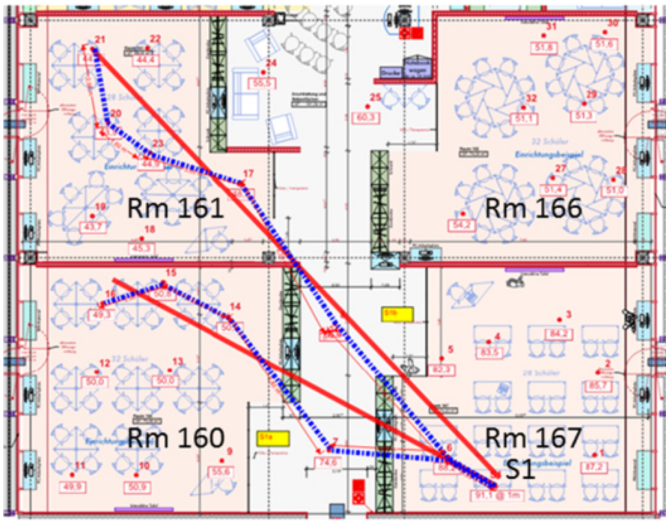


Figure 8 S1 - sound level measurement positions between room 167 and adjacent rooms

S1 - Sound attenuation Classroom Rm 167 - Measured effective sound reduction [dB] between classroom 167 and adjacent classrooms 160 and 166 is comparable with guidelines for the sound insulation between classrooms in regular schools where 40-45 dB reduction is required to gain sufficient acoustic privacy. The sound reduction to circulation areas of 16-30dB(A) by comparison is less than recommended, as a result of the opening in the separation wall. However, the visual transparency seems to self-manage this.

S1 - STI Classroom Rm 167 - STI values with NC-25 as background noise level. Room 167: between (0,63 and 0,78) Good – Excellent. Rooms 160, 160 and 166 from Room 167 (<0.1) Bad. The STI in Rm 167 is at least good for speech intelligibility even with the relative high BNL in this room of 39dB(A) due to the overhead projector. Switching this off would improve the STI further. Speech sounds carried from Rm 167 to the adjacent rooms (160, 161 and 166) would not be understood as the STI-values are all <0,10 ensuring a high amount of acoustic privacy in accordance with the STI criteria (see figure 7). The STI in the circulation area depends on the position and distance to the (doorway) opening in the partition between classroom and circulation area. Close STI values of 0,5 means that conversations can be heard. Moving further away or behind the partition barriers, the STI-value decreases rapidly as a result of the presence of the sound absorbing ceiling and walls in the circulation area. Speech Clarity C_{50} for room 167 is 8dB. This is similar to the value for speech clarity in classrooms deemed suitable for hearing impaired despite the RT being above 0.4s at 0.48s.

Sound path S2 - Cluster of 6 classes (measured from the multi-purpose open space). Multi-purpose open space into the neighbouring circulation and class spaces (sound path S2 from the multi-purpose open space Rm 162).

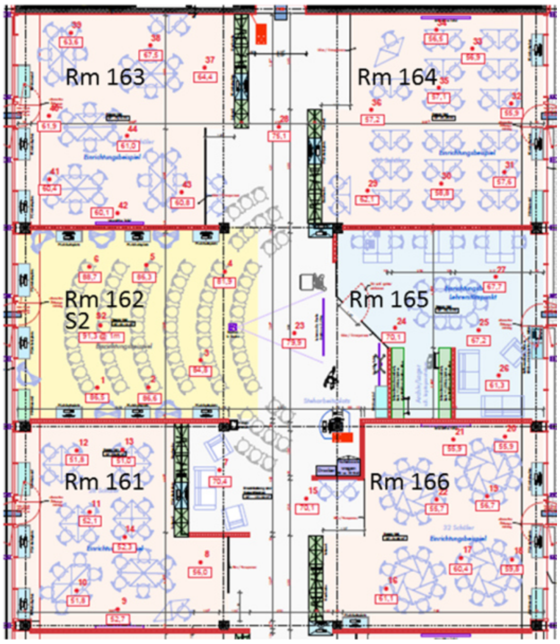


Figure 9: sound level measurements and positions measured from position S2.

Open learning space 162 - Sound propagation slope (S2) path is compared to free field conditions in the Report[22]. The RT for Rm 162 is 0,50s. The STI values with NC-25 as BNL are: in the open space 162 (0,75 and 0,86) excellent for speech locally and speech at a distance in Rm 161,163, 164,165 and 166 is rated bad <0.2 and not intelligible and values of <0,10 due to the absence of direct 'sound lines' between the open learning space and these rooms and the presence of high performing sound absorption. There is good acoustic privacy from speech conversation in the open learning space with only the places closest to the open entrance of the rooms suffering any potential loss of privacy. Towards the staff Rm 165, STI values >0,30 mean while the open learning space conversations can be heard, they can hardly be understood. This is due the effect of the direct sound line between both rooms.

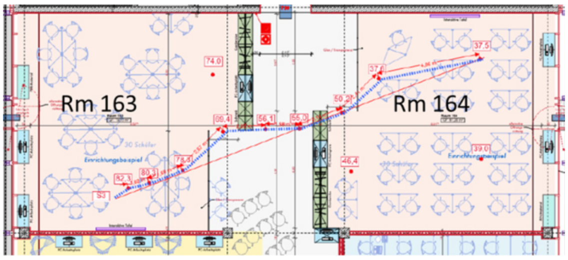
Sound Attenuation from open space 162

Between the open learning space 162 and adjacent rooms 161, 166 and 164 the sound attenuation is about 35 dB(A) and towards room 163 is about 30 dB(A). Towards the staffroom 165, the attenuation is more than 20 dB(A). For this situation with a direct opening between both rooms this can be judged as good. In the standards comparison table[22] values for sound attenuation of 20 dB are recommended between class base areas in order to achieve sufficient privacy.

S3 and S4. How the sound propagates between two class spaces

From one class space (a front and typical teaching position) across the circulation space to the neighbouring class space. Then from the same class space (a rear and typical student position) across the circulation space to the neighbouring class space (sound paths S3 & S4 from room 163).

S3 – Cluster of 2 classes (measured from a front and typical teaching position Rm 163**)** across the circulation space to the neighbouring class (Rm 164) space.



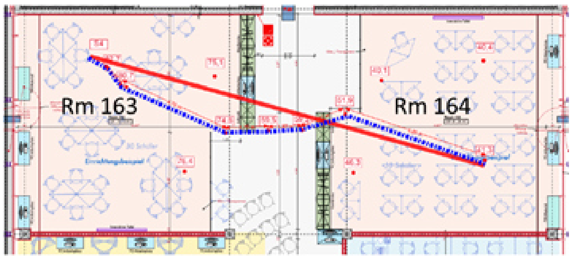


Figure 10: Figure 11:

Figure 10: S3 - sound level measurement positions between room 163 and room 164

Figure 11: S4 - sound level measurement positions between room 163 and room 164

The sound propagation for both sound trajects was measured (S3 and S4). The graph results represent the positions measured and are shown as colour dots in the figures below. The three zones are 1. Nearfield / class zone (blue dots) 2. Transition area / circulation zone (red dots) close to the freefield slope (orange line) 3. Behind sound trap / obstacles zone.

Fig 12 S3

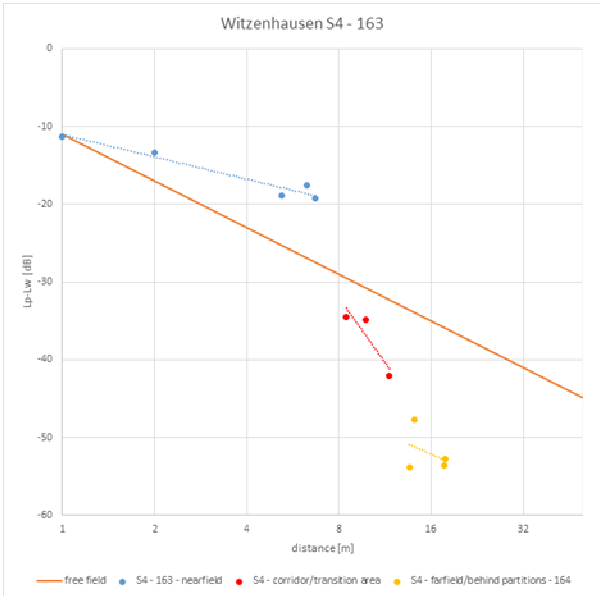


Fig 13 S4

Figure 12: S3 - Sound propagation between Rm163 and Rm164 compared with free field conditions

Figure 13: S4 - Sound propagation between Rm 163 and Rm 164 compared with free field conditions

S4 – Cluster of 2 classes (measured from a rear and typical student position (Rm 163) across the circulation space to the neighbouring class (Rm 164) space.

An interesting aspect of this acoustic data is that it gives a clear insight into the sound level reduction in and between class spaces and multi-purpose open areas; over distance and due to high absorption materials, physical barriers and effectively designed sound traps.

In Figure 14 & 15 below, teachers have visual transparency (line of sight, visual contact / interaction) without a line of sound compromising the different learning spaces with noise distraction / annoyance. Students are not distracted by the transparency due to the placement of solid opaque walls and blurred semi-translucent glass stickers at eye level when sitting.

Figure 14: **Figure 15 :**

A potential acoustic discussion point might be to look more deeply into unoccupied BNL levels. As there is often natural masking and blurring of speech sounds with mechanical ventilation and ceiling projectors, it would be interesting to look into whether this is necessary or helpful. This is unclear as there is likely in any event to be continuous masking from the activity noise in the way of unintelligible speech and ambient noise from other spaces once occupied and in operation, so masking might contribute to the onset of the Lombard Effect [11], potentially increasing general noise. Masking may also be counterproductive, increasing vocal behaviour and not helpful in order to achieve an indoor ambient noise level between 30-35 dB Laeq Greenland, Shield [20] 1011 ASA journal. The BNL was around 30dB(A) and ranged between 36-42dB(A) with the ventilation on. In general the overhead projector seemed to add around 3 dB.

Usage, activities, findings

While the learning spaces work well independently it should be noted that they do not achieve total privacy, like traditional cellular classrooms. However, they have visual transparency (although blurred to an extent so as to disguise exactly who is going past etc.) which fittingly could be applied to describing the speech intelligibility between spaces –blurred speech not unheard but which cannot be understood. The speech works at a relatively low level due to a good signal to noise ratio appropriate for normal conversations, so is less likely to build up in a Lombard Effect [11] and contribute to increasing the overall background noise.

There is very positive feedback from the head teacher about what they were hoping to achieve and how the learning spaces actually work. "The goal was to build a school providing the best conditions for the students' education as well as a good work environment for the teachers. We are delighted with the result, as it's exactly as we had intended from the start.… The students' behaviour is now more positive and they manage to start the lessons earlier in comparison to the old rooms."

The key to the acoustic design is more than just high performance absorption on the ceilings. The placement of the wall absorbers and the integrated design including physical and passive sound traps almost sound insulates the separate learning zones by dramatically reducing the potentially disturbing paths of sound. Overall, this creates an acoustic situation similar to free field anechoic conditions.

6. **The acoustic data is compared to acoustic standards and recommendations** from key research studies. The comparison table[22] looks into how the measured values compare to the

requirements and recommended values for Absorption area, sound reduction, RT, STI within groups and between separate class groups and effective reduction of sound.

DISCUSSION AND CONCLUSIONS

It is clear that pedagogic changes around the learning activities are a driving force for addressing what characteristics and needs future learning environments should satisfy. From the outset of the Witzenhausen case study, the development of the learning space requirements involved input from the educators before any design drawings were made. This allowed the architect to focus the design of the spaces around teaching and learning activities. This activity based design approach helped to make sure the function and effectiveness of the teaching and learning activities was not compromised. From an acoustic perspective, we can see this also and crucially, the project group included an activity based *acoustic* design approach. In this quite unique school design, it has been especially interesting to understand that opening up a learning environment physically from a visual perspective, does not necessarily mean the need to open up the space from an acoustic and noise perspective. There was careful placement of full height glass partitions and consideration taken to map out the potential detrimental sound paths. These sound paths needed to be controlled with specific placement of absorption, barriers and sound traps to ensure there were no reflective surfaces which could contribute to wanted sound in local areas being reflected and subsequently heard as unwanted noise in the neighbouring areas. Cost effective and very simple really, however it doesn’t resemble any other learning environments so far…..

To relate to the typologies of space A-E referenced earlier, as Witzenhausen is quite cellular in some respects, it shows that embracing change and understanding the use and design of spaces can produce a very effective learning environment even though it has perhaps Type B/C spaces which might seem not to either open or cellular and thus lacking clear identity. Of course it appears in reality to be the opposite and supports the transition of teaching and learning activities very well and it’s an ILE which can visually embrace the transparency and the associated culture of openness. However at the same time with carefully designed sound traps the acoustics and vital speech communication and concentration are not compromised. Activity noise from one space does not spill over into the neighbouring spaces making it difficult for teachers and students alike to function effectively. Students can achieve most of the necessary learning activities in the class space, however are free to move to other multi-purpose spaces and break out spaces for individual work and small group discussions. Teachers can potentially collaborate more as they are more connected.

Witzenhausen has carefully designed zoning between different learning spaces with full height walls and immovable barriers where appropriate such as sound absorbing ceilings and wall panels, complemented by furniture limiting the spread of unwanted noise. In addition, to maintain a sustainable learning environment, leadership appears to be key. Inspiring and empowering teachers and students in the organization and management of the various teaching and learning activities; including culture and etiquette, careful timetabling and cooperation from teachers around the learning activities in the neighbouring learning spaces: team teaching, can address managing potential conflicts.

Flexible learning spaces should be wary of being able to facilitate all activities. This is not possible and certain activities need to be isolated and located separately. Concentration activities and personal meetings require high levels of sound reduction and low levels of background noise. Sound needs to be controlled. Spaces which amplify sound where speech communication is a key part of the activities means that speech will amplify and is likely to encourage raised voices. Active students then compete with peers increasing the likelihood of the Lombard Effect[19] and thus increasing the noise which will then spread to and disturb neighbouring areas.

It is possible as we have seen in this Witzenhausen case study, to have a learning environment which is educationally quite open whilst being acoustically quite closed.

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 Berufliche Schulen Witzenhausen acoustic measurements Report and film http://www.acousticbulletin.com/wp-content/uploads/2012/03/witzenhausen_report_1-5_update.pdf
23. e Berufliche Schulen Witzenhausen acoustic measurements Report and film http://www.acousticbulletin.com/acoustics-in-german-semi-open-school

24. Astolfi A, Puglisi G, Acoustic comfort in HS classrooms, IBPC 2015 Turin.
25. Clark,J.H., Dobinson. N, Larrieu.F. Use of G and C50 for classroom design (2014)
26. ISO 3382 – 2: Acoustics – Measurement of room acoustic parameters – Part 2: Reverberation time in ordinary rooms.
27. ISO 3382 – 3: Acoustics – Measurements of room acoustic parameters – Part 3: Open plan offices