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Acoustical requirements of classrooms and new concepts of teaching

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In recent years acoustic requirements for classrooms have been published in various guidelines. It is important that the present knowledge be implemented, but how should this be accomplished? And how do the acoustic requirements correspond with new concepts of learning? These questions were the basis of a collaboration between the Laboratory of Acoustics at Empa, Duebendorf and the School of Teacher Education, Aarau, both in Switzerland. The collaboration itself is one way to transfer knowledge. In addition it was planned but not yet completely implemented to develop a transfer of knowledge by student work. Classroom acoustics was discussed in seminars and a number of diploma theses were completed. One project dealt with the acoustic problems of a new teaching concept. Part of the concept is that teaching of four groups of pupils may take place in three classrooms and in the corridor. The doors of the classrooms remain open and at the same time pupils work individually and in groups. In addition, a small group is instructed by a teacher. Suggestions for improving the acoustics were made, but for various reasons could not be accomplished.

1 Significance of hearing in instruction

Hearing has always played an important role in instruction: Aside from the central role that oral-verbal communication plays in all subjects, persons participating in speech and music instruction are directly dependent upon hearing in relation to the subject itself. In addition, the ability to listen is important in the formation of social relationships and is vital in acquiring social competence. Listening clearly influences not only occupational success but also effects a person's personal happiness in his or her private life. Unfortunately, until now the ability to listen has mostly been neglected by the general public. In schools, however, it is increasingly being recognized as being vitally important.

Listening is a basic factor in human communication and likewise an art: One must listen closely to catch the undertones and meaning of what is being said. Still, this blessing is also a curse: In contrast to the eyes, one cannot close the ears. Conscious "ignoring" in an increasingly loud world is therefore vital. However, it is important not to miss important information. Thus, the old cultural technique of listening must now be learned as conscious hearing and selective listening.

In normal instruction, precise listening is a basic prerequisite for the success of the teaching and learning processes. Current long-term studies of school children show that even a slight handicap in acoustical perception correlates highly to failure in a school career. [1]

Listening and perceiving depend however not only upon the physiological condition and attitude of the listener but also on the basic conditions encountered, namely the background noise, the room acoustics and the activities and acoustical events occurring within the room. We all know how tiring and strenuous it is to try to follow a conversation in a noisy environment or to experience the ever rising background noise in a gymnasium or a festival tent. The acoustics of a room must be evaluated as a function of its use: Schoolrooms are speech rooms with particular requirements. The concepts of learning, the role of the teacher, teaching aids and the form of instruction and thus the use of the schoolroom have changed radically in the last decades. The respective challenge to the acoustics is obvious.

2 Teaching, learning forms and acoustics

Today's society demands a learning culture from the elementary school in field of *subject - individual - relationships - environment*. The learning environment should therefore be problem related and transdisciplinary. Learning should be individualized and dialog-oriented, social- and team-oriented, creative, integral and practice (life) oriented.

Even Galileo Galilei (1564 - 1642) said: *You cannot teach a person, you can only help him to learn by himself.* This old observation is confirmed by current learning research: Learning is a subjective adjustment of the senses, transformation of consciousness, adaptation and interpretation of the world. The corresponding new teaching culture leads to a change in teaching concepts and to an expanded definition of the role of the teacher. As a learning coach and moderator of learning processes, the teacher has the following tasks:

- to vary the teaching concepts and aids
- to adapt and individualize learning strategies to the subject
- to allow participation and reflection into the learning process
- to recognize learning difficulites and take them seriously
- to offer learning aids and advice

Thus, school is not an institute where one simply gets "filled up" with knowledge but rather a place where learning is made possible. In conceiving a learning environment and learning institute a long list of old and new learning media are now available:

- verbal language (oral and written)
- non-verbal language (glances, gestures, signals etc.)
- tones, sounds, isolated speech sounds, noises
- books, pamphlets, copies, magazines
- pictures, graphs, maps
- learning material and learning games
- computers, Videos, CDs, blackboards, projector screens

Aside from the frontal instruction, dominant in earlier times, a multitude of different teaching and learning forms are in practice today. The sketches in Figure 1 illustrate schematically some of the most important, typical seating plans.

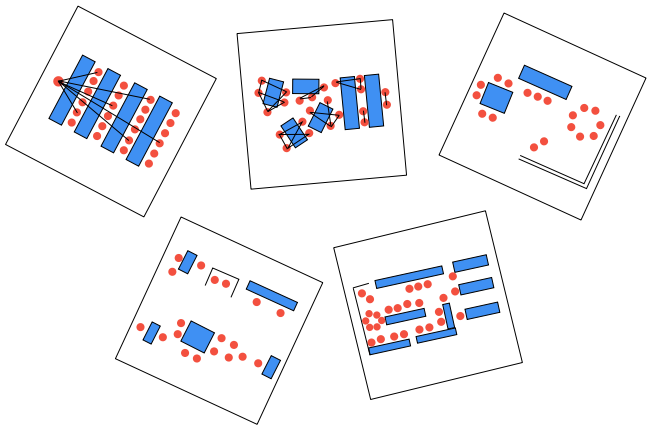

Figure 1: Typical seating plans for some of the most important instruction methods and organization forms.

Today, schoolrooms are utilized by the same instructor with his or her class in very different constellations and arrangements. Furthermore, with integrated school organizations more than one instructor are often active at the same time in one classroom. The pupils work individually, in tandem or in teams, often supporting themselves with various learning aids; they are involved in different problems. During the frontal sequences (lectures, presentations), mainly the instructor speaks. The location and direction of speaking are clearly defined. This serves the class well for discussions and exchanges on equal terms or a common game. For projects, shop and weekly planning instruction, group puzzles, 'Leitprogramm' or case studies the schoolroom resembles rather an open-plan office or a studio. Frequently further rooms and the corridor are included and the classroom remains open. The individual forms of organization and methods are employed selectively and serve different didactical figures. The noise level in the room and the listening conditions always play a role, depending on the activity.

a) Frontal sequencies involve

- lectures and reports
- transmitting information, reading
- imitating and demonstrating (including acoustical)
- explaining and exemplifying (including acoustical)
- questions and answers
- instructional discussions

b) A circular seating plan and other patterns apply to

- discussion in plenum
- exchange and reflection
- playing, resp. performing music
- development of organization
- mutual conflict solutions

c) Group and partner work are preferred for

- discussions, explaining viewpoints
- practicing together (also auditory and acoustical)
- producing something (also acoustical)
- exchanging experiences

d) In regard to projects, it is distinguished between action-oriented and theme-oriented projects. Aside from the figures already mentioned under a) to c) this concerns activities such as

- development of a work plan
- gathering information and material
- shared or divided production of products or solutions (also acoustical)
- exchange and guidance (also acoustical)
- presentation of results (also acoustical)

e) In learning shops the instructor organizes learning situations in which the pupils can learn independently. These apply especially to

- practicing skills and capabilities (also auditory and acoustical)
- introduction into a theme
- gathering experience (also auditory and acoustical)
- going deeper into a theme (also auditory and acoustical)
- gathering data

f) Working along a weekly schedule, many different work concepts should be taken into account.

This flexible use of the classrooms sets demands on the persons participation and the furnishings, but also on the room layout. Based on the use and the delicate requirements of the multifaceted school day, the acoustical design should be considered from the outset in planning new or renovating of classrooms. Feedback from students and teachers indicates that poor room acoustics in the classrooms often are strenuous and tiring for all. In extreme cases, unfavorable room acoustics in classrooms can lead to school failure, loss of attention and disciplinary and health problems.

3 Acoustical requirements

3.1 Common requirements

The acoustical requirements for classrooms and schools have been discussed at length in recent years. New research results show that a good acoustical environment in schools is basic in achieving good teaching and learning conditions. Various guidelines have been published, resp. standards revised. Requirements for background

noise and reverberation time have been established, In the revised Swiss Standard SIA 181 [2], which is based upon DIN Standard 18041 [3] the recommended reverberation time for classrooms of 125 m^3 - 250 m^3 was set at approximately 0.4 - 0.6 seconds. The recommendations concerning background noise are given in DIN 18041 for noise stemming from outside of the room (traffic noise, noises from neighboring rooms) and technical noises (heating and air conditioning, projectors, etc.). For both types of noises the permissible equivalent A-weighted sound pressure level ranges from 30 to 40 dB(A) and is a function of the distance between the speaker and listener as well as whether the room is to be used by the hard of hearing or for instruction in foreign languages.

3.2 Requirements for open plan schools

Few informations have been found on the acoustical requirements of open plan schools. In a paper of a working group of the European Acoustics Association EAA (TC-RBA WG3: Acoustics in Open-Plan Schools and Offices) the following requirements are listed: [4]

Partly open-plan schools:

- The reverberation time should be short, less than 0.3 - 0.4 seconds.
- The acoustic attenuation between two teaching groups should be at least 15 - 20 dB. This should also apply between teaching groups and corridors (using detachable screens, mobile walls or built-in walls with glass).
- The propagation should be attenuated by 5 - 8 dB for each time the distance doubles.
- Within teaching groups, the STI should be greater than 0.6. The STI between teaching groups should be less than 0.2; this can best be checked by using a computer model of room acoustics.

4 Collaboration between acoustics and pedagogics

It is logical that hearing and listening in general and particularly in regard to classroom acoustics should be handled as part of pedagogic education. At School of Teacher Education of the University of Applied Sciences in Aarau the theme classroom acoustics was taken up within the framework of a series of presentations under the title "Music and Man". Many members of the college and interested external participants visited an evening lecture on classroom acoustics. Thereafter the material was made available for the entire semester. In this so-called research studio students worked with both authors, i.e., the lecturer of the School of Teacher Education and the acoustical expert for the subject of classroom acoustics. The students realized that until now they had been unaware of the role that hearing plays in teaching. Thanks to the seminar, they were greatly sensitized to the theme hearing and began to pay more attention to the acoustical environment. Another goal was that students should incorporate this theme into their diploma thesis.

A number of ideas were developed as to how to attack the problem of poor acoustics in schools within the framework of the School of Teacher Education. As an example, it was studied how simple methods [5] could be used to determine how many classrooms in the Canton Aargau in Switzerland do not fulfill the acoustic requirements. Furthermore, a concept could be developed how the topic could be brought to the attention of authorities, school officials, teachers and parents. The goal was to build up pressure to achieve the rapid correction of the defective rooms.

Eventually four students decided to devote their diploma theses to the question of classroom acoustics. Their work will be discussed in the following section. The subject "acoustics and schools" remains a theme at the School of Teacher Education in Aarau.

5 Diploma Theses

5.1 Schafisheim

In the first thesis project [6] two students selected a school in Schafisheim, Switzerland, where both had done their practical training as a teacher. The main questions were: How good are the acoustics in the classrooms in Schafisheim and how do the teachers and the classes find them? How can rooms with poor acoustics be improved in with simple structural measures? In 13 classrooms the reverberation time and the speech transmission index STIPA [7] was measured. A questionnaire was also given to the teachers and classes.

It was found that the person questioned were fairly satisfied with the acoustical conditions in the classical classrooms. This correlates well with the measurement results which indicated that reverberation times fulfilled the requirements in most of the rooms. However, in some rooms, including the one where the two students had taught, the requirements were not fulfilled.

Therefore as an illustration, they decided to correct the acoustics in their own room. They wanted to show that even simple techniques sufficed to correct the acoustics of a classroom. A part of the ceiling was replaced with an efficient low-cost acoustics material. The new ceiling elements were mounted by the students themselves (see Figure 2). The results were satisfying. The classroom then fulfilled the requirements and the listening conditions for instruction were improved. The students suggested that their knowledge be presented in suitable form to interested teachers, as a kind of self-help.

5.2 Birmenstorf

5.2.1 Initial situation

The second project [8] will be discussed here in greater detail. It involves a school in Birmenstorf, Switzerland, where new concepts of teaching are being used, which are acoustically somewhat problematic. The school is integrated, where all the children have a right to an individual and holistic advancement.

Figure 2: Replacing of parts of the ceiling in Schafisheim.

In three classrooms, each of four classes is taught in groups of three levels (see Figure 3). In the form of a weekly plan the pupils receive assignments covering a certain time interval from one to several weeks. In the weekly plan, they work independently on these assignments. In addition, the pupils receive guidance from the instructors. New themes are introduced and older material reinforced. When the pupils are working on their weekly plans, they can choose their own workplaces. The doors of the three conventional classrooms remain open and the rooms and connecting corridor may be entered at will. In the rooms, one or more small groups may be working at the same time and lesson may be given, for example in a foreign language with a teacher and five pupils.

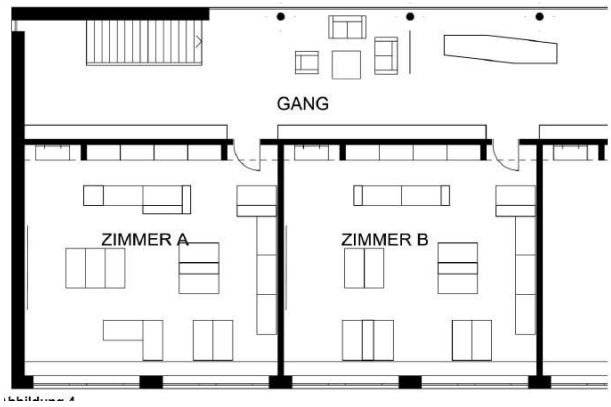

Figure 3: Part of the first floor plan of the school in Birmenstorf: Two classrooms (Room A and Room B) with the corridor and stairway. In the corridor the children can also work. The doors to the classrooms remain open.

The pupils adapt to the situation quite well. The change in workplace occurs relatively quietly. However, a certain background of talking is always present, among other reasons due to lessons taking place simultaneously. School children who are being instructed one floor lower can also cause a disturbance. The sound is transmitted via the stairway.

The question arose as to how these acoustical disturbances influence the children in their learning, respectively, how the situation can be improved, especially in view of a new schoolhouse now being designed. How can the rooms be arranged in order to facilitate the new school concept and to minimize the acoustical disadvantages? These questions were to be considered within the framework of two diploma theses (for the exisiting and the new building).

5.2.2 Installation of movable walls in the existing situation

Unfortunately the design of the new schoolhouse was stopped, so that only one diploma thesis could be carried out. It involved the existing situation and focussed on the question how sound absorbing, transparent movable walls influence the acoustical and pedagogic situation. The movable walls were intended to separate the individual instruction from the rest of the room. Micro-perforated, transparent movable office-walls were employed. Only a small number of these walls were used in order to be able to maintain the original use of the room as far as possible. The transparency was to minimize the visual effect of the walls. Figure 4 shows how the walls (width 1.25 m, height 2.5 m) were arranged.

Figure 4: Classroom without (above) and with (below) transparent micro-perforated movable walls.

5.2.3 Acoustical measurements

A measurement of the reverberation time in the classrooms showed that the values lie within the recommended ranges in all the octave bands. With the three movable walls in place the reverberation time was reduced slightly. Likewise, in the corridor a short reverberation time was measured, which lies within the tolerance for instruction.

The STIPA (speech transmission index) was measured for different speaker-listener positions. For positions within the classrooms values over 0.65 were measured with and without the movable walls. For the speaker position within the classroom and the listener outside, in the corridor, the values were lower, as would be expected (0.20 - 0.50). For the speaker position (teacher instructing a small group) behind the movable walls, no or only a small difference was measured compared to the condition without the movable wall. Similarly, the level difference without/with the movable walls was small (< 4 dB). Evidently the possibility of separating one region of the classroom from the other acoustically is limited with a minimum number of movable walls, since many possibilities for reflections exist although the ceiling is sound absorbing.

5.2.4 Questionnaires

Questionnaires of the pupils and teachers were taken with regard to the situation with and without the movable walls (one classroom was provided with movable walls, a second one, was not). No significant subjective improvement in the acoustical situation was observed through the use of the movable walls. On the contrary, the pupils felt that the movable walls were a definite hindrance in sectioning off the room. In addition, they chose the region in the corridor, not the classroom as their preferred location for individual work. This choice remained the same whether the movable walls were in place or not. The transparency of the walls was described as insufficient: one could see the other person unclearly but could still hear him well.

5.2.5 Summary

The acoustic improvements were minimal. The requirements of [2] and [3] concerning the reverberation time were fulfilled. But the proposed values of [4] concerning speech intelligibility and sound level attenuation between teaching groups were missed for the most part.

Even the minimum of three movable walls was regarded by the pupils as a hindrance. This observation by the pupils led to the conclusion that it would be more sensible to separate the room entirely. It remains open to decide whether the acoustical disadvantages of this learning concept are greater than the postulated advantages compared to a conventional arrangement.

For a new design it would be interesting of course to try to find a feasible floor plan for coupled and partial rooms which would allow the learning concept of Birmenstorf and at the same time minimize the acoustical disturbances.

6 Conclusion

In collaboration with the Pedagogic College and an acoustic research laboratory, various people could be alerted to the question of good acoustics for teaching and learning. In diploma theses of future teachers it was found that it is simple to meet the acoustical requirements with conventional learning arrangements. As the work at the school in Schafisheim (5.2) showed, this can be accomplished even with simple measures. For new learning concepts, as illustrated by the example Birmenstorf (5.2), it is much more difficult to create good acoustical conditions. Without doubt this can only be accomplished through a coordination between the acoustics and pedagogic with the goal of finding practical solutions. This project set a foundation for a collaboration which now must be intensified.

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