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TEACHERS' INDOOR ENVIRONMENTAL SATISFACTION AND SOUND EXPOSURE IN ENCLOSED AND FLEXIBLE LEARNING SPACES

Jenni Radun[1*] **Marjaana Veermans**[2] **Sanna Rantanen**[2] **Valtteri Hongisto**[1]
[1] Built Environment Research Group, Turku University of Applied Sciences, Turku, Finland
[2] Department of Teacher Education, University of Turku, Turku, Finland

ABSTRACT

This study examined how teachers experience indoor environment and their sound exposure during teaching in flexible and enclosed learning spaces. Here flexible learning spaces mean spaces that can be used for teaching several 20–30 students' groups and enclosed spaces traditional classrooms for one group. Altogether 21 basic education schools were inspected. In each school, the activity sound pressure levels were measured for five working days in four learning spaces and a survey was sent to teaching personnel. Altogether 332 teachers answered the questionnaire, 247 respondents working in enclosed and 85 in flexible learning spaces. The teachers in flexible learning spaces were less satisfied with their indoor environment, especially with sound environment and disturbances, and they felt that the learning space supported their teaching less than teachers in enclosed learning spaces. However, the average activity sound pressure levels during teaching were slightly lower in flexible (63 dB) than in enclosed learning spaces (65 dB). Therefore, in flexible learning spaces the problem is not the high sound pressure levels, but rather disturbances coming from school's other activities. Open learning spaces should be built to schools with consideration and their usage should always be coordinated and planned together.

Keywords: *school, activity sound, learning environment, experience, sound pressure level*

[*] ***Corresponding author***: *jenni.radun@turkuamk.fi.*

1. INTRODUCTION

Many new schools have flexible learning environments that are different from traditional enclosed environments (usually called as classrooms). While traditional enclosed learning environments are suitable for teaching one group of 20–30 students, flexible learning environment enables teaching more than one this kind of group at a time in one space because of larger floor area. Flexible learning environments can be openable (e.g., with a sliding wall) or completely open. The flexible learning environments are supposed to enable larger range of pedagogies than the traditional enclosed learning environment [1]. They are also supposed to support student-centered pedagogies, while enclosed environments are thought to restrain these [2].

From acoustical viewpoint, learning environments can be classified to open (several 20–30 student groups) or enclosed (one 20–30 student group). Therefore, the flexible environments with, for example, sliding walls can be used both in enclosed and open modes.

Open learning spaces have been criticized for noise disturbance, especially intrusive noise from adjacent groups, reduced speech intelligibility and privacy, which cause distraction and dissatisfaction to both students and teachers [3]. In open learning spaces, the adjacent groups' activity might raise the learning spaces' sound pressure levels (SPLs) even 10 dB L_{Aeq} [4]. However, no difference was found in the average lesson SPLs in open learning spaces (40 lessons average 63.2 dB L_{Aeq}) compared to enclosed learning spaces (234 lessons average 64.4 dB L_{Aeq}) [5].

Experiences related to flexible, and enclosed learning spaces have been mostly examined from students' point of view [6,7] or with qualitative approach [7]. There is a lack of studies quantitatively comparing teachers' experiences of

their environments in different learning space types. The aim of this study was to examine teachers' environmental satisfaction and activity SPLs in different learning environment types.

2. METHODS

2.1 Schools

Twenty-one schools were selected for the study, with about half having flexible learning spaces and the other half primarily traditional. Floor plans of all schools were requested, based on which the principals of the schools were interviewed remotely about the school's facilities and their use. In addition, guided tours were conducted in all schools.

2.2 Survey

All teachers and teaching assistants in the 21 schools were invited to participate in the survey. The schools located in several cities to avoid possible bias due to possible local design conventions. The respondents were classified into **learning environment groups** based on the question: "What is the most common space you use for teaching?" The response options were: A) A space where one class/group and one teacher operate simultaneously, B) A space where multiple classes/groups and teachers operate simultaneously, C) A flexible teaching space (a closed teaching space, plus, for example, an aquarium outside the space, or a corridor/common area to which the teaching space can be expanded), D) Other, what kind? Respondents in category A were classified into the enclosed environment group, while all other respondents were classified into the flexible environment group.

Total environmental satisfaction was assessed by answering the question: "How satisfied are you with your teaching space overall?" The response scale was 7-point: -3 very dissatisfied, -2, -1, 0 neutral, +1, +2, +3 very satisfied.

Satisfaction with indoor environment factors was assessed on the same satisfaction scale by answering the question: "How satisfied are you with the following aspects of your teaching space?" The indoor environment factors to be assessed are listed in Table 1.

2.3 Activity sound measurement

Activity sound levels were monitored in 20 schools in four learning environments each. Sound level meters (NTI Audio XL2, with M2230 microphone) were installed in locations where teachers were most commonly present. The sound level meters recorded the average equivalent A-weighted sound level per minute ($L_{Aeq,60s}$). Typically, the meters were installed near the teacher's desk at a height of 1.55 meters close to the wall to avoid obstruction. The installation height of the microphones varied between 1.5 and 2.7 meters. The meters were left in the space for at least five working days, during which teachers recorded the time of events, the number of people present, and the main activity in the space. Based on this information, the data was filtered to identify the times when teaching was marked as occurring. Sounds caused by transitions (5 minutes at the beginning and end of lessons) were removed from these periods. Teaching periods were defined as those lasting more than 5 minutes and involving 10 or more people. A total of 1369 such teaching periods were selected. The average sound level (L_{Aeq}) for each space was calculated from these periods.

To examine the difference between the types of learning spaces, **the learning spaces** were divided into enclosed and open. An enclosed space referred to a space that could accommodate one group of 20–30 people and was surrounded with doors, windows and walls extending to the ceiling. An open space referred to a space that could accommodate multiple groups of 20–30 people at a time. A flexible space was classified as open when open and enclosed when used in the closed mode. The information of the usage mode of the flexible space was recorded by the teachers for each measurement period.

2.4 Statistical analysis

The differences between the environmental groups were analyzed using Linear mixed effects analysis with environmental group as the fixed effect and the school as a random effect.

3. RESULTS

The survey received 361 responses, of which 332 were teachers that will only be examined here. Altogether 194 (58%) worked in traditional schools and 138 (42%) in flexible schools. Out of them, 247 (74%) worked in enclosed learning spaces (enclosed environment group) and 85 (26%) worked in flexible learning environments (flexible environment group).

Teachers in flexible environment group were less satisfied with their total working environment than teachers in enclosed environment group (p=0.004; Table 1). Similarly, teachers in flexible environment group were less satisfied with acoustic factors, sound insulation, and sound environment in general, as well as the amount and undisturbedness of space (Table 1).

The average activity sound levels in enclosed learning spaces were higher than in open learning spaces (p=0.004; Table 2).

Table 1. The mean estimations and their standard deviation (in brackets) presented for the learning environment groups. P-values describe the significance of differences between the learning environment groups, where significant is $p<0.05$ (* $p<0.05$; ** $p<0.01$; ***$p<0.001$). Red cells denote the learning environment group with statistically lower satisfaction rating.

	Enclosed		Flexible		P-value
Amount of light	1.1	(-0.4)	1.4	(1.4)	0.971
Sound insulation to outside**	**1.2**	**(-0.3)**	**0.8**	**(0.8)**	**0.002**
Teaching equipment	0.8	(1.2)	0.8	(0.8)	0.981
IT-solutions	0.7	(0.2)	0.6	(0.6)	0.426
Acoustics for talking**	**0.7**	**(-0.2)**	**0.0**	**(0.0)**	**0.001**
Temperature	0.3	(0.2)	0.4	(0.4)	0.997
Total environmental satisfaction**	**0.6**	**(0.8)**	**-0.2**	**(-0.2)**	**0.004**
Sound insulation to neighbor classrooms***	**0.6**	**(0.7)**	**-0.6**	**(-0.6)**	**<0.001**
Sound insulation to the corridor*	**0.2**	**(0.6)**	**-0.5**	**(-0.5)**	**0.032**
Functionality of transit routes***	**0.2**	**(0.2)**	**-0.7**	**(-0.7)**	**<0.001**
Amount of storage space**	**0.2**	**(-0.5)**	**-0.7**	**(-0.7)**	**0.009**
Furniture	-0.1	(-0.2)	-0.5	(-0.5)	0.174
Air freshness	-0.4	(-0.9)	-0.5	(-0.5)	0.126
Amount of dust or dirt	-0.5	(0.7)	-0.4	(-0.4)	0.5
Amount of working space*	**-0.2**	**(1.1)**	**-0.8**	**(-0.8)**	**0.033**
Undisturbedness of space**	**0.0**	**(0.3)**	**-0.9**	**(-0.9)**	**0.002**
Sound environment***	**-0.3**	**(-0.1)**	**-1.1**	**(-1.1)**	**<0.001**

Table 2. The average activity sound pressure levels and ranges presented in learning space types.

Sound pressure level	Learning space type			
	Enclosed (N=61)		Open (N=22)	
	Mean	Range	Mean	Range
L_{Aeq} [dB]	65.3	(60.3-73.9)	62.6	(56.8-69.9)

4. DISCUSSION

First, the teachers were less satisfied with their flexible learning environments in general compared to enclosed learning environments. This was surprising, as flexible learning environments are supposed to offer more action possibilities than the enclosed traditional classrooms [1].

Furthermore, teachers were less satisfied with the sound environment in general in flexible learning environments than in enclosed learning environments. This was seen also in satisfaction with sound insulation and acoustics for talking.

Therefore, even though the review of Shield et al. [3] is 15 years old with much older studies reviewed in it, the sound environment is still a problem in these flexible learning environments and new pedagogical approaches (e.g., student-centered learning) have not changed this.

However, the higher activity sound levels do not seem to be the problem, as they were lower in open than in enclosed learning spaces. Previous studies have shown similar activity sound pressure levels in open and enclosed spaces [4]. The difference in our study was also very small, only 2 dB. This might mean that the difference is meaningless. On the other hand, it might reflect the fact that the sound is distributed to a larger area in open spaces. It might also be caused by a change in behavior, as people do not want to disturb the adjacent group.

The problem with flexible learning environments seems to come from the visual, social, and acoustic disturbances and interruptions. These might come from the unfunctional transit routes or maybe from the insufficient amount of space. The flexible schools are slightly newer than the enclosed schools and the amount of space might reflect the fact that new schools are more space efficient than the older schools were. Space efficiency might also be related transit routes going through open learning spaces to other enclosed learning environments in schools.

One study suggested that the improvement of room acoustic quality in classroom could improve the acoustic satisfaction among pupils [8]. Therefore, we also measured the room acoustic conditions in the classrooms, where the activity sound level measurements were conducted [9]. Current

Finnish regulations were fulfilled in 63% of enclosed and 9% of open learning environments. This suggests that more attention should be paid to the improvement of room acoustics in open learning environments. However, the Finnish regulations are very new and immature for open learning environments. We cannot guarantee, that our survey results would be significantly improved after room acoustic enhancements. More research is needed about the role of room acoustic design in open learning environments.

5. CONCLUSIONS

The teachers were less satisfied with their learning environments in flexible than enclosed learning environments, but the problem did not seem to be the higher activity sound pressure levels, but rather the disturbances from the neighboring groups or transit routes, for example. When designing flexible learning spaces, undisturbedness of space during activities must be considered. There are few ways to accomplish this: by separating transit routes, dividing the space, room acoustics solutions, or coordinating activities in the open space.
Full results will be presented in journal paper, which is under review [10].

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