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Acoustic treatment of school spaces and its impact on students and teachers. Users' self-assessment.

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ABSTRACT

The paper presents the latest research concerning the correlation between changes in the school building room acoustics and noticeable changes in the communication, behaviour and wellbeing of students and teachers. The primary school covered by the research is the second largest school of this type in Poland. There was a comprehensive acoustic intervention in 2018 as a part of a pilot study for Warsaw municipality preparing for systematic improvement of acoustics in capital schools. This case gave an excellent opportunity to assess the impact of changes in room acoustics on students' school performance, teachers' effort and wellbeing of both groups. The research used the Acoustic Change Feelings Scale (ACFS-T, ACFS-S: English acronym, SOZA-N, SOZA-U: Polish acronym) for teachers and students. The questions concerned wide range of scholar activity aspects: concentration, speed of work, level of task fulfillment and school achievements, short term memory capacity, fatigue, students behaviour during lessons and breaks, level of excitement and aggression or teachers' voice effort. 378 students, and 40 teachers were included in the study. Acoustic measurements were made (before and after acoustic treatment), including measurement of the equivalent sound level L_{Aeq}, reverberation time T, speech transmission index STI and spatial decay of sound.

Keywords: School, Treatment, Teachers.

1. INTRODUCTION

The vast majority of rooms in the school buildings in Poland is devoid of any solutions providing good room acoustics. Very few schools have a comprehensive solution to the problem. The reason for this is a relatively low awareness of the importance of the room acoustics in school premises for the well-being, efficiency and the health of their users. This awareness is low both among the designers of school buildings and the officials responsible for the development and maintenance of the school base. This is due to deficiencies in the syllabus at the faculties of architecture and perhaps, first of all, due to the lack of suitable regulations. This unfavourable situation began to change due to the PN-B-02151-4: 2015-06 standard published in 2015 - very first Polish Standard that defines requirements in relation to the room acoustics in public buildings (mandatory since 2018).

Meanwhile, Koszarny and Jankowska (3) drew attention to the noise in Polish schools in the 1990s. Measurements carried out in the Warsaw primary schools by Augustyńska et al. (1) also pointed to high sound levels in the school corridors, canteens, sport halls as well as in after-school clubs and classrooms. As part of the same research, a survey was conducted among the teachers, in which they explicitly pointed to noise as the most common physical nuisance which they are exposed to at their workplace. Measurements made by Mikulski and Radosz (5) showed, however, excessive reverberation of the classes in these schools as well as low STI values. Kotus et al. (4) analysed the impact of the acoustic treatment on the noise level in the school corridors of two Warsaw elementary schools. Wróblewska and Leo (6) analysed the impact of classroom acoustic treatment on speech

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intelligibility measured by objective and subjective methods.

The comprehensive acoustic treatment of one of the largest primary schools in Poland gave the possibility to conduct a broader survey – in terms of number of types of rooms and situations assessed as well as the number of the participants.

2. PROBLEMS OF RESEARCH, MEASURING METHODS

2.1 Methodology

The research puts forward the main research problem related to searching for a correlation between the Acoustic Change Feelings Scale improvement and changes in school functioning experienced by the students and teachers. The research problem is included in the question:

Whether and to what extent the acoustic treatment of the school interior influenced the assessment of changes observed by the students and teachers?

The students' and teachers' opinion surveys used the proprietary measurement scale prepared for the needs of this study: Acoustic Change Feelings Scale for teachers and students – ACFS-T and ACFS-S. The studies were based on statistical calculations using a Wilcoxon rank test based on rank values. All calculations were made at the significance level $\alpha = 0.05$.

2.2 Research area

Primary school no. 340 in Warsaw with its 1200 students was (2016) the second largest primary school in Poland. The school building was constructed in 2012 according to a design that did not take into account the room acoustics at all. Hard finishing of the rooms and very large number of students meant that the building was loud enough so that the Parent Board started efforts to carry out acoustic treatment. In 2016, the City Council of Warsaw decided to allocate some funds to this task and the works, performed according to the design of Andrzej Kłosak (acoustics) and Weronika Nowak (architecture) was finished in August 2018. Acoustic treatment covered all classrooms, after-school clubs, corridors, lobbies, canteen, auditorium, gymnasiums and sport hall.

2.3 Study population

378 students and 40 teachers participated in the study. The study involved students from the second grade to the eighth grade of the primary school. The most numerous represented classes was the fourth grade (45% of the study population) and the fifth grade (30% of the study population).

3. ACOUSTIC TREATMENT

3.1 Sound absorbing solutions applied

Acoustic treatment in school consisted in installation of sound absorbing solutions described in the Table 1. The main objective was to fulfil the demands of PN-B-02151-4:2015-06 standard, although it was sometimes impossible due to existing building limitations. More about that issue writes Kłosak (2). Below are description of some particular rooms cases: applied solutions and measured effects.

Table 1 – Sound absorbing solutions used for acoustic treatment

Sol.	Description	Practical sound absorption coefficient α_p, Hz					
		125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
A	15 mm glasswool, 200 mm air gap	0,40	0,85	1,00	0,90	1,00	1,00
B	100 mm glasswool, no air gap	0,80	1,00	1,00	1,00	1,00	0,95
C	40 mm glasswool, no air gap	0,25	0,80	1,00	1,00	1,00	0,90
D	40 mm glasswool, no air gap	0,25	0,75	1,00	1,00	1,00	1,00
E	100 mm glasswool, no air gap	0,80	1,00	1,00	1,00	1.00	0,95

3.2 Classrooms

The building has 36 classrooms with the floor surface area between 31.3 m^2 and 72.3 m^2, where most of these rooms (63%) have the surface area between 59.0 m2 and 67.0 m2. The height of all classrooms before the treatment was 3.0 m. Floors finished with seamless PVC lining, masonry and plastered walls, reinforced concrete ceiling slabs floors, plastered.

The acoustic treatment consisted in the installation of sound absorbing solution B on the ceiling, around the perimeter of the rooms (coverage from 43.4% to 50.6%). Due to the building regulations specifying the minimum height of classrooms, it was not possible to cover the more surface of the ceilings. The same solution was used on two walls of each classroom (rear and one of the side walls). Panels covering the entire available surface of these walls higher than 200 cm.

Figure 1 presents values of reverberation time (before and after acoustic treatment) measured in 6 classrooms for early education located on the first floor. Despite the limitations mentioned above, the basic requirements of the standard for classrooms (RT ≤ 0,6 s) have generally been met, subject to minor exceeds of the permissible values in few cases. These exceedances occurred mainly within the 250 Hz octave band and were usually no more than 5%, which is permitted by the standard. These exceedances occurred in the classrooms in which the furnishing was more modest or in which there were additional building restrictions resulting in a smaller amount of sound absorbing materials introduced. At the same time, it should be noted that among 9 classrooms for early education and linguistic teaching only one met the tougher recommendations of the same standard regarding these type of classrooms (RT ≤ 0,5 s).

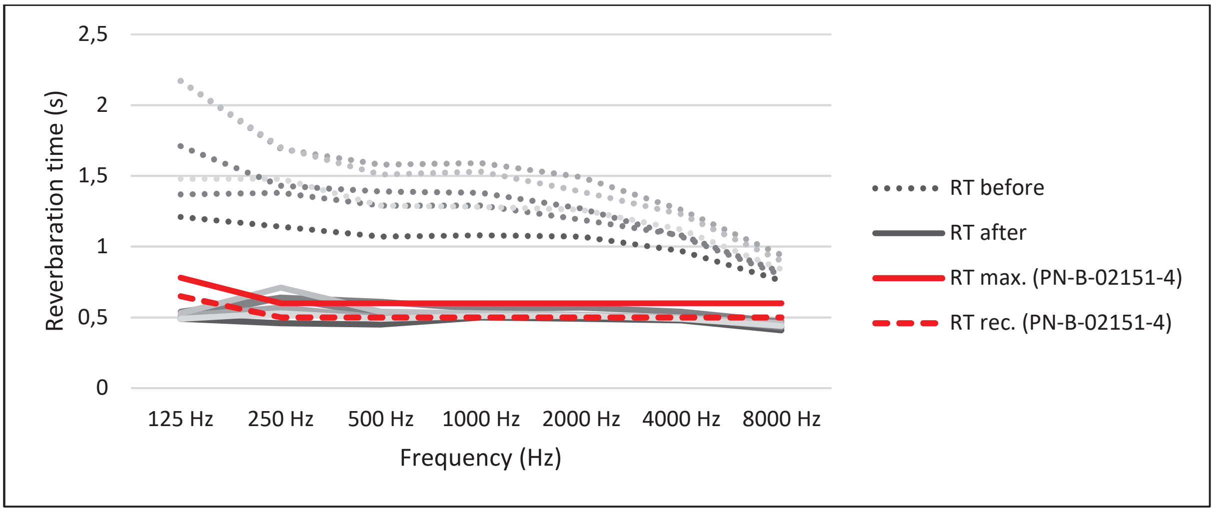

Figure 1 – Classrooms (early education), reverberation time RT, (s), before and after acoustic treatment

Table 2 presents the results of speech transmission index STI measurements in three classrooms (one from each category: early education, language education and general). As a result of the acoustic treatment, a significant improvement was achieved by increasing the averaged STI values by 0.20 – 0.23 for each room. Thus, the requirements of the standard were met with a large margin.

Table 2 – STI values measured before and after acoustic treatment in selected classrooms

Room	Speech transmission index STI					
	minimum		before		after	
	average	lowest	average	lowest	average	lowest
Classroom 116, Polish language	0,60	0,55	0.49	0.46	0.71	0.68
Classroom 123, English language	0,60	0,55	0.47	0.45	0.70	0.68
Classroom 137, early education	0,60	0,55	0.52	0.50	0.72	0.69

3.3 Sport hall

The sport hall has the floor surface area of 1068.0 m2 and volume of 11,072.0 m3. There are masonry and plastered walls, sports floor on joists, a single-sided roof with a structure made of glued laminated timber and covering with sandwich panels.

Due to concerns regarding the load-bearing capacity of the roof structure, the designers decided to introduce sound absorbing solutions only on the walls of the hall. On both gable walls and on one of the longitudinal walls, 50 cm to 370 cm high (from the floor level), sound absorbing solution D was installed. On all walls of the sport hall, above the height of 370 cm (from the level of the floor), sound absorbing solution E was mounted. The total area of sound absorbing solutions is 77.3% of the total wall surface area. The achieved reduction of the reverberation time value is presented in Figure 3.

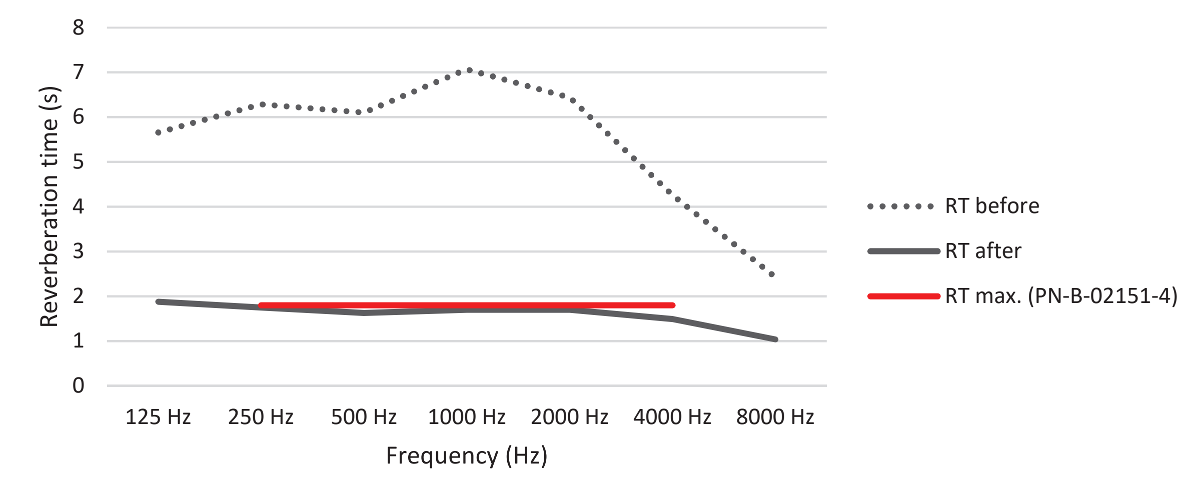

Figure 2 – Sport hall, reverberation time RT, (s), before and after acoustic treatment

3.4 Corridors and halls

The layout of each floor of the building are organised around of spacious hall (670 cm wide) converging narrower corridors (313 – 340 cm wide). The height of the corridors and halls before the acoustic treatment was 330 cm (ground floor) and 300 cm (1st and 2nd floor). Masonry and plastered walls, reinforced concrete ceiling slabs, plastered, floor finished with seamless PVC lining.

The acoustic treatment consisted in the installation of the sound absorbing solution A covering the entire available ceiling area (in many places it is limited by the plasterboard casing of the building technical services). Additionally, sound absorbing solution C installed on available wall sections above the height of 200 cm. As a result of this treatment corridors' total equivalent absorption area was raised 8 to 10 times by far exceeding level demanded by standard PN-B-02151-4:2015-06.

A significant increase in sound absorption of most rooms in the school led to a significant reduction in the sound level in these rooms. Before and after the modernisation, a number of random sound level measurements were carried out to capture the scale of the phenomenon. Table 4 presents the results

Table 3 – L_{Aeq} values measured before and after acoustic treatment in selected rooms

Room	Activity	L_{Aeq} (dBA)	
		Before	After
Sport hall	Dodge ball: 40 students involved in the play in central sector of the hall; in side sectors two other groups of 20 students each occupied with quieter tasks	82.0	75.7 - 76.3
After-school club	Free activity: 30 students playing in groups	79.2 - 81.5	72.8 - 77.2
Hall	Break: 50-70 students, no smartphones allowed	81.4 - 86.9	73.8 - 80.0
Canteen	Lunch: 70-140 students	85.5 - 86.0	73,4 – 76,6

4. SURVEY RESULTS AMONG THE STUDENTS AND TEACHERS

4.1 General questions

In the first points in both questionnaires (for teachers and students) participants were asked to point out situations and spaces where they noticed changes after acoustic treatment. The presented data show that about 68% of children observed any sort of changes in functioning of the school and the most numerous group noticed general decrease of sound level in the building. Smaller but significant group pointed better speech intelligibility in various situations (Table 4).

Table 4 – General changes noticed by the students after acoustic treatment

Observed changes	Number of answers (n=378)	Percentage
I can see the difference (generally).	256	67,72%
There is more quiet at school.	163	43,12%
There is more quiet in corridors	154	40,74%
Children are less running now in corridors	18	4,76%
Children are less quarreling in the corridors	19	5,03%
I understand the teacher better in the classroom	100	26,46%
I understand the teacher better in the gymnasium	80	21,16%
I understand the teacher better in the corridor	68	17,99%

The teachers seem to be much more sensitive to the changes in acoustic environment (Table 5). This group appreciated mostly better speech intelligibility in classrooms and corridors, lower voice effort and decreased level of fatigue. They also pointed out better students' performance.

Table 5 – Changes in teachers' working conditions and students performance noticed by the teachers after

Observed changes	Number of answers (n=40)	Percentage
improved general comfort of work	34	77,27%
in fatigue level after working day	18	40,91%
in vocal effort during the day	20	45,45%
in work comfort while on duty in corridor	19	43,18%
in students' performance during individual work	19	43,18%
in students' performance during team work	15	34,09%
in the level of understanding verbal instructions in classes	27	61,36%
in the students' behaviour during breaks	15	34,09%
in communication with the students during breaks	27	61,36%

When teachers and students were asked to evaluate level of observed changes in different types of spaces they pointed mostly for classrooms: 30% of the students and 77% of teachers answered that changes here were large or very large.

4.2 Detailed questions

In this part of the survey respondents were asked to assess impact of the acoustic treatment on particular aspects of school activities. Each evaluation was made in 5-level range. For each case statistical calculations using a Wilcoxon rank test based on rank values were made. All calculations were made at the significance level $\alpha = 0.05$. In all calculations, the hypothesis H_0 was assumed that the average results of the assessments determined by the respondents (before and after acoustic treatment) are significantly equal and the alternative hypothesis H_1 that the average results of assessments determined by the researched subjects (before and after acoustic treatment) are significantly different.

4.2.1. Students' level of concentration

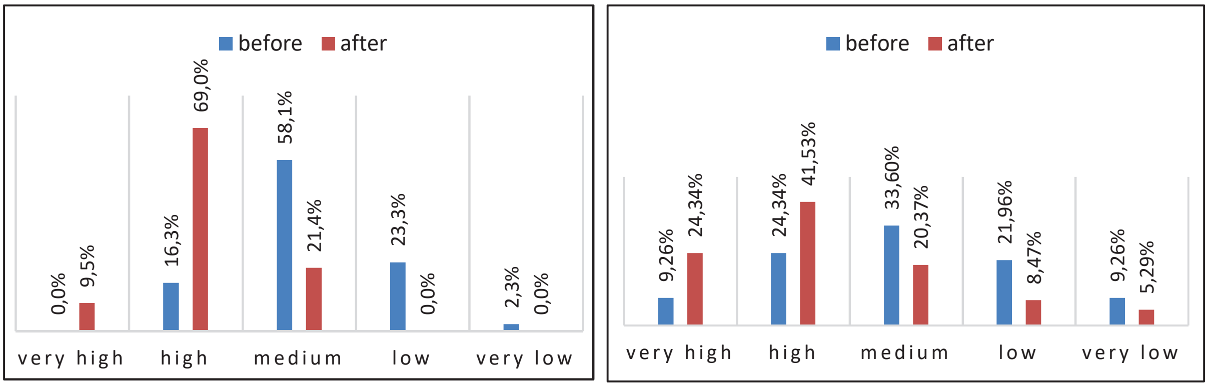

Figure 3 – Students' level of concentration on task during individual work, assessment made by teachers (left) and students (right).

4.2.2. Students' pace of work

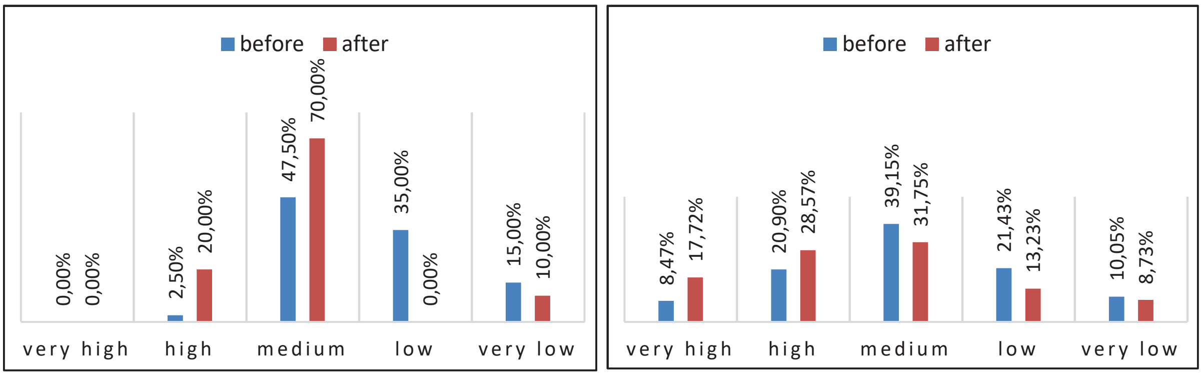

Figure 4 – Students' pace of work during afternoon lessons, assessment made by teachers (left) and students (right).

4.2.3. Students' short term memory capacity

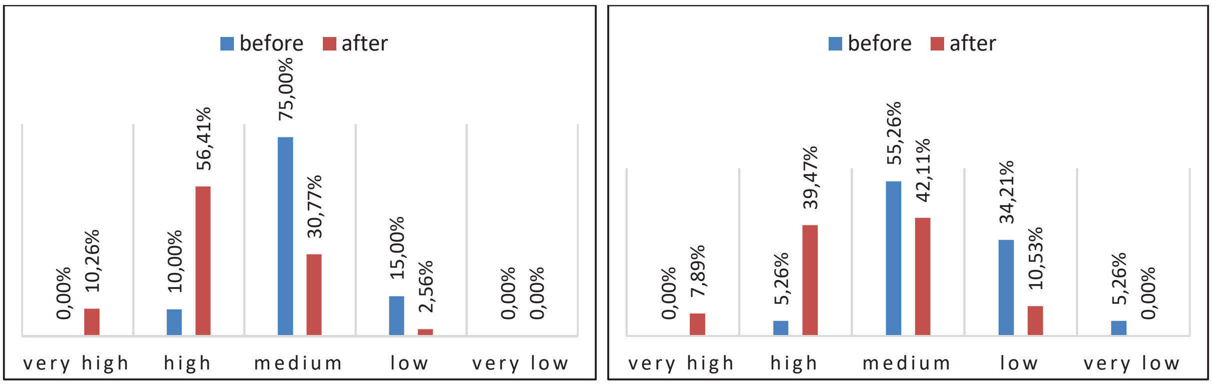

Figure 5 – Students' short term memory capacity, assessment made by teachers and concerning new content (left) and difficult content (right).

4.2.4. Students' task fulfillment

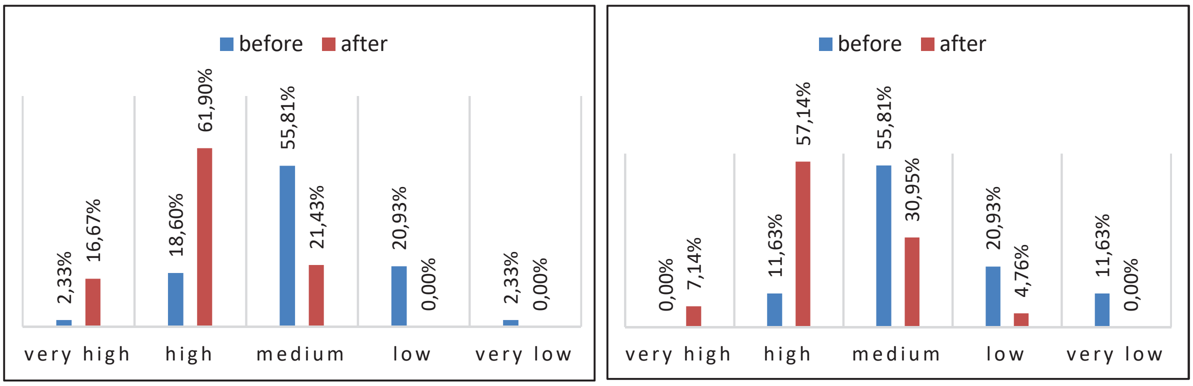

Figure 6 – Students' task fulfillment, assessment made by teachers for simple tasks (left) and complex ones (right).

4.2.5. Students' fatigue

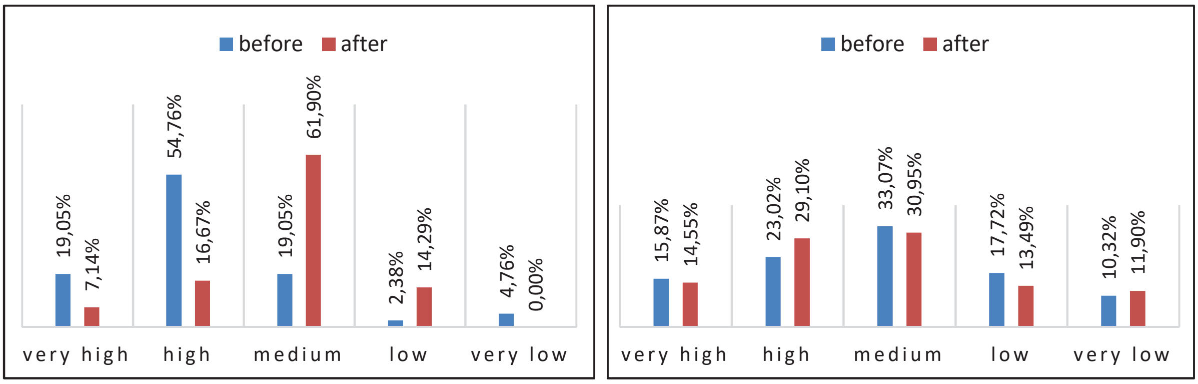

Figure 7 – Students' fatigue during afternoon lessons, assessment made by teachers (left) and students (right).

4.2.6. Students' level of aggression

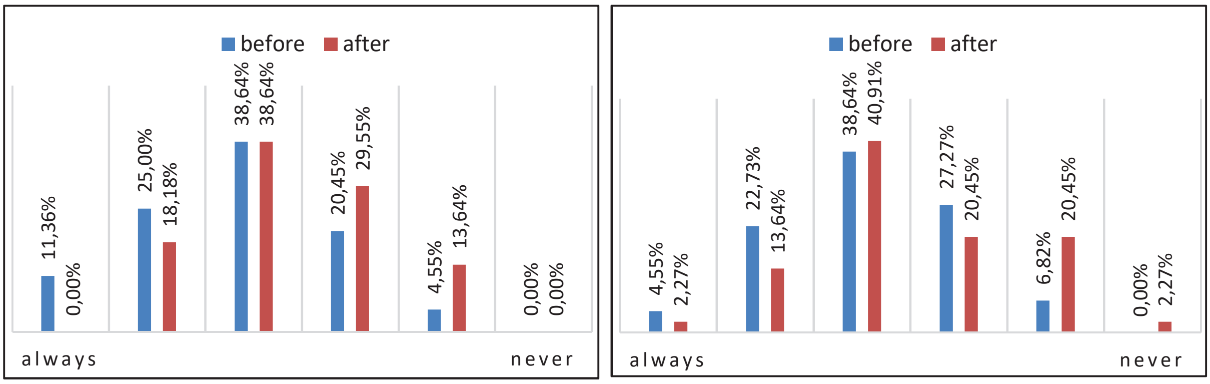

Figure 8 – Students' level of aggression during breaks in assessment of teachers: physical aggression (left) and mental aggression (right).

5. DISSCUSSION

Presented above data are just a part of all collected during survey answers. The whole material shows following consequences of acoustic treatment of school premises.

Teachers asked about students' performance and behaviour noticed positive changes in level of concentration and pace of work (both during individual and group work), task fulfillment, short term memory capacity, durability of memory, level of fatigue and aggression and above all level of speech intelligibility.

When asked about their working conditions they can see benefits in lower fatigue, lower voice effort, lower prevalence of hoarse, headache and tinnitus and lower level of stress. In both groups of questions statistical calculations allowed for positive verification of the assumed hypotheses, therefore the acoustic treatment at school has a positive effect on teachers' wellbeing and students' performance and behaviour.

Students asked about their own performance noticed better concentration, speech intelligibility and pace of work. They point out lower level of aggression. Expressed levels of changes are lower than among teachers, however statistical calculations allowed for positive verification of the assumed hypotheses with just one exception: students can't see any difference in their level of fatigue.

Both groups pointed out higher students' school achievements after acoustic renovation of the building, but the teachers found stronger correlation. 76% of teachers assess that students' school achievements are higher and 14% said that semester grades are far better (while 86% said that changes are small or none). Corresponding percentage for students are 29% and 26% (while 69% pointed small or none changes and 5% reported worse grades).

Interesting observation was made concerning classrooms. In these school, like in most of others, when discussion on "damping" started, teachers and parents were focused on corridors, sport hall, canteen and after-school clubs. Classrooms were of secondary interest. However survey proved that these rooms are the spaces were acoustic changes were most appreciated and where acoustic treatment was most needed.

6. CONCLUSIONS

Data collected in the survey clearly confirms positive opinions spontaneously expressed by the users just after school modernization. It shows how important is acoustical environment of the school for wellbeing and performance of both, students and teachers. Thus it proves need of wide acoustic treatments in existing buildings. Subsequent research results will be presented in later studies of the authors

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