Acoustics as a factor of Ergonomics
Communication Behavior and Workload of Pupils and Teachers
in Highly Absorbent Classrooms

Research project
Field Study performed by the
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Acoustic Ergonomics of Schools
2001 - 2006

Research project
published by:
Federal Agency of Occupational Health
Fb 1071

Research at ISF
Institute of Interdisciplinary School Research
ISF
Workload of Teachers
1998-2001
Noise in Educational Institutions
2001 – 2004
Acoustic Ergonomics of Schools
2001 – 2006
The health and performance implications
of the school environment
2006 - 2008

Who decides?
Transdisciplinare Approach!
Stressconcept „Noise“ (Sust & Lazarus 1997)

Project Overview

- 5 involved schools:
  → 1 Primary School in Havixbeck (near Münster) → „Labschool“
  → 2 Primary Schools in Bremen
  → 1 Primary School in Bremerhaven → „Fieldschool“
  → 1 High School Center in Bremen (Haupt-, Realschule, Gymnasium)

- 28 involved classes from 1st to 10th grade (1 week each)
- 575 observed lessons

1. Measured Value: Room Acoustics

2. Measured Value: SPL

3. Measured Value: Pedagogics

4. Measured Value: Heart Rate (ECG)
"Modern" Teaching ?!

- Openness
- Independence
- Individualisation

How to measure Teaching?

- Direct Teaching (dT)
- Teacher generated Speech (TgS)
- Student generated Speech (SgS)
- Student-centred Teaching (ScT)

How to measure Teaching?

Graph showing the relationship between direct teaching (dT) and student-centred teaching (ScT) with percentages.
a first surprise

The teacher is not the main sound source in class – neither during student-centred nor during direct teaching phases.

Results

1. Room Acoustics
2. SPL Analysis
3. Pedagogical Relevance
4. Workload & Acoustic Ergonomics

1.) Room Acoustics

Variance of RT depending on occupation of classroom

Full filling of the classroom compared with empty room

\[ \delta RT = 0.052 - 0.249 \times RT \]

\(r = 0.94\)

Influence of occupation becomes negligible after the first approx. 10 pupils.

Keyword: Diffusity

Soundwaves propagate equally

SPL is generated by direct and reflected sound
vertical soundwaves are absorbed by the ceiling

SPL is generated by direct and reduced reflected sound

Sound field structure in partly diffuse rooms

Nilsson, E.: Decay Processes in Rooms with non-diffuse Sound Fields

Influencing factors
Influencing factors

Room Acoustics = T60?

Example:
- Classroom near Kassel
  - Very low wall diffusion

Influencing factors

- Room Acoustics = T60?

Short:
- "Non-grazing sound field" Angle of incidence ca. 10 - 90°/ceiling
  - Main influencing factors: ceiling
  - Determines Sound Pressure Level

- "Grazing sound field" Angle of incidence < 5 - 10°/ceiling
  - Main influencing factors: wall (& furniture)
  - Determines Reverberation Time

2.) SPL Analysis

Original SPL recording [dB(A)] during a typical school morning
2.) SPL Analysis
Frequency distribution of $L_{Aeq,5min}$ before ($\Delta_L$) and after (\textcolor{red}{$\Delta_L$}) refurbishment
working noise level

Before (\textcolor{red}{$\Delta_L$})

- Approx. 0.7 s
- Approx. 0.4 s

2nd floor

1st floor

3.) Pedagogic relevance

- Working noise level during direct and student-centered teaching phases before and after acoustic refurbishment
- $\Delta L_{A95,5min} = 8.8 \text{ dB}$
- $\Delta L_{A95,5min} = 3.31 \text{ dB}$

- Teaching Reality

- 8 similar classrooms in one school in two storeys

- $T60$ before: approx. 0.7 s
- $T60$ after: approx. 0.4 s

- $\text{STI} vs. \text{basic sound level} L_{A95,5min}$
- $\text{all classes}$
- $\text{all lessons.}$

- Fieldschool; Database:

- $L_{A95,5min}$
- $\Delta L_{A95,5min}$
- $A_{95,5min}$
- $A_{95,cac}$

- $\Delta L_{A95,5min} = 8.8 \text{ dB}$
- $\Delta L_{A95,5min} = 3.31 \text{ dB}$

- $\text{STI} vs. \text{basic sound level} L_{A95,5min}$
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- Fieldschool; Database:

- $L_{A95,5min}$
- $\Delta L_{A95,5min}$
- $A_{95,5min}$
- $A_{95,cac}$

- $\Delta L_{A95,5min} = 8.8 \text{ dB}$
- $\Delta L_{A95,5min} = 3.31 \text{ dB}$
4.) Workload & „Acoustic Ergonomics“

Workload Reaction
Example: SPL and HR\textsubscript{ref} of a female teacher

Teachers Health
Basic activation under different acoustic conditions (Labschool)

Teachers Health
Basic activation under different acoustic conditions (Fieldschool)

Noise as a factor of strain
ISF Study 1999 Report of questionnaire about workload of teachers

Concerning the students I am primarily stressed by...

[105] ... noise, made by students.

Example: SPL and HR\textsubscript{ref} of a female teacher

Speakers: often
Speakers: seldom
Speakers: never

Heart Rate [beats/min]

Frequency [%]

0 - 5
10
20
30
40
50
60
70
80
90
100

65 to 70
70 to 75
75 to 80
80 to 85
85 to 90
90 to 95
95 to 100

Heart Rate [beats/min]
So, what happens:

- Improved room acoustics
- Improved communication
- Reduced working SPL
- Reduced speech effort
- Lower stress
- Change of behaviour

Good acoustics is a measurable ergonomic factor and contributes to better human working conditions in school environments!

Thanks for your attention!