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Technical Note

Acoustics and new learning environment – A case study

Rauno Pääkkönen [a,*], Tommi Vehviläinen [b], Jaana Jokitulppo [c], Olli Niemi [d], Suvi Nenonen [e], Juha Vinha [f]

[a] Finnish Institute of Occupational Health, Tampere, Finland
[b] Sirate Group Ltd, Tampere, Finland
[c] Akukon Ltd, Oulu, Finland
[d] University Properties of Finland Ltd, Tampere, Finland
[e] Aalto University, Helsinki, Finland
[f] Tampere University of Technology, Finland

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ABSTRACT

This study presents the results of an acoustic performance evaluation of classrooms and their corridors on a test area of the Finnish Oulu Normal School. The project, "Spaces for learning and creation of new knowledge", was organised by Rym Ltd and was a re-design pilot study where spatial analysis of some new schools and new forms of future school design have been made.

Two different acoustical setups were evaluated by measurements of the reverberation time, sound pressure level (A-weighted equivalent level, L_{Aeq}), and sound insulation. Other acoustical parameters were also measured via sources of reverberation time to verify the difference of the test rooms. Speech Transmission Index (STI), disturbance radius (r_D), spreading attenuation ($D_{2,S}$), Clarity (C_{50}), and Rapid Speech Transmission Index (RASTI) were calculated. Measurements of noise followed the Finnish guidelines. Measurements of reverberation time and sound insulation followed the International Standards ISO 140-4, ISO 140-5, ISO 717-1, and ISO 3382.

The acoustic quality of the classrooms was analysed based on the measurements' results (sound insulation and reverberation time), which were compared with the reference values found in the Finnish Standard SFS 5907. Results revealed good acoustical quality of the surveyed classrooms, for both test setups studied. The soft carpet on the floor made the acoustical performance of corridor areas usable for educational purposes. However, the sound insulation and background noise level of all the classrooms did not meet the guidelines of Finnish Standards. Discussion on new learning concepts and acoustical design reveals that new tools for the evaluation of learning spaces should be developed.

1. Introduction

The acoustics of educational spaces should support learning by promoting the needed sound spreading and hindering unwanted noise. New learning spaces are interactive, participatory, and mobile [1–10]. The "New Learning Environment" is one of the Indoor Environment research programmes included in Living Labs, where participatory and inspiring learning environments are being developed [10]. New studies have indicated the emotional regulation system being part of the learning process: people more easily remember things that have aroused interest or positive feelings in them and learning environment plays its own part in this process. However, new technology affects the need to alter future classroom design. As tablets and other mobile devices have conquered the market in the last few years, technology supports education, and this presents a new challenge for space that is both physical and mental at the same time: a social event complemented by a virtual space created by devices.

The Rym Ltd Learning Environments work package has modelled the effectiveness of learning methods and the impact of spaces on learning with the help of multidisciplinary research. According to a study led by the University of Helsinki, the way people experience an indoor environment significantly affects their learning [10].

The changes in learning spaces are also demanding changes in their acoustical performance. Traditional learning spaces are planned for the lecture style or teacher-centred instruction, where teaching is done in front of the class. This is no longer the main teaching method, at least in Finland. More and more alternate

* Corresponding author.
E-mail addresses: rauno.paakkonen@gmail.com (R. Pääkkönen), tommi.vehvilainen@sirate.fi (T. Vehviläinen), jaana.jokitulppo@luukku.com (J. Jokitulppo), olli.niemi@sykoy.fi (O. Niemi), suvi.nenonen@aalto.fi (S. Nenonen), juha.vinha@tut.fi (J. Vinha).

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forms of teaching such as participatory learning, group work, solitary work, or open learning are being implemented. New forms of pedagogy and learning spaces need more practical ways to design the learning environment.

The acoustics of learning spaces affect learning processes through the students' capacity to hear sound properly and communicate with nearby persons. Because of the useful sound reflections from the classroom surfaces, the wanted sound – the teacher's voice – can be heard even from the back of the classroom. However, at the same time there might be unwanted harmless reflections of space surfaces such as the ceiling and floor that disturb the discussion because of the high reverberation time in the room. Mutual discussion among the pupils is more important in learning than the teacher's speech [7].

In a new learning space there are several small groups that can disturb each other. The previous Refs. [2–11] conclude that the acoustics should be flexible and controllable, and background noise must be suitable for its purposes. Controllability means that the communication environment must be inspiring, and quietness is sometimes needed for concentration purposes.

How can we measure and evaluate these new learning spaces? Traditionally, Finnish Standard SFS 5907 [11] is being used, which offers guidelines for different space types, including schools. There are classrooms, corridors, halls, and special classrooms like music, gymnastics, and technical work spaces. The Standard divides spaces into four classes, A–D, where class C represents minimum demand and the level of basic construction orders [12]. Classes A and B represent the better acoustical demands planning compared to classes C and D. Class D is reserved for evaluation purposes only and for old buildings. For example, the airborne sound insulation index shows that the R'_w between a classroom and corridor varies in classes A and B between 39 and 48 dB, while the minimum value of the normalised impact sound insulation level, $L'_{n,w}$, is 63 dB. The highest accepted background noise level for the A-weighted equivalent level (L_{Aeq}) for HWVE (heating, water, ventilation, electricity) equipment is between 28 and 38 dB, and for outdoor noise between 30 and 35 dB. The reverberation time is recommended to fall between 0.5 and 0.9 s for classrooms and corridors, and the minimum value of the Sound Transmission Index (STI) or RASTI shall be at least 0.7. These recommendations have probably come from the traditional frontal teaching [12,13]. In addition to measurable indoor acoustics, there should be ideas on non-measurable, qualitatively evaluated sound experience [11].

The purpose of this work is to describe the influence of changes in learning space upon the acoustical environment. Simultaneously, our purpose has been to evaluate how the present acoustical guidelines work in this new learning space situation.

2. Materials and methods

We measured traditional and new learning spaces at Oulu Normal School during 2013 and 2014. In this study a new learning environment setup was made. The idea of spaces were zoning from private to public zone for fully functional learning communities in Cells (Fig. 1). All spaces had their own character and the focus was on traffic and movement in space. In the zone cells the pupils can freely move between rooms and, for example, sit on the floor with their iPads. Special attention was paid to self-regulated learning events, learning spaces, and evaluations at all teaching periods. Pupils can divide their learned material by mobile devices through social media [2].

Different acoustical conditions were set in identical classrooms with their area and volume. The test area volume for classrooms were 240 m^3 and for the corridors 750 m^3 (Figs. 1 and 2). The test area including corridors and classrooms had a soft carpet on the floor (Fig. 1). Both the test and reference areas had acoustical panels on the ceilings (Table 1). Test area classrooms also had special soft furniture (chairs) besides normal desks and chairs.

The height of the classrooms was 3.3 m and the height of the corridors 3.3–5.6 m. The structure of the walls between classrooms and between classrooms and the corridor was 10–15 mm of wood plate + 70–100 mm of absorbing material and again 10–15 mm of wood plate. The structure was same both on test and reference spaces. The structure was also same both in stationary walls and moving wall structures. The moving wall structures were tightened towards stationary walls by rubber seals.

Reference areas were left with their original hard surfaces and traditional classroom furniture (wooden desks and chairs). The school building was on one floor.

With the used setup it was possible to create two comparable acoustical test environments, hard and soft, to carry out acoustical measurements (Fig. 1 and Table 2). We carried out airborne sound insulation and impact sound insulation measurements, A-weighted sound pressure measurements, and other acoustical measurements such as reverberation time. We measured the airborne sound insulation measurement with standardised airborne sound insulation (EN 140-4:1998 and ISO 717-1:1996), impact sound insulation (EN 140-7:1998 and ISO 717-2:1996), and reverberation time (ISO 3382-2:2008). A background noise level with the A-weighted equivalent level (L_{Aeq}) was measured according to the Finnish national guidelines [13].

Reverberation time T20, T30, and EDT (Early Decay Time) were all measured. Other acoustical parameters were calculated from the reverberation time values: Sound Transmission Index (STI), disturbance radius (r_D), spreading attenuation (D_2), Clarity (C_{50}), and Rapid Speech Transmission Index (RASTI) [1].

The C_{50} parameter (Clarity or Klarheitsmass) is the early to late arriving sound energy ratio, expressed in dB. It is defined as:

$$C_{50} = 10\log\left(\frac{D_{50}}{1 - D_{50}}\right) \quad (1)$$

D_{50} is the early to total sound energy ratio expressed in percentage. It is defined as:

$$D_{50} = \frac{\int_0^{0.050s} p^2(t)dt}{\int_0^{\infty} p^2(t)dt} \quad (2)$$

The used measurement equipment was the sound source dBTechDVXD10, signal generator NTI Minirator AG MR1, impact sound generator B&K 3207, microphone B&K 4189, sound analyser B&K 2250, and sound level calibrator B&K 4231. Guidelines for the used parameters are given in Table 2.

3. Results

The results of the airborne sound insulation R'_w from two measured classrooms (test area and reference area) were 39 and 42 dB. Neither of the results filled the demand of 44 dB by the standard of SFS 5907. The airborne sound insulation between classrooms and corridors were 24 and 32 dB, neither of which reached the demand of 34 dB (Table 3).

The impact sound insulation $L'_{n,w}$ measured 45 and 55 dB in the test areas (both classrooms with carpet on the floor) and 69 and 72 dB in the reference area (no carpet on the floor) (Table 3). The demand of the SFS 5907 was not reached at the reference area, but in the test area the Finnish Standard demand was reached.

The reverberation times as T30 varied between 0.38 and 1.00 s. There was no specific difference between T20 and T30, or EDT in the same test room. All the decays of the classrooms reached the target level of class A/B according to a standard of SFS 5907. However, the result of classroom R134 was less than the