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Assessing the indoor soundscape approach among university students' home study places

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ABSTRACT

University students spend a considerable time at study places. The acoustical quality of these study places is one of the indoor environmental qualities (IEQ) that can have an impact on student's health, comfort, and performance. The indoor soundscape approach has been introduced to better understand occupants' sound perception and experience of sounds in relation to the environment. This study aims to explore the indoor soundscapes of home study places of these students by conducting semi-structured interviews with 23 university students with different profiles. For qualitative analysis, open coding was used. Sub-categories, based on the codes, and categories were created and assigned to the soundscape themes that are defined in ISO 12913-1. An affinity diagram consisting of the themes, categories, and sub-categories was initially developed. Then, it was validated through two workshops with participants. The results showed that the interpretation of the sound environment, responses, and outcomes differed among the students. In a previous study, 451 students were clustered in 5 clusters with similar acoustical preferences (profiles). Therefore, it is recommended to consider making the indoor soundscape approach applicable for different profiles of occupants.

1. INTRODUCTION

Research has shown that university students spend their studying time in study places (i.e., informal learning spaces), such as home or educational buildings [1–3]. University students mainly perform cognitively demanding tasks in these spaces, such as reading, writing, and problem-solving activities [4]. In general, people are exposed to different environmental stimuli while staying indoors, which are related to indoor environmental quality factors (IEQ), including indoor air quality, thermal comfort, visual quality, and acoustical quality. These qualities can affect people's health and performance [5,6], and they are strongly related to students' well-being [7]. During the COVID-19 pandemic, a study showed that students stayed

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at home for 20 hours per weekday resulting in suffering from home-related symptoms, including headache and tiredness [8]. Hence, well-designed home study places that align with students' preferences and needs are significant for promoting both health and performance [9].

Acoustical quality is one of the four IEQ factors that influences students' well-being in study places [10,11]. Previous studies have focused on the adverse effects of background noise on students' health, comfort, and performance [12]. Little is known about the students' sound preferences of their study places [13]. The soundscape approach enables to explore in-depth how individuals experience the sound environment for a certain context [14]. It consists of several data collection methods, including questionnaire, interviews, and sound level measurements[15]. While this concept was developed for the urban environment context, it has been applied in the indoor environment context [16]. However, indoor soundscape studies within the context of educational and study places are still limited [13].

Few studies have investigated until now the indoor soundscapes in the context of learning and studying environments. For instance, Visentin et al. [17] explored the indoor soundscapes of primary school classrooms. They concluded that sounds generated by pupils were the most frequent and perceived as unpleasant sounds by them, while they prefer the presence of calm sounds such as music and natural sounds. Topak and Yılmazer [18] investigated the indoor soundscapes of classrooms and computer laboratories of a high school building. They also found that natural sounds and low music levels were evaluated positively by students. They concluded that students' sound perception was not only related to sound level but was associated with the context. However, these two studies were focused on the context of a classroom setting.

In terms of the context of study places, Acun and Yilmazer [19] assessed the indoor soundscapes of four open study places on a university campus. They explored the sound sources, students' reactions, coping methods, and their sound perceptions of these places using quantitative research methods comprising questionnaires and sound level measurements. The study revealed that students' sound perceptions did not correlate with the sound level. During the COVID-19 pandemic, Dzhambov et al [20] explored the relationship between the indoor soundscape of university students' homes and their self-reported health using a questionnaire. The questionnaire included questions related to the most frequent sounds present at home, students' sound perception concerning the pleasantness of these sounds, health, and building characteristics. They found that mechanical sounds (e.g., home appliances, construction, and sirens) were associated with low self-reported health of the students.

To date, there is still limited information about the sound experience of students at their home study places within the context of studying. Therefore, this study aims to answer the following research question: To what extent can the soundscape approach be used to assess the sound environment experience of each student at their home study place?

2. METHODS

A qualitative research design, comprising a semi-structured interview and two workshops (see Figure 1), was applied to explore the sound environment experience of each student at his/her home study place. Additionally, building inspections data and sound pressure level (SPL) measurements, of which the collection is described in [21], were used.

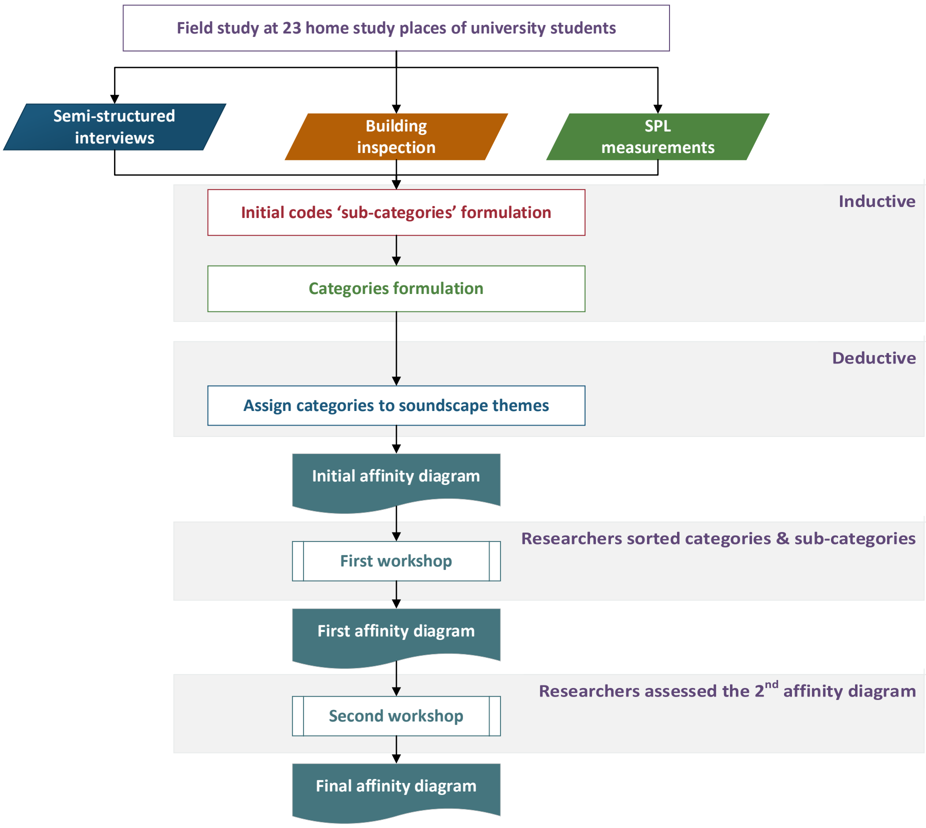

Figure 1. Overview of the study design.

2.1. Semi-structured interviews with students

23 university students accepted to participate in this study, which took place between November 2022 and February 2023 in the Netherlands. Each of them received an invitation email, including the interview questions and a consent form which they were asked to sign [21]. An offline audio recorder device (TASCAM DR-05X) was used to record the interview with the consent of the student. Generally, interviews lasted for 15 to 30 minutes. The interview with each student included eight sound environment-related and psychosocial aspects (e.g., privacy) questions, presented in Table 1. These questions are related to the seven elements of soundscapes that are defined in ISO 12913-1 [14], which are context, sound source, sound environment, auditory sensation, interpretation of auditory sensation, responses, and outcomes. While most of these questions were extracted from ISO 12913-2 [15], three of them were introduced by the authors (questions 4, 7, and 8).

Table 1. Interview sections and questions.

Questions	Theme
1. What are the study-related activities you often do when you are in your study place?	• Context
2. Which sounds are present at your home study place?	• Sound sources • Sound environment
3. What do you do when you are exposed to sounds you mentioned when you are at your study place? *(explained in a scenario)*	• Responses
4. In your opinion, when do you think that a specific sound is considered a noise while you are at your home study place?	• Interpretation of auditory sensation
5. Are there any sound(s) that you prefer that stimulate you during your study-related activities at your study place? [21]	• Sound sources • Outcomes
6. How do you think sound can be controlled?	• Responses
7. What do you think the optimal sound environment for your study place should look like? [21]	• Sound sources • Sound environment • Outcomes

Questions	Theme
8. How can you define the meaning of privacy in your home study place?	• Context

2.2. Data management and analysis

Each of the audio recording files was anonymized and transcribed into verbatim transcription. Then these transcriptions as well as the building inspections and SPLs were inductively coded (in vivo coding) using ATLAS. ti 23 software by applying the Gioia method [22]. Next, the initial codes (n=776) of the eight questions under the sound environment section were exported into an Excel file, in which these codes were organised under their related interview questions. Then, focused coding was done by assigning labels to the initial codes. Constant comparisons between these labels were done iteratively to eliminate repeated labels and reduce code numbers (n=557). After that, each label was categorised deductively under one of each of the seven pre-determined themes extracted from ISO12913-1. Finally, an axial coding was done where similar labels under each theme were grouped (n=139) and they were labelled with a category (23 categories formulation). The qualitative results including themes, categories, and sub-categories were illustrated in an initial affinity diagram.

2.3. Workshop

Two workshops were conducted to validate the initial affinity diagram and to avoid subjective bias. The facilitator sent an invitation email to the participants (PhD students from the Faculty of Architecture and the Built Environment at TU Delft) which included reading materials about the soundscape themes as defined in ISO12913-1. Both workshops were conducted in meeting rooms at the Faculty of Architecture and the Built Environment at TU Delft. The first workshop was conducted on the 23rd of June 2023 and the second one on the 6th of July 2023.

2.3.1. First workshop

The first workshop aimed to validate and assess the relevance of the categories to the themes as well as the sub-categories to the categories. This workshop was facilitated with seven participants. The facilitator organised seven empty boards (Figure 2), each representing one of the soundscape themes with its definition. The participants used three materials in three different stages within the workshop, which are yellow cards, purple cards, and black dots. A list of 23 categories was presented in a yellow card which were presented in random order. First, the facilitator asked the participants to assign collaboratively the list of 23 categories to their relevant soundscape themes. Then, the facilitator gave each participant a list of sub-categories presented in randomly organised purple cards. After that, each participant voted on the relevance of each sub-category to its assigned category using the black dots. Finally, the facilitator opened a discussion with the participants on the sub-categories that received three or less than three votes if it could be assigned to different categories.

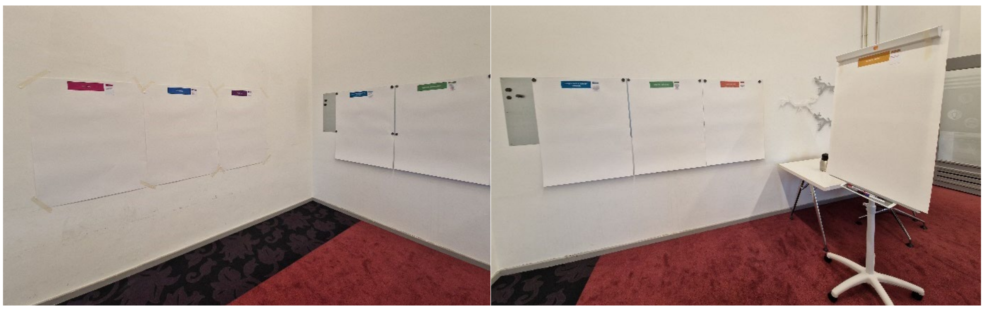

Figure 2. The first workshop setup comprised seven empty boards.

After the workshop, the affinity diagram resulted in seven themes, 22 categories, and 133 sub-categories. Additionally, two categories with in total 14 sub-categories were not assigned to any of the seven themes and received less than three votes. Next, 59 sub-categories and three categories that received less than three votes and were assessed to be not relevant to the data structure, were eliminated. It should be noted that this elimination included the whole theme 'auditory sensation' because of its relation to the physiological and psychological state of the ear (such as noise sensitivity [17]), which was not accounted for in this study. This resulted in the first affinity diagram comprising six themes, 19 categories, and 73 sub-categories.

2.3.2. Second workshop

In the second workshop, aimed to validate the first affinity diagram, six of the seven participants that participated in the first workshop, were asked to assess the relevance of each category to its assigned theme as well as each sub-category to its assigned category in the updated affinity diagram. The facilitator prepared the workshop by placing the categories and sub-categories of each theme on its corresponding board (Figure 3). Only the black dots were used by participants in this workshop. Hence, each participant was asked to vote first on the relevance of each category to its assigned theme, and then the relevance of each sub-category to its assigned category. This was followed by an open discussion on the categories and sub-categories that received less than three votes during this workshop and the first workshop. This open discussion helped to re-name the unclear categories, re-assign categories to the most relevant theme, and exclude unrelated categories from the affinity diagram. All participants agreed that the two categories with their 14 sub-categories from the first workshop could not fit into none of the themes. Then, three categories and seven sub-categories from the building inspection and the SPL measurements [21], were added to the affinity diagram.

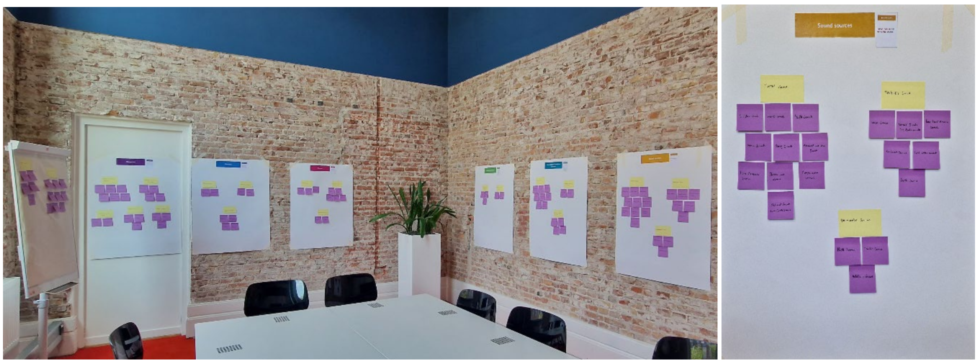

Figure 3. The second workshop setup comprised six theme boards.

2.4. Ethical aspects

This study was approved by the Human Ethics Committee (HREC) at Delft University of Technology on the 31st of January 2022. The participants received a voucher for their participation to the workshops.

3. RESULTS

The indoor soundscapes of the home study places of university students are illustrated in an affinity diagram in Figure 4, consisting of six soundscape themes (context, sound sources, sound environment, interpretation of auditory sensation, responses, and outcomes), 22 categories, and 80 sub-categories. Each of these themes is explained further in the following sub-sections along the outcome of the interviews and the visits.

Figure 4. The final affinity diagram comprises themes, categories, and sub-categories of students' experience of the sound environment at their study places.

3.1. Context

Context refers to the interrelationship between occupant, building, and activity. The context in home study places consists of four categories that are: ‘spatial aspects’, ‘building type’, ‘psychosocial aspects’, and study-related activities, which all were connected to the context of their study place. The ‘spatial aspects’ differed among the 23 students. More than half of the students (n=16) placed their home study place close to a window, of which five of them preferred to have a view to the outside or daylight. Seven of these home study places faced a roadside, and seven were adjacent to a living room. With regards to the ‘building type’, most of the interviewed students were living in student housing, studying either in a private room (n=10) or in a private studio (n=3). The majority of the interviewed students (n=16) claimed that they study at home study places where privacy, a ‘psychosocial aspect’ is provided. It should be noted that five of these students prefer to study alone, and seven of them did not prefer the presence of others. The ‘study-related activities’ were strongly connected to the context of the sound environment. Six students indicated that the sound quality of the environment is important for demanding tasks such as studying for an exam.

Student: *“My study place is adjacent to the living room. One day, I was trying to study while one of my roommates invited friends who have relatively loud and low voices. So, I could literally hear them word by word, and I could not study.’’*

Student: *“So privacy is important to me when I have to do a very demanding task such as math. I also cannot listen to music while I am doing it.”*

3.2. Sound sources

Sound sources refer to the existing sound sources that the interviewed students were exposed to while studying at their home study places. These were attributed to three types: ‘human sounds’, ‘natural sounds’, and ‘mechanical sounds’. Most of the interviewed students (n=17) were exposed to people talking or moving sounds (from outside or inside). It was found that different students were exposed to different sound sources. More than half of the interviewed students (n=13) were exposed to traffic sounds, five of the students were exposed to natural sounds such as birds, 11 students were exposed continuously to home appliances sounds such as refrigerator, and three students were exposed to mechanical ventilation sounds. Noting that sound sources are related to the context. For example, a student can be continuously exposed to traffic sounds due to the special aspect ‘facing roadside’.

Student: *“From the inside, I hear sounds of people walking and sometimes making noise.”*

Student: *“From the outside, I clearly hear noises from the busy road because the window has a single glazing which is not absorbing sounds from the outside.”*

3.3. Sound environment

The sound environment refers to how a certain sound is propagated inside an indoor environment. Based on the data from [21], three categories were found to be related to the sound environment of home study places: the ‘sound absorption materials’, ‘SPL’, and ‘building geometry’ (e.g., room hight and gross area). While most of these home study places (n=18) had sufficient sound-absorbing materials (e.g., sound absorbing ceiling panels), five home study places did not have sufficient sound-absorbing materials. The majority of these home study places had a relatively low background sound level (less than 40 dB(A)), and in three home study places the SPL exceeded 40 dB(A).

Student (home study place’s SPL is less than 40 dB(A)): *“If I am studying here and my roommate is on a phone call in the adjacent room, the wall has no sufficient sound-absorbing material, I hear everything and it is super distressing.”*

3.4. Interpretation of auditory sensation

Interpretation of auditory sensation refers to how students experience, perceive, and prefer the sound environment within the context of their home study places. These interpretations can be categorised under four categories: 'sound source perception', 'sound source preference', 'quantitative characteristics of sound perception', and 'qualitative characteristics of sound perception'.

With regards to 'sound source perception', the perception of the same sound source differed among the 23 students. For example, while four students did not perceive traffic sounds as noise, two students perceived it as noise. For the aspect 'sound source preference', most of the students (n=17) preferred to listen to music while studying, but the types of music differed among students. More than one-third of students (n=10) preferred the presence of natural sounds while studying, such as bird songs or rain. In contrast, the preference of the same sound source can differ among students. For instance, while there were five students that did not prefer to listen to people sounds, three students preferred the presence of people sounds at their home study places.

The 'quantitative characteristics of sound perception' were divided into two sub-categories that are 'long duration sounds are noise' and 'loud sounds are noise'. 10 students considered any sound that lasts for a long time as a noise while studying.

'Qualitative characteristics of sound perception' can be distracted sounds, discontinuous sounds, and constant sounds. Almost half of the students (n=11) perceived the discontinuous sounds (e.g., construction sounds) as noise. In contrast, while four students perceived continuous sounds (e.g., mechanical ventilation) as noise, two students did not perceive it as noise.

Student: *"I consider a sound as a noise if it lasts for a long time. If it is for few minutes, I do not mind. But after a while, if I notice that it is lasting too long and I am not sure when it is going to stop, then it does bother me."*

Student: *"I can study with some ventilation sounds. I do like some little noises when I'm studying, like a coffee machine. So, I do not need a completely quiet space."*

3.5. Responses

Responses refers to short-term reactions and emotions. In this study, three reactions and two sub-categories for emotions were found.

Concerning reactions, students reacted differently to coping with the sound environment in terms of interaction with either the physical environment, or with the sound environment, or with people to cope with the (background) noise. More than half of the students (n=13) interacted with the sound environment by using headphones or earbuds to avoid the background noise (unwanted sound during studying). 10 of these students applied the sound masking technique by playing a sound source preference such as music. One-third of the students (n=7) interacted with the physical environment, such as closing windows or door and moving to another place (n=5). Similarly, few students interacted with people, such as asking people to stay quiet (n=3).

Pertaining to emotions, some students experienced positive emotions while others experienced negative emotions that were evoked by a certain sound environment. The majority of students (n=17) experienced motivation while studying with the presence of their sound source preference, such as music or natural sounds. In contrast, one-third of students (n=7) experienced negative emotions such as annoyance while studying with the presence of background noise (e.g., people talking or construction sounds).

Student: *"If noises from outside are not too loud, I just close the window. And if it does not work, I put headphones on. And when noises of people from inside are loud, I put my headphones on with music up loud because I do not consider music as disruptive."*

Student: *"I can ask people here if they can be quiet. And when there is a party above here, I can go there and ask them: can you stop putting music on. I feel safe here so I can always ask that to people here."*

3.6. Outcomes

The outcomes refer to the effect of the sound environment of a study place on the student's experiences. Three types of outcomes were identified in this study, which are positive, negative, and neutral outcomes. Almost half of the students (n=11) experienced a positive outcome: 'affecting focus positively' while they were studying with the presence of their sound source preference. The majority of students (n=19) experienced a negative outcome: 'distracted' when they were exposed to unwanted sounds. 11 students experienced a neutral outcome: 'acceptable current sound environment' while studying at their home study place.

Student: *"Sometimes when my roommates are talking in the living room, but I also need to socialize. So, sounds from people give a more positive experience."*

Student: *"There has been a lot of construction work in the adjacent area. And especially at the beginning, it was so annoying, like the thudding sound. So for me, especially because I had to study at home, it was really distracting and I could not focus that well."*

Student: *"When you are here, it is mostly the sounds of the cars moving on the road. I think these sounds are there all the time. So, after a while, I got used to it because these sounds became like a white noise that I could just filter them out."*

4. DISCUSSION

4.1. Advantages of the indoor soundscape approach

The soundscape approach contributes to understanding how occupants experience the sound environment in a certain context by exploring their interpretation, responses, and outcomes of sound sources in a specific sound environment. In addition, it might contribute to better design of indoor sound environment through accounting for occupants' positive experiences. In learning and study environments, the indoor soundscape approach consists of a number of data collection methods, including guided interviews with which the student's sound environment experience can be studied. Qualitative analysis methods (e.g., grounded theory) were used in previous studies to develop a conceptual framework that represents the indoor soundscape of a learning environment. For example, Topak and Yilmazer [18] found six themes of the conceptual framework of the indoor soundscape at a high school's classroom and computer laboratory: the built environment, perception, context, acoustic environment, responses, and outcomes. Five of these themes are similar to the themes that we found in the indoor soundscape assessment of the home study places. We found that the theme context such as spatial aspects (e.g., close to a window) influenced two themes: sound sources and interpretation of auditory sensation. For instance, one of the student's home study places is facing a roadside which influenced the student's sound source perception and preference. This is a similar result of the study by Topak and Yilmazer [18] who also concluded that context is an important aspect of how sound sources are interpretated.

The indoor soundscape approach enables the exploration of sound sources that students are exposed to continuously and sound sources that the students prefer to be present while studying. For instance, Visentin et al. [17] discovered that primary school children were mostly exposed to sounds generated by the children themselves of which they perceived as unpleasant sounds in the classroom. Similarly, we found that the majority of university students were exposed to sounds generated by people. However, we noticed that some students prefer this sound source to be present and others do not prefer the presence of it. Furthermore, the soundscape approach explored how students cope with the sound environment at their home study places. It was revealed that more than half of the students put on headphones/earbuds to eliminate unwanted sounds at home study place. This is also in line with the findings in the two studies (based on questionnaires) by Braat-Eggen et al. [10] and Acun and Yilmazer [19] that more than one-third of the students used the headphones/earbuds when they were unsatisfied with the sound environment at open study places.

4.2. Limitations of indoor soundscape approach

Two limitations of indoor soundscape approach were found and discussed below.

4.2.1. Indoor soundscape for an 'average' student

In this study, the outcome of the indoor soundscape approach in the affinity diagram represents the sound experience of an 'average' student, regardless of the different characteristics among students. For example, the most dominant sound source identified was people talking/moving sounds. Acun and Yilmazer [19] also found that students frequently hear sounds generated by people while studying at study places on campus, indicating that these were perceived as the most disturbing sound source. Interestingly, in our study the perception of people sounds differed among the interviewed students: five students did not prefer the presence of people sounds, while three students preferred the presence of people sounds. In addition, students differed in their responses (i.e., coping methods) when they were exposed to an 'annoying' sound of which some of the students interact with the sound environment by using headphones/earbuds while others interact with the physical environment by closing the window or door. These findings convey that students differ in their experience (including preferences, perceptions, and coping methods) of the sound environment at study places.

Within the context of study places and learning environments, students differ in their preferences and needs. and students can be clustered based on their preferences and needs by applying Two-step cluster analysis [23] resulting in clusters with different profiles (preferences and needs). Hamida et al. [21] identified five profiles of university students based on their acoustical and psychosocial preferences, named 'sound extremely introvert', 'sound unconcerned introvert', 'sound partially concerned introvert', 'sound concerned extrovert', and 'sound unconcerned extrovert'. These profiles differed significantly in their acoustical and psychosocial preferences at study places. Also, Zhang et al. [24] found six clusters (profiles) of primary school children based on their preferences and needs of IEQ in classrooms. Two of these profiles ('sound concerned' and 'smell and sound concerned') were highly concerned with the having individually controlled devices, such as headphones. The cluster analysis can be followed up with qualitative research methods such as interviews to better understand the aspects related to these preferences [21,25,26]. For instance, Hamida et al. [21] concluded that building-related indicators, such as the location of the home study place affected students' acoustical preferences. Hence, it consequently affects how the student experiences the sound environment at a study place.

4.2.2. Indoor soundscape mainly focused on sound

The soundscape approach is mainly focused on sound. There are other IEQ factors that interact with the sound environment. Toressin et al. [16] highlighted that the indoor soundscape approach integrated with a multisensory approach can be effective in understanding individual's perception of the sound environment in a comprehensive manner. For instance, we found in our study that several students placed their study place close to the window because they like the view to the outside. This visual aspect is associated with the sound sources from outside (e.g., traffic sounds) that could affect the student's sound experience. Also, psychosocial aspects, such as privacy, were found to be related to the sound environment. When we asked the students their meanings of privacy at their home study place for example, one student mentioned that privacy is important while performing a high demanding tasks of which the student needs also a quiet sound environment. Hence, interview questions could be developed to include questions related to both other IEQ factors and psychosocial aspects.

4.3. Limitations of this study

This study is limited to study plans of university students from the faculty of Architecture and the Built Environment in the Netherlands. Additionally, the workshops only included PhD students from the faculty of Architecture and the Built Environment. Moreover, this study used the pre-determined themes of the soundscape approach presented in the ISO12913-1 standard. We noticed other themes, such as psychosocial aspects and other IEQ factors, that could be added.

5. CONCLUSION

In this study, the indoor soundscape approach was applied to understand the sound environment experience of 23 university students at their home study places, using mixed data (qualitative and quantitative) of interview transcriptions, building inspections, and SPL measurements. This resulted in an affinity diagram consisting of themes, categories, and sub-categories that explain the sound experience of these students at their home study places. The affinity diagram was validated through two workshops with participants.

To answer the research question of this study, the indoor soundscape approach is indeed useful to better understand the context of the home study places in relation to sound sources, students' interpretation of these sound sources, responses, and the outcomes. However, this approach is limited to the sound environment experience of an 'average' students and does not account for the different needs (e.g., health and lifestyle) as well as preferences of these students. Moreover, the soundscape themes are limited to sound environment-related aspects. Therefore, it is recommended to consider making the indoor soundscape approach applicable for different profiles of occupants. In addition, the indoor soundscape themes could be extended to include other IEQ factors (e.g., visual comfort) and psychosocial aspects (e.g., privacy) to better understand a student's sound experience of a study place.

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