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"Modern Teaching" Needs Modern Conditions – Communication Behaviour of Pupils and Teachers in Highly Absorbent Classrooms

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This paper investigates the kind of work and communication behaviour in classrooms in two elementary schools. Using a database of 175 examined lessons an analysis is made of how different kinds of work (frontal lessons vs. differentiated lessons) have an effect on the sound level in the classroom. Parameters are discussed, which can describe classroom acoustics appropriately. Also discussed are how altered room characteristics (eg. increased absorption, shortened reverberation time and improved speech intelligibility) affect the sound level in the context of each kind of work. A methodical examination of the database allows an assessment of mean values but also of the detailed teaching phases, as characterised by certain pedagogical factors. The results provide the basis for discussion of stress and work demands of teachers.

1. INTRODUCTION

Previous investigations into the phenomenon of the acoustics in schools have shown that schools have become noisy places [1], [2] and [3]. Unlike conventional workplaces, the noise levels in schools is not determined by machinery or other external factors, but by the people working there. It depends on the process of teaching and the behaviour of each individual as well as the group. The noise is also determined by room acoustic properties.

One of the principal reasons why acoustics in classrooms is on the agenda and to a certain extent under revision is the fact that the educational systems in many countries are changing radically. This is shown not only in an external school re-organisation but particularly in changes in working practice. It is therefore about new teaching methods, often called "student-centred learning", a term that includes different activities, e.g. project work, planned teaching, pupil-centred working or workstation learning. The essential characteristic of this new teaching and learning culture is that pupils are more frequently working and learning independently. This leads not only to greater individuality of what is learnt but also changes the interaction within the classroom. The image of the teacher as a distributor of material; a conduit for preconceived knowledge, is receding. Pupils now need to spend more time on experiment, appraisal and discussion. Discussion groups, project groups and role-play are becoming the mainstay of the learning approach.

2. IN SITU ASSESSMENT

In a recent study by the Institut for Interdisziplinäre Schulforschung; (Institute of interdisciplinary School Research ISF) of the University of Bremen [4] the acoustic-physical properties of the classroom were evaluated in as realistic a teaching context as possible. This required a multi-dimensional observation, which compares the key factors of pedagogy, room acoustics and occupational medicine, in a real setting (see Figure 1).

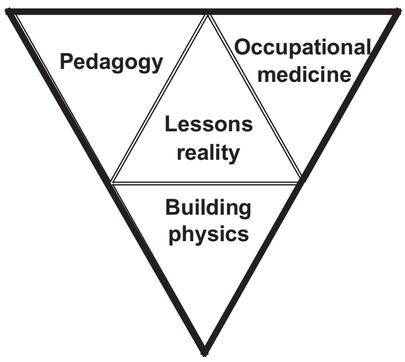

Figure 1. Simplified interaction model of factors influencing “lessons reality”

2.1 EXTENDED DATASET

To achieve the required holistic description of “teaching reality”, 175 lessons in 2 primary schools were observed and analysed. Four data pools were developed:

- basic classroom acoustic data from the (mainly RT and STI)
- sound pressure levels recorded during lessons
- the pedagogical procedure of the teacher
- the teachers’ physiological reaction, detected by means of heart rate.

As there was no previous data available for comparison, special attention was given to observation. Two students, trained beforehand with video recordings, observed in real-time the details of parameters, that are necessary to describe the given communication scenario. The pedagogical process was broken down into teaching methods and the associated communicative behaviour (Table 1).

All characteristics were recorded at the start and the end of their occurrence, at 1 sec. intervals and transferred to a computer. The second observer was employed in noting other events, accompanied by noise, on a monitoring sheet.

2.2 PROCEDURE

The data set from one class in school 1 provided practical monitorable parameters. The same teacher taught the same class in the same classroom with almost the same timetable. The investigation period was free from unusual events. The only significant difference was a change in the room acoustics, which took place half way through the period. Based on recommendations from former studies [1,5], the classroom was furbished with highly absorbent material at the ceiling and parts of the rear wall (Class A according to EN ISO 11654; $\alpha_w > 0.9$). The reverberation time was reduced from approx. 0.7 s to 0.4 s.

School 2 delivered a larger data set covering different classes, age groups, teachers, subjects and room acoustic conditions. This school provided rooms at two storeys with small differences in RT and STI (from 0.7 “good” to 0.8 “very good”).

In the first step, the effects of different teaching methods and communication scenarios on sound pressure level in the classroom were

Table I. – Details of recorded parameters

Teaching Method	a) Direct Teaching
	b) Individual Work
	c) Working in Pairs
	d) Working in Groups
	e) Others
Share of Speech	a) Teacher to the whole class
	b) Teacher to individual pupils
	c) Pupil to the Teacher
	d) Pupil to the whole class
	e) Pupil to individual pupil
Organisation	Organisational Activity

analysed. In the second step, the effect of room acoustics was investigated, in the context of the respective teaching methods. A detailed time series analysis, in conjunction with the large dataset, made it possible to evaluate not only hourly average values but also to observe directly the teaching phases dominated by specific pedagogical features. The results formed the basis for further ergonomic questions about stress, fatigue and workload in teaching (see companion paper [8]).

3. EXCURSUS: EFFECT OF ROOM OCCUPANCY ON ACOUSTICS

The classrooms that were measured between 2001 and 2005 showed a good correlation between the classical descriptors for communication rooms: RT and STI. All of them contained scattered furnishing and provided comparatively diffuse sound fields. In general, the room occupancy did not affect the room acoustics as much as expected. The change in reverberation time, due to changes in pupil occupancy, was less than 0.1 s unless the reverberation time in the empty classroom was around 0.7 s or more (as shown in Figure 2).

On closer inspection, this relationship was not as linear as first assumed. In the analysis of the effect of 50 % room occupancy, it emerged that with less density of pupils in the classrooms, the relationship between the original reverberation time and reduction due to changed occupancy, increased with increase in initial value. In rooms with an initial RT of below 0.5 s, the changes were less than 0.05 s, and therefore already within the order of magnitude of normal measurement tolerances (Fig. 3).

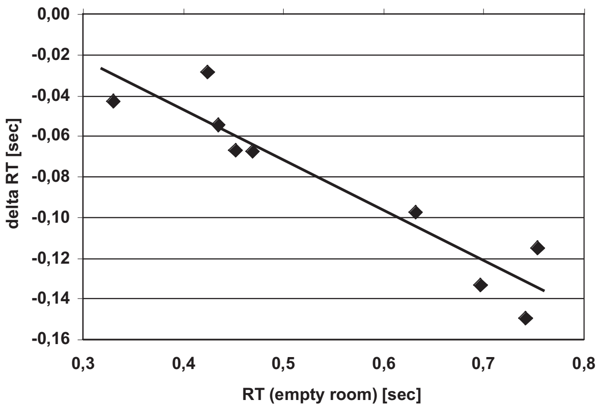

Figure 2. Change in reverberation time due to change in pupil occupancy, compared to the classroom when empty

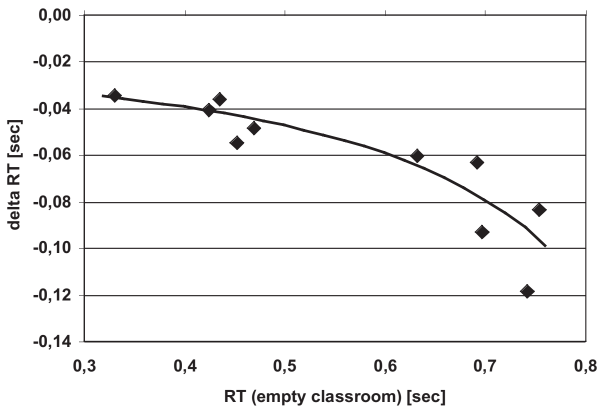

Figure 3. Change in reverberation time, from half-filling the classroom compared with the classroom when empty

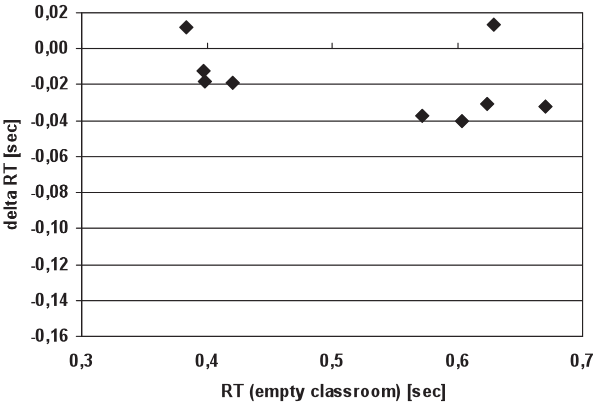

Figure 4. Change in reverberation time, on filling the classrooms, in comparison with the classrooms when half-full.

It became clear that a significantly greater change of reverberation time was due to the occupancy of the first 10 pupils. Any further effect of filling up the classrooms, up to 30 pupils was negligible (Fig 4).

A question arises as to the equivalent absorption of pupils of primary school age in the furnished classroom. If the additional absorption (surface) generated by the pupils, is calculated using the Sabine's formula, taking into account all the uncertainties associated with this, the dependency on the density of the occupation, is again evident. Figures 5 and 6 show the differences, both as the total absorption surface, and the absorption surface per pupil, respectively. The latter is about 0.4 m^2 per pupil, from 500 Hz to 4 kHz, with full occupancy, i.e. with 2.2 to 2.6 m^2 floor area per pupil. The value is approximately 0.6 m^2 per pupil when the classroom is half-full, i.e. approx. 4.5 to 5.3 m^2 floor space per pupil.

It is again clear how little the second half of the room occupancy contributes. With a mathematically derived absorption surface of an average of 0.28 m^2 per pupil, these pupils contribute little to the result. Since all pupils contribute similar physical absorption characteristics, the reason for this divergence requires further investigation. It might be worth considering, for example, a closer observation of the pupil as a scattering body and the changing distributing body density that accompanies occupancy. It might also be worth considering room diffusion in classrooms. (Measurements in the half-full rooms were taken with as even a distribution of the children as possible.)

These findings therefore give some indication that using Sabine's formula, assuming more or less diffuse conditions, for predicting classrooms may not be appropriate. They question the popular practise of measuring empty

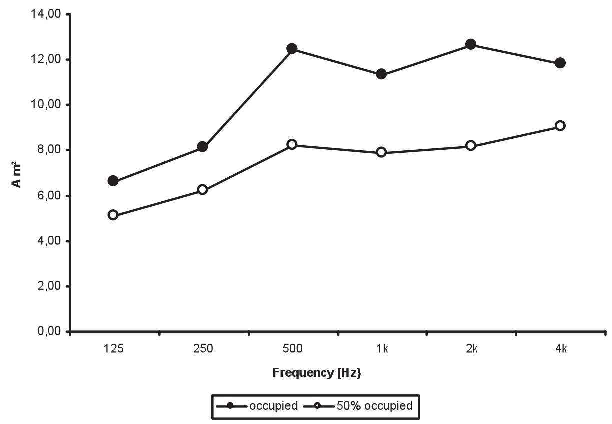

Figure 5. Equivalent absorption surface of pupils, per class, at full and half-full occupancy

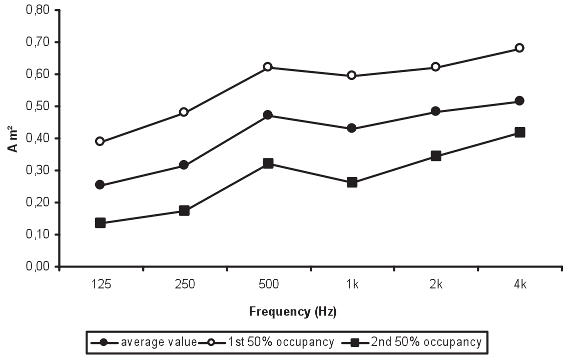

Figure 6. Equivalent absorption surface per pupil at different occupancy densities

rooms and then adding pupil absorption.

Investigations in less diffuse classrooms confirmed these findings. Without scattering objects close to the wall, the measured reverberation times in a newly refurbished secondary school classroom, deviated from the calculated values in the high frequency bands by more than 100%. Some acoustic scattering, at the hard and smooth back, was obtained by wooden slats (Fig. 7). The RT at 2 kHz and 4 kHz, was reduced by more than 0.1 s without adding any absorption or making other changes to the room (Fig. 8).

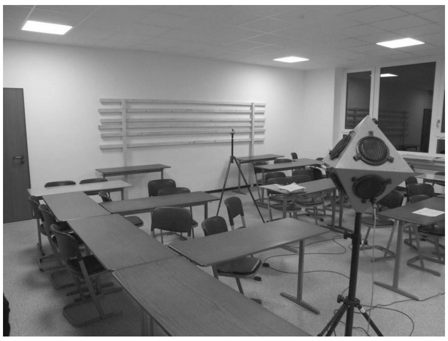

Figure 7. A school classroom with wooden scattering slats

Results by Svensson and Nilsson [7] confirm that there is not a clear relationship between absorption surface, subjective perception of the room and measured reverberation time in classrooms. Therefore RT alone, is not a reliable descriptor for the room acoustic comfort of classrooms but should be complemented with other parameters e.g. EDT, STI, G or C_{50}.

4. RESULTS AND DISCUSSION

Both the working noise level and the background noise level, in both schools, depend on the classroom acoustic conditions. The more absorbent the classrooms, and the better the speech intelligibility, the quieter is the classroom. The relationship is unexpected in terms the order of magnitude (Fig. 9) and linearity (Fig. 10).

The field data from school 2 not only confirmed the findings in school 1 but showed that even small differences in room acoustics can have a significant effect on the generated sound pressure level during classes. Similar results have

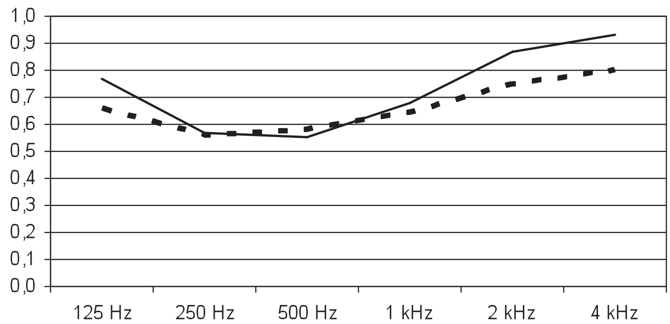

Figure 8. Measured RT without (____) and with (- - - -) slats

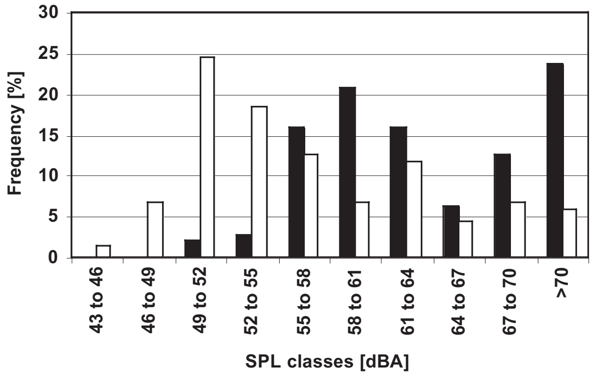

Figure 9. Frequency distribution of the working sound pressure level, before (●) and after (○) refurbishment (school 1; incl. all observed lessons)

been reported of a preliminary investigation that showed a linear reduction of the sound pressure level of around 1.6 to 2 dB. per 0.1 s reduction in reverberation time [6].

This reduction does not arise from a changed pedagogical behaviour or by the fact that pupils and teachers spoke less. The cause must therefore lie in a reduced speech volume amongst those involved.

There was also another phenomenon shown in school 1. While in particular sound pressure level increased by on average 10 dB over the morning lessons, before refurbishment, this rise was not evident after installing absorbers [4].

The assumption that student-centred teaching methods generate greater sound pressure levels than direct teaching methods was only partly confirmed by the present study. Surprisingly, in both schools the different teaching methods give rise to the same share of teacher and/or pupil-generated speech. Direct teaching accordingly does not mean that the pupils are not involved in the teaching events while student-centred teaching for its part does not mean that the teacher stops talking.

Nevertheless, the respective teaching methods differ significantly with respect to sensitivity to the influence of the room's acoustic environment.

The aforementioned dependence of the sound pressure level generated during lessons, on the reverberation time and/or the speech intelligibility in the classroom, was not the same for all teaching methods. In school 1, the reduction in level was on average 12 dB, during student-centred working in comparison to before refurbishment. The reduction, during direct teaching-phases was around 5 dB. It is clear that during direct teaching, a majority of the reduction is achieved by the physical absorption, while student-centred phases are particularly affected by a

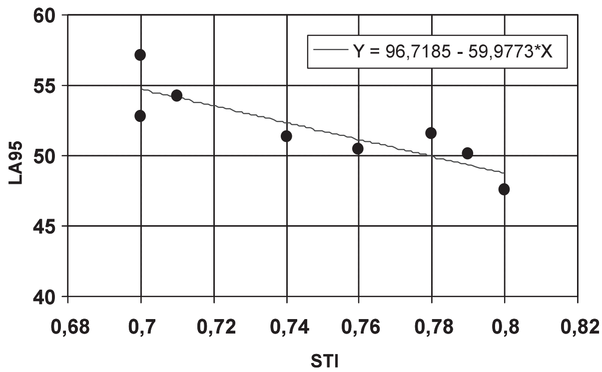

Figure 10. Sound pressure level in relation to the STI for 8 classrooms in school 2, with different acoustic properties.

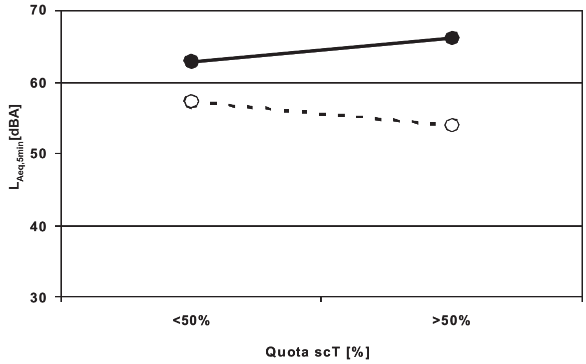

Figure 11. Sound pressure level $L_{Aeq,5min}$. in relation to share of student-centred teaching (scT) before (●) and after (○) the refurbishment, school 1.

changed (quieter) behaviour of those in the room. The acoustic quality of the room is more significant for student-centred working. While, before the refurbishment, the sound pressure level generally rose, the greater the time spent engaged in student-centred teaching. This relationship is no longer discernible under the improved room acoustic conditions. After refurbishment, student centred work was, on average, quieter than during conventional direct teaching (Fig. 11).

CONCLUSIONS

In the context of today's teaching methods, including new communication scenarios, the acoustic environment has a significance impact in the classroom. Even classrooms that worked well for decades under traditional teaching methods (one speaker, quiet listening) require re assessment for new methods, such as student centred learning. Small differences in room acoustics can have a significant effect. Heavily absorbing classrooms, with reverberation times less than 0.5 s, result in lower generated pressure levels, than rooms with reverberation times about 0.6 s.

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IN BRISBANE…

Police receive, on average, 1500 noise complaints a month. In the summer, the average number of noise abatement orders issued is 200 a month. If the orders are ignored, police can seize any equipment that's making the noise. At present, its up to the investigating officers to decide whether any noise is 'excessive'.

NEW ORDINANCE MAY CAUSE HUSH OVER CITY

A new noise ordinance is expected to keep sounds in Hartford (Conn.) to a whisper — at least that's the hope, officials said. Hartford's new law makes it illegal for anyone to make noise that can be heard more than 100 feet away, unless they have a permit. That distance is equivalent to the distance between two city light poles. "We have heard loud and clear from community over the past few years about the importance of dealing with this issue," said Jim Boucher, of the Hartford City Council. Mayor Eddie Perez and Police Chief Daryl Roberts kicked off a campaign to educate the city about the new ordinance. They said the goal is to improve the quality of life for residents. Violations can range from a car muffler, loud motorcycle, or blaring music from a car or home, Roberts said. But police officers who respond to noise complaints won't carry noise meters. They'll simply issue a citation if they can hear the noise 100 feet from the source. Consequences for violators include community service, a $90 fine or 25 days in jail.

SARASOTA NOISE ORDINANCE, VEHICLE SEIZURES CHALLENGED: UNCONSTITUTIONAL

Two Sarasota County residents, represented by the American Civil Liberties Union of Florida's Sarasota/Manatee/DeSoto Chapter, have filed a lawsuit challenging Sarasota's unconstitutional noise ordinance, which allows for police to seize and impound vehicles when drivers are charged with playing their music too loud. The lawsuit was filed in state court against the City of Sarasota and Police Chief Peter Abbott. The lawsuit was brought on behalf of Mark Cannon, a resident of Sarasota, and Latrese Allen, a resident of Bradenton. Plaintiff Cannon was stopped for "loud music" and his vehicle was seized and impounded. Plaintiff Allen was stopped while traveling on Martin Luther King, Jr. Way while singing along with a song written in memory of a deceased friend. She was ticketed for violating the city's noise ordinance. The City subsequently dropped the charges. Florida Statute § 316.3045 makes it illegal to drive a car if the sound system can be heard more than 25 feet away. Sarasota's Ordinance, passed in May of 2008, goes one major step further, allowing police to seize the car of a person who is found to be violating the statute. Florida's Second District Court of Appeal has twice struck down similar noise ordinances as being unconstitutional. Despite being aware of the potential exposure to lawsuits, the City Council decided to go ahead and empower police to seize and impound cars. "While communities across the country can legitimately restrict excessive noise and prohibit disturbances," noted ACLU Chapter President Pete Tannen, "they have to do it correctly. The 25-foot standard in the state law fails the test of a reasonable regulation. And the power to seize an owner's vehicle whenever a Sarasota police officer feels that there is too much noise coming from it gives too much discretion to our local police department." "The problem with this ordinance," Tannen added, "is both the standard of what is 'too loud' and the excessive penalty that allows the police to seize and impound a person's vehicle." In the case, Cannon and Allen v. City of Sarasota and Abbott, the residents are asking the court to rule that the city's policy is unconstitutional, and issue a preliminary and permanent injunction to stop its enforcement. The ACLU is also seeking damages for the cost of the seizure and fines incurred by those residents whose vehicles had been impounded, as well as attorney fees.