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A study in Chile

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Students' Perceptions of acoustic comfort in traditional and flexible learning environments: a study in Chile

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Abstract. The acoustic quality of educational spaces has an important impact on well-being and occupant performance. This study investigates noise perception and hearing ability among primary students in traditional learning environments (TLE) and flexible learning environments (FLE). A survey was conducted in Santiago de Chile, involving 21 teachers and 315 children from 13 schools, to gather responses on acoustic comfort. Additionally, a checklist was used to inspect the physical spaces. The analysis of students' responses revealed that self-reported complaints related to indoor environmental quality (IEQ) predominantly focused on noise discomfort in both types of learning environments. A significant relationship was found between the type of space and children's perception of noise from their peers. Although students in TLE reported greater annoyance with noise, those in FLE experienced slightly more listening problems. Interestingly, in FLE, students with an occupancy density greater than 2.1 m2 per student did not feel bothered by the noise produced by their classmates speaking. Although further research is needed, these findings highlight the crucial role of acoustic conditions in ensuring the comfort and hearing abilities of young students. Adequate acoustic treatment and enough space per student are important to mitigate potential indoor noise issues.

1. Introduction

The acoustical quality of educational spaces has an important influence on well-being [1, 2] and occupant performance [3]. Over recent decades, interior design has sought to offer adaptable and re-configurable learning settings to promote a diversity of teaching practices with a student-centered approach [4]. In comparison to traditional classrooms, with a hierarchy of desks and chairs arranged into rows in front of one board, flexible learning environments (FLE) promote a diverse range of learning activities through the space adaptation, seating arrangements and different types of furniture depending on pedagogical needs [5]. A review of those spaces concluded that one of the biggest challenges would be achieving an adequate acoustic comfort [6]. However, the research mostly focuses on open-plan or semi open-plan typology without considering flexible learning environments in enclosed spaces.

In Chile, some refurbished and new learning spaces are promoting new pedagogical approaches according to the design criteria of flexibility, sustainability, and innovation [7], but rarely include acoustic conditioning. To gain more insights into the current role of the new learning environments in the acoustic comfort of students, the aim of this field study was to examine the noise perception and the hearing ability of primary students in traditional learning environments (TLE) and flexible learning environments (FLE) without acoustic treatment.

2. Methodology

2.1. Study design
The underlying study is part of a larger field study in Santiago de Chile to investigate on acoustic comfort of primary students in flexible learning environments. The field study comprises a questionnaire for teachers and students and a checklist of inventory space characteristics. During March and April of 2023, thirteen learning spaces of five schools were surveyed. The selected schools were refurbished in 2018-2019, improving the thermal-light conditioning. In addition, to develop teaching in transversal spaces (learning resource centres and project rooms), new furniture, and technological elements were incorporated to promote student-centered pedagogies (Figure 1).

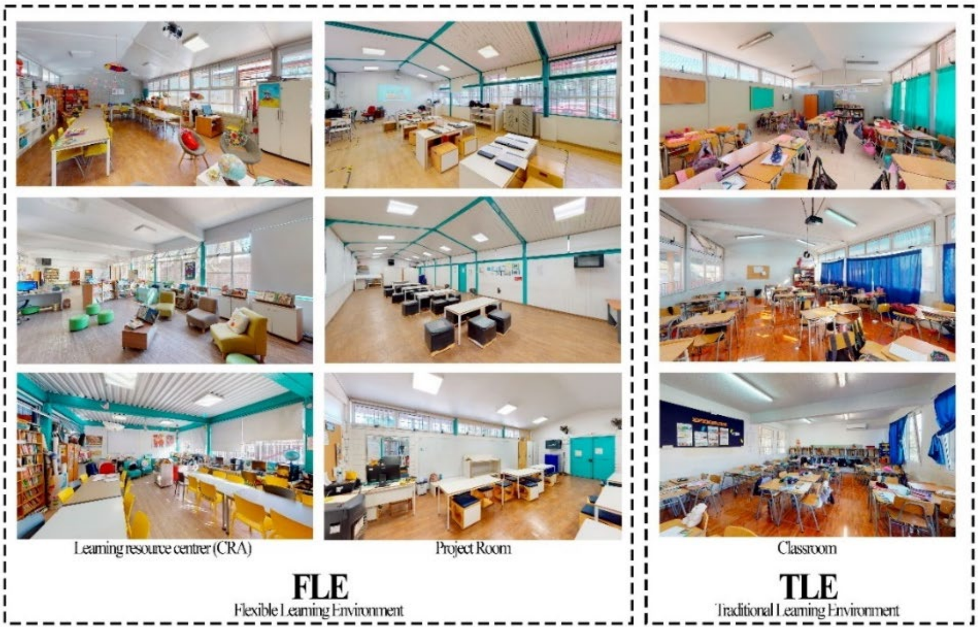

Figure 1. Photographs of some learning spaces surveyed.

2.2. Questionnaires
The teacher's questionnaire was based on previous research [8, 9] and it was distributed among 21 teachers of the 13 learning environments to ask about the percentage of time devoted to different teaching approaches. The students' questionnaire was based on previous questionnaires about acoustic and IEQ comfort [1, 10]. It comprised four sections: (1) *demographic*; (2) *IEQ comfort* on a four-point ordinal scale (very uncomfortable, uncomfortable, slightly uncomfortable, not uncomfortable); (3) *Noise source annoyance,* which consist of 6 items that ask about the perceived annoyance of noise coming from both within and outside the learning space on a three-point ordinal scale (annoying, slightly annoying and not annoying); (4) *Hearing ability,* which consist of four items that ask about their ability to hear the teacher and other students in different scenarios (quiet activities and group work) on a 5-point scale from very good to very bad. Both questionnaires were tested in a pilot study at one school in November of 2022.

2.3. Procedure and ethical aspects
The Ethics committee of the University of Bío-Bío approved the study. Before the survey, the parents received a consent letter from the school managers. An introduction with information about the study purpose, oral instructions for filling out the questionnaire, and the opportunity to ask questions were

given at the school under the supervision of the researchers. On the same day of the questionnaire procedure, the space was inspected.

2.4. Data analysis

All the data from the questionnaires and checklists were imported and analyzed IBM SPSS Statistics 29.0. About 315 children's questionnaires were manually checked and 42 cases with missing data were eliminated. All data was separated into two groups for the statistical analysis (FLE and TLE). First, the percentage, mean and standard deviation (SD) of data were calculated using descriptive analyses. Second, the analysis was compared between TLE and FLE using chi-square or Mann-Whitney U. Third, the significant relationships between these analyses were calculated with the characteristics of the learning spaces using one-way ANOVA test.

3. Results

Table 1 shows the demographics of children and space characteristics. From the total responses analyzed (*n=272),* 111 students filled out the questionnaires in 5 TLE and 161 students in 8 FLE.

Table 1. Demographics and learning space characteristics

		TLE	FLE	All
Gender	Female	60.2%	62.3%	59.2%
	Male	37.0%	36.4%	35.3%
	Other	2.8%	1.3%	1.8%
Age	Years (*sd*)	9.9 (*1.1*)	10.5 (*0.8*)	10.3 (*1.0*)
Native language	Spanish	97.2%	96.8%	97.0%
	Other	2.8%	3.2%	3.0%
Space characteristics	Number of spaces	5	8	13
	Floor size m^2 (*sd*)	51.2 (*0.9*)	76.8 (*21.3*)	66.9 (*20.8*)
	m^2 per student (*sd)*	1.6 (*0.3*)	2.2 (*0.7*)	2.0 (*0.6*)
	Ceiling height m (*sd*)	3.0 (*0.1*)	3.0 (*0.2*)	3.0 (*0.1*)
	Volume m^3 (*sd*)	152.0 (*7.4*)	232.9 (*66.1*)	201.7 (*65.1*)
	Glazing percentage (*sd)*	10.2% (*2.7*)	10.1% (0.8)	10.1% (*1.7)*

3.1. Teaching approaches

The percentage of time dedicated to teaching activities was investigated (Figure 2). The results indicated that TLE spent more time in teacher instruction (43%) than FLE (21%), but no statistically significant relationships at the 5% level were found (p-value of Mann-Whitney U test: 0.110). However, significant correlations were observed between the type of learning environment and teamwork (p-value: 0.024). It is worth saying that the difference between teamwork and group work is that in the first more than one teacher works with groups of students during the class. Therefore, in FLE, teachers spend more than 50% of the time in collaborative activities Compared to 27% in TLE.

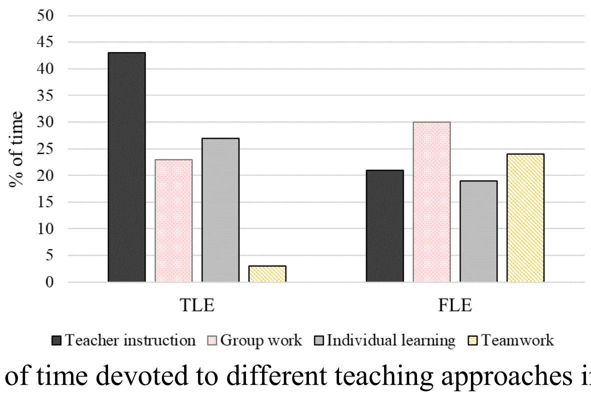

Figure 2. Percentage of time devoted to different teaching approaches in Traditional learning environments (TLE) and Flexible learning environments (FLE).

3.2. Acoustic comfort

Regarding IEQ comfort perception (Table 2), a significant relationship was observed between the typology of learning space and noise. In general, 92% of children in TLE were bothered by the noise (82% FLEs). In noise comfort perception, 50% of children were very uncomfortable in TLE (34% FLE), 20% were uncomfortable in TLE (16% FLE), 22% were slightly uncomfortable in TLE (32% FLE), and 8% were not uncomfortable in TLE (18% FLE).

Table 2. Students in discomfort with IEQ conditions

	TLE (%)	**FLE (%)**	**All (%)**	**[a]p**
Temperature	50,5	45,3	47,4	0,340
Air quality	58,6	57,8	58,1	0,219
Daylight	20,7	30,4	26,5	0,326
Noise	91,9	82,0	86,0	**0,012**

[a] p-value of Chi-Square tests between learning spaces. p-values in bold refer to significant relationships at 5% level.

In order to understand the types of noise that cause more annoyance to students, the children were asked if they ever heard some kind of noise sources (yes or no). If the children gave an affirmative answer (yes), then they needed to answer a second question: "Are you annoyed by the noise…? on a three-point scale of annoying, slightly annoying, and not annoying. If the children answered no to the first question, the answer was considered as not annoying. As shown in Table 3, more than half of students were annoyed by different noise sources, except the noise from fans or air conditioning 19% (21% FLE). It is important to mention that all the TFE had air conditioning and half of the FLE has fans. Additionally, 73% of children (71% FLE) were annoyed by noise from outside the school, 77% (75% FLE) by the noise from the schoolyard or hallways, 55% (52% FLE) by noise from other learning spaces, 83% (82% FLE) by children talking inside the space, and 64% (62% FLE) by children moving in the space. A significant relationship was found between the typology of the space and the noise annoyance from children talking inside the learning space. The distribution of noise perception of children talking inside was 54% annoyed in TLE (36% FLE), 31%, slightly annoyed (46% FLE), 15% not annoyed in TLE (18% FLE).

Table 3. Students annoyed by noise sources and hearing ability problems

Annoyed by different noise sources:	**TLE (%)**	**FLE (%)**	**All (%)**	**[a] p**
Noise from outside (traffic, construction, etc.)	73.9	71.4	72.7	0.114
Noise from schoolyard or hallways	79.3	74.5	76.5	0.120
Noise from other learning spaces	59.1	51.6	54.6	0.097
Noise from fans or air conditioning	17.3	20.5	19.2	0.596
Noise from children talking inside the space	84.7	82.0	83.2	**0.011**
Noise from children moving inside the space	65.8	62.1	63.6	0.545
Hearing ability difficulties:				
Teacher speaking during quiet activities	22.5	23.0	22.8	0.428
Teacher speaking during group work	24.3	29.2	27.2	0.565
Classmates speaking during quiet activities	35.1	38.5	37.1	0.486
Classmates speaking during group work	22.5	26.7	25.0	0.260

[a] p-value of Chi-Square tests between learning spaces. p-values in bold refer to significant relationships at 5% level.

Regarding hearing ability perception, the children answered the question "How well can you hear your (teacher or classmates)" in four scenarios. The hearing ability problem considered the students answer, "not very well", "bad", or "very bad". If the children answered, "very well" or "well", it was considered as good hearing ability perception. Around 25% declared hearing difficulties in all scenarios, but no significant relation was found between spaces. Nevertheless, in FLE the complaint was slightly greater than TLE, especially in the scenario of classmates speaking during group work with a difference of 8%.

3.3. Relationships between noise annoyance and space characteristics

A series of one-way ANOVA were carried out between the noise perception from children talking inside and the spaces characteristics (height, volume, glazing percentage, floor size, and student density). A significant effect of the spatial density was found on the student's noise annoyance from children talking inside the space (*p-value: 0.029*). As shown in Figure 3, the difference of the medians between the degree of annoying was 0.2 m^2 per student. For the group of students annoyed, the median of the spatial density was 1.7 m^2, in the group of children slightly annoyed was 1.9 m^2, and the children not annoyed was 2.1 m^2 per student. However, the interquartile range of both "not annoyed" and "slightly annoyed" groups showed more statistical dispersion than the group of children annoyed. Regarding the other spaces' characteristics, no significant relationships were identified.

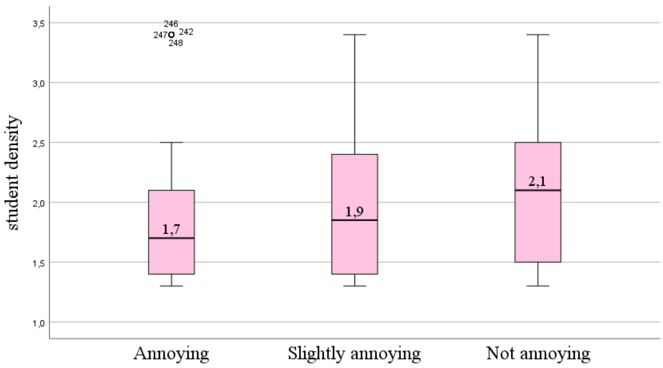

Figure 3. m^2 per student and noise annoyance from children talking inside the space.

4. Discussion

This study examined the perception of noise and hearing ability among primary students in traditional learning environments (TLE) and flexible learning environments (FLE) in Chile. Firstly, as previous studies conducted in the global north [8, 11, 12], these findings suggested that flexible learning environments promote student-centered learning and, consequently, more noisy activities. However, it is important to mention that the perception of sounds depends not only on the physical condition of the learning space but also on the cultural context in which it is located.

Looking into the IEQ aspects, self-reported complaints showed that noise was the primary discomfort factor in both types of spaces. On one hand, the results demonstrated a significant association between noise annoyance and the type of space. On the other hand, the IEQ results can be attributed to the absence of acoustic treatment in the walls or ceilings of either type of space, while thermal and daylight conditions were improved through double gazing (HR), PVC window frames, air conditionings, and artificial lighting.

Regarding noise sources, the most concerning aspect was the annoyance rating in all spaces. Over 50% of children were bothered by external and internal noises. However, the noise perception from children talking inside was higher and significant between the spaces. Surprisingly, despite FLE promoted more group activities, the dissatisfaction rate was slightly higher in TLE. This could be explained by the results related to occupancy density, with FLE having a higher mean than TLE. According to Shield et al. [13] occupant density was identified as a significant factor in noise control, although no specific limitations were recommended. This study suggests that a minimum standard of 2.1 m^2 per child would be necessary for acoustic comfort in learning spaces without acoustic conditioning, while less than 1.7 m^2 per student would be problematic. Additionally, it was observed that students in FLE perceived less annoyance from noise, although they indicated slightly greater difficulty in listening to their teachers and classmates in various scenarios.

Furthermore, this study has two main limitations. Firstly, although some of the FLE had soft furnishing, none of the learning spaces included acoustic treatment with absorbent materials. Therefore, it was not possible to compare the noise perception between acoustically conditioned and non-conditioned spaces. Secondly, the type of FLE included in this research consisted of enclosed classrooms with flexible furniture, but a flexible learning space could also involve the adaptation of the built environment [14]. Hence, further research is needed to complement these findings.

5. Conclusion

In summary, the results of this study highlight the crucial role acoustics in ensuring the comfort and hearing abilities of young students. Achieving an adequate acoustic environment for instructional purposes, characterized by a reverberation time of 0.6 seconds, a speech transmission index of 0.6, and a background noise level between 30-45 dBA, may be relatively straightforward. However, new challenges arise with the incorporation of more collaborative activities [15]. Therefore, it is recommended to implement appropriate acoustic treatment that considers the pedagogical use of the space, incorporating additional acoustic strategies to reduce noise between children. Additionally, it is crucial to provide enough space per student to mitigate potential indoor noise issues.

Acknowledgments

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