Exploring Users' Sensory Experiences in Physical Learning Spaces: Politecnico di Milano School of Design as a Case Study

Reejy Atef Abdelatty Mikhail, Design Department, Politecnico di Milano, Italy
Anna Barbara, Design Department, Politecnico di Milano, Italy

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Abstract
The paper aims to identify learning space users' sensory needs and preferences and determine which interior design elements and strategies best meet them to positively influence behavior and impact learning, educational performance, and individual and social well-being. A two-phase mixed-methods research (MMR) methodology is employed in the study. First, a thorough literature review was conducted to understand the sensory characteristics of learning spaces, particularly in higher education institutions (HEIs), and the common metrics for assessing the sensory performance of learning space users. This was followed by a field research methods phase encompassing surveys of 55 participants, including students and educators, at Politecnico di Milano (PoliMI) School of Design regarding their sensory experiences in four different classrooms. In addition, direct observation was done in the same classrooms. The findings of this paper have revealed that sight is the most important sensory factor, followed by sound, smell, touch, and taste. Lighting, indoor air quality, and ventilation are the interior design elements with the greatest sensory importance, with the highest equal percentage of 58.2%. Acoustics and noise level are next, with 54.5% and 52.7%, respectively, followed by thermal comfort, colors, smells, shapes, and textures. Furthermore, a noisy learning space reduces focus and raises anxiety, while poor air quality and insufficient temperature can cause headaches. This highlights the necessity of improving the quality of learning space design and taking sensory preferences into account during the design process.

Keywords: Learning Spaces, Sense-Based Design, User Experience, Spatial Behavior

Introduction

Higher education institutions are constructed facilities to host and support academic-related activities, such as teaching, learning, and research. These facilities typically accommodate a variety of faculties with various specializations (A. O. Abisuga et al., 2019). Additionally, they have a range of spaces, including offices, lecture halls, classrooms, open areas, cafeterias, libraries, studios, workshops, and laboratories. The effectiveness of these learning environments affects staff and student behavior, health, and productivity (Abisuga et al., 2015, 2016; Leung & Fung, 2005; Vafaeenasab et al., 2015). Therefore, it is essential to understand students' perceptions of their physical learning spaces to meet their needs.

Students engage their five senses—sight, touch, smell, taste, and hearing—to perceive, gather, and analyze data from the learning environment. Each of these senses serves a purpose by collecting data from the environment and relaying it to the brain, which analyzes the information (Kaleem, 2022). When the brain receives information about the environment via perception and cognition, such as light, aesthetic shapes, textures, colors, patterns, acoustics, odors, objects, and furniture, the brain responds with what is known as "spatial behavior" (Mostafa, 2008; X. Zhang, 2016). Together, these mental processes enable the students to respond to their surroundings, affecting their performance (Kaleem, 2022).

Although research into the design of learning spaces is receiving more attention (Perks et al., 2016), more needs to be understood about what students consider a high-quality learning environment (Riley, 2013; H. Wilson & Cotgrave, 2020). In HEIs, architects, estate/property managers, and teaching staff do most of the research on space design and often make recommendations based on pedagogical or technical considerations; students' sensory perceptions are rarely explored in their studies (Cleveland & Fisher, 2014). This highlights the necessity for improving the quality of learning space design and taking sensory preferences into account during the design process (Patel et al., 2022).

Therefore, the objective of the paper is to recognize the sensory requirements and inclinations of individuals using learning spaces. It seeks to establish the most effective interior design elements and approaches that can have a constructive influence on behavior, enhance learning, improve educational performance, and contribute to individual and communal well-being.

Learning Environments' Sensory Experience Evaluation Tools

As the number of new learning spaces has increased, academics have begun to look into ways to evaluate these new environments. Many of these methods are discussed in two Australian books where researchers suggest various tactics for figuring out how these novel spaces function (Alterator & Deed, 2018; Imms et al., 2016). These methods are classified according to the occupancy stage, including pre-and post-occupancy evaluation tools.

Acton, Riddle and Sillers (2018) present a study of post-occupancy evaluation methods and list the most common techniques, such as surveys, interviews, focus groups, and teaching practice observations. They also introduce additional emerging tools for evaluating spatial data, such as the Most Significant Change (MSC) approach, a narrative-based dialogic process, and the Day Experienced Method, which analyzes student perspectives and experiences through diaries, photos, videos, and audio recordings. Loughborough University (Bryant et al., 2009), Sheffield Hallam University (Harrop & Turpin, 2013), Iowa State

University (Rands & Gansemer-Topf, 2017), Singapore Institute of Technology (Mui et al., 2019).

On the other hand, the pre-occupancy tools include the Learning Space Rating System (LSRS), Learning Environments Evaluation Programme (LEEP), Pedagogy-Space-Technology (PST) Framework, Learning Space Toolkit (LSTK), and Flexible Learning Environments eXchange (FLEXspace). They generally provide a framework for assessing the potential performance of a learning space, that is, what learners and instructors can do in it (Brown et al., 2017). These tools have been used to evaluate the learning spaces of several universities, such as Bond University (G. Wilson & Randall, 2010), PoliMi (Sancassani et al., 2019), and Penn State University (Waltz et al., 2020).

However, Cleveland (2016) criticizes current guidelines for learning space evaluation for failing to consider the learning environment's social or human aspects and urges the development of new prospects that directly link pedagogy and space. Similarly, Oliver (2016) notes that existing evaluation models frequently occur in the distinct fields of architecture or education. The common assessment elements associated with the sensory dimension are listed in Table 1 and have been collected from a variety of evaluation tools and studies. Each element is presented as a feature of a broad evaluation category, not especially for evaluating the sensory performance of the learning community users. They are summed up into eight different elements, including lighting, acoustics, colors, thermal comfort, visual display, furniture, equipment, and layout, as well as indoor air quality and ventilation.

Assessment Elements	Relevant Literature/Reference
Lighting	Christensen Hughes (2002), Hebert & Chaney (2012), Brown (2015), Sanni-Anibire & Hassanain (2016), Mustafa (2017), Kim et al. (2018) and Peng (2022)
Indoor Air Quality Ventilation	Christensen Hughes (2002), (Cooper & Kerns, 2006), Griffin (2007), Ashrae (2009), Yang et al. (2013), Sanni-Anibire & Hassanain (2016), Mustafa (2017), Kim (2018), Z. Zhang (2019) and Peng (2022)
Acoustics	Christensen Hughes (2002), Yang et al. (2013), Dunn et al. (2014), Brown (2015), Beckers et al. (2016), Sanni-Anibire & Hassanain (2016), Mustafa (2017) and A. O. Abisuga et al. (2019)
Colors	Ukoha & Beamish (1997), Liu (1999), Hassanain (2008), Fatoye & Odusami (2009), Hassanain et al. (2010) and Sadiq Mahmoud et al. (2018)
Thermal Comfort	Christensen Hughes (2002), Yang et al. (2013), Beckers et al. (2016), Sanni-Anibire & Hassanain (2016), Mustafa (2017), Watch & Tolat (2017), Kim et al. (2018), Sadiq Mahmoud et al. (2018), Lau et al. (2019) and Peng (2022)
Visual Display	Ukoha & Beamish (1997), Christensen Hughes (2002), Griffin (2007), Ashrae (2009), Fatoye & Odusami (2009), Brown (2015), Watch & Tolat (2017) and Sadiq Mahmoud et al. (2018)
Furniture and Equipment	Christensen Hughes (2002), Fianchini (2007), Yang et al. (2013), Muhammad et al. (2014), Brown (2015), Sadiq Mahmoud et al. (2018) and A. O. Abisuga et al. (2019)
Layout and Size	Penn et al. (1999), NRC (2000), Toker (2004), Griffin (2007), Toker & Gray (2008), Watch & Tolat (2017), Sadiq Mahmoud et al. (2018) and Peng (2022)

Table 1: The common assessment elements for the sensory dimension gathered from several studies. Source: table created by the researcher, based on literature review

Politecnico Di Milano School of Design as a Case Study

The literature review findings reveal the common metrics for measuring and assessing the sensory performance of learning space users. These metrics served as the cornerstone for the activities that followed in the field study phase in accordance with the research methodology.

The results of the field research activities, which began with an analysis of PoliMi space typologies, provided a framework for the following observations and surveys. Figure 1 illustrates the nine learning space typologies present at the design campus, as classified by PoliMi. It includes department classrooms, lab rooms, teaching labs, meeting rooms, conference rooms, a library, exhibition spaces, and study rooms. The spaces' learning activities are divided into four groups: lecture classrooms, individual study, drawing, and computerized spaces. To better compare spaces with the same activity, surveys, and observations for the typology of the teaching rooms—particularly those hosting design studios—were initially conducted.

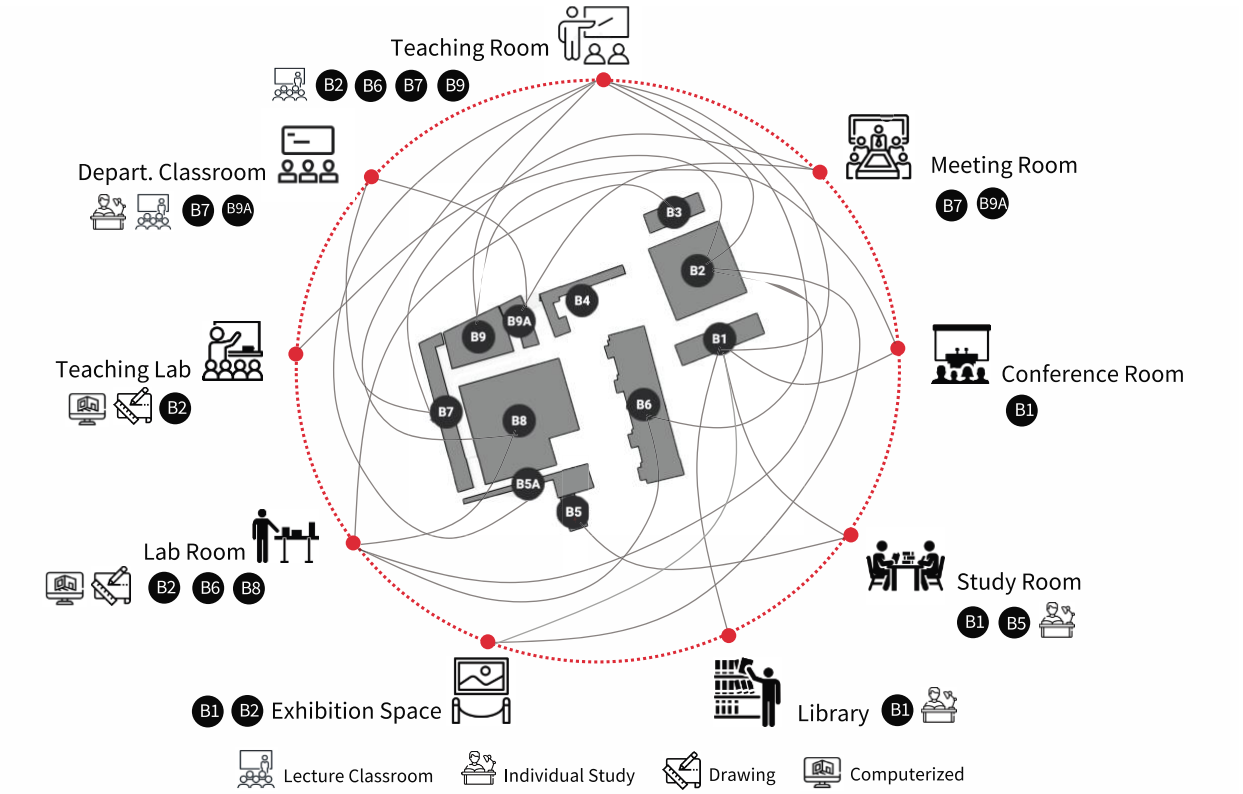

Figure 1: Learning space typologies and activities of Politecnico di Milano, Design campus
Source: figure created by the authors

The Design of The Survey Form

The online survey was developed and analyzed using Microsoft Forms. The online link was published via WeBeep platform, the official communication channel of PoliMi Design community, after taking permission from the class teaching staff. The survey collected 55 responses and feedback from bachelor's and master's students, teaching assistants, Ph.D. candidates, researchers, and professors regarding their sensory experiences in design studio classrooms. In particular, the interior design elements include sound, light, color, smell, texture, and visual stimuli. Appendix A illustrates the structures of the survey questions and the methods of answering available.

Analysis of Survey Responses

The first three questions in the survey were about the respondent's identity, including their profession, gender, and design major of study. There were 55 participants in the survey; the

number of bachelor students was 31, with 56%, followed by master students, at 33%, and Ph. D. candidates and researchers, at 5%, and ended with teaching assistants and professors at 4 and 2%, respectively (see Figure 2). Females were the primary gender of the respondents, with 85% and interior design was the respondents' highest design major compared with the rest of the majors.

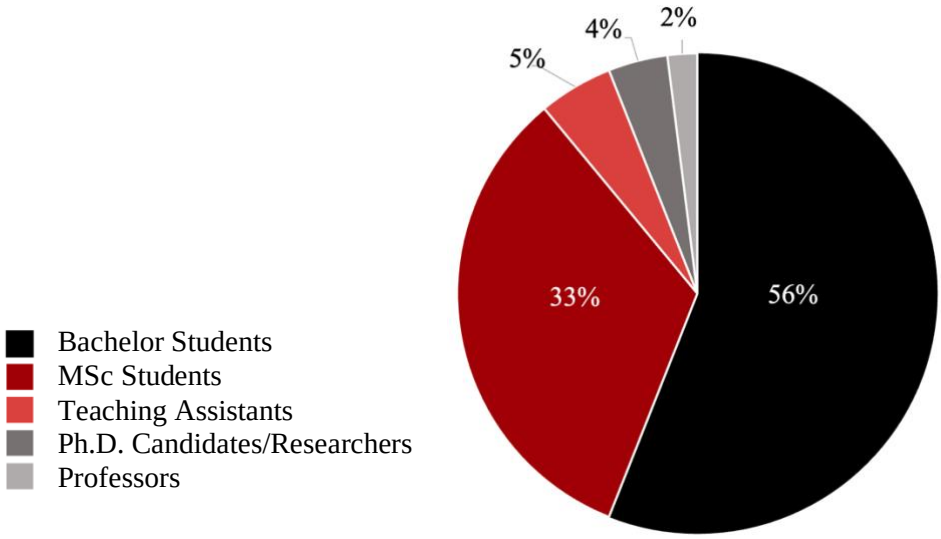

Figure 2: The percentage of survey respondents by profession
Source: figure created by the authors

In order to better understand how feedback might vary depending on the classroom, the fourth question asked about the respondent's design studio classroom. The findings revealed that the respondents had evaluated 12 classrooms, with B1 Aula Fratelli Castiglioni, B2.2.2, B2.1.2, B2.1.3, and B2.1.13 receiving the most ratings. The evaluation of the learning environment began with an awareness of the respondent's feelings while staying in the selected classroom through the fifth question, in which the respondent had the option of selecting more than one response from among eight possible feelings. These included feeling anxious, unfocused, out of the mood, cannot wait to leave, calm, focused, inspired, productive, motivated, and safe. As shown in Figure 3, the feeling of calmness received the most votes (20), followed by productivity and motivation (17). At 11 and 10, respectively, the contradictory feelings of being focused and unfocused were extremely closely rated. Being anxious received nine responses, and being out of the mood and feeling safe received seven responses each. Desire to leave the classroom receives the lowest percentage.

A. Anxious
B. Unfocused
C. Out of mood
D. I cannot wait to leave
E. Calm
F. Focused and inspired
G. Productive and motivated
H. Safe and secure
I. Other

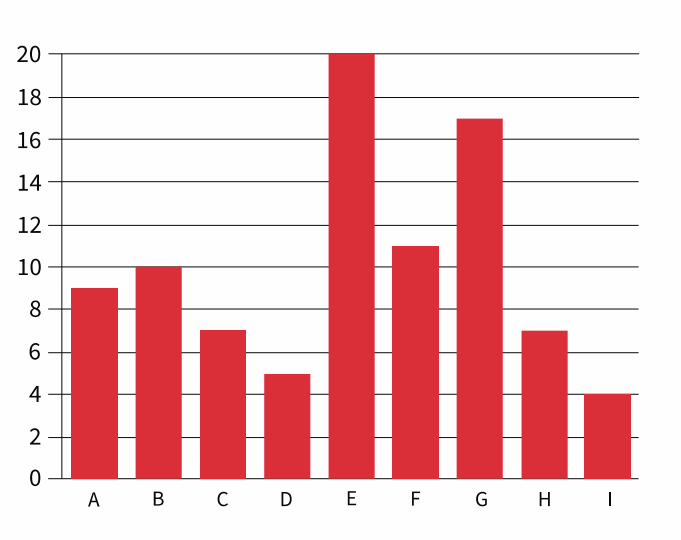

Figure 3: The ratings of respondents' feelings in the learning space
Source: figure created by the authors

The sixth question required the participants to rank their senses regarding how much they impacted their overall performance in the learning environment. The outcome revealed that sight comes first, followed by sound in second, and smell in third. The fourth and fifth positions are given to touch and taste (see Figure 4). 27 respondents provided justifications for ranking and selecting particular senses and feelings towards the learning environment in response to the following question. They relate the value of sight to the impact of colors, lighting, and shapes on productivity and positivity. On the other hand, a noisy learning space reduces focus and raises anxiety. Poor air quality and insufficient temperature might cause headaches, especially when spending too much time in the same classroom. The significance of smells in remembering the space has also been addressed through their ability to trigger vivid memories and emotions, making them a valuable element in our perception and recollection of interior environments.

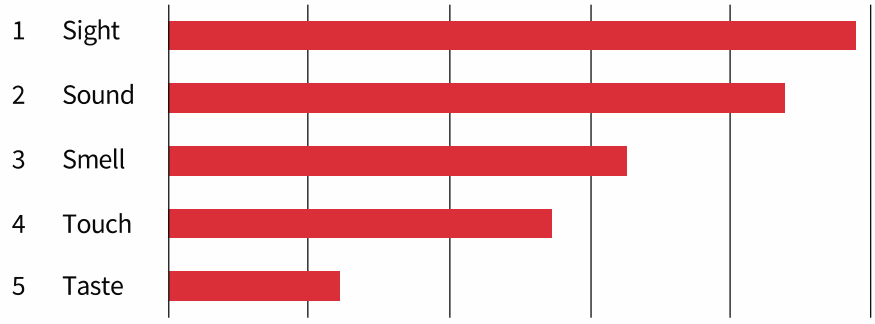

Figure 4: The ranking of senses according to their importance in affecting the overall performance in the learning space. Source: figure created by the authors

Question eight aims to evaluate the interior elements that affect the sensory experience in the learning space based on the literature review. The respondent is therefore given a list of factors, including lighting, colors, interior shapes, acoustics, noise level, textures of walls and

furniture, smells, indoor air quality and ventilation, thermal comfort, and furniture layout, to rate on a scale of extremely ineffective to extremely effective. The percentage of respondents who rated the element as extremely effective is indicated in dark red in Figure 5, in which lighting, indoor air quality and ventilation have the highest equal percentage of 58.2%. Acoustics and noise level are next, with 54.5% and 52.7%, respectively. Thermal comfort got 47.3% of the vote, followed by colors (32.7%), smells (32.6%), shapes (18.2%), and then the textures of the furniture and walls (5.5%).

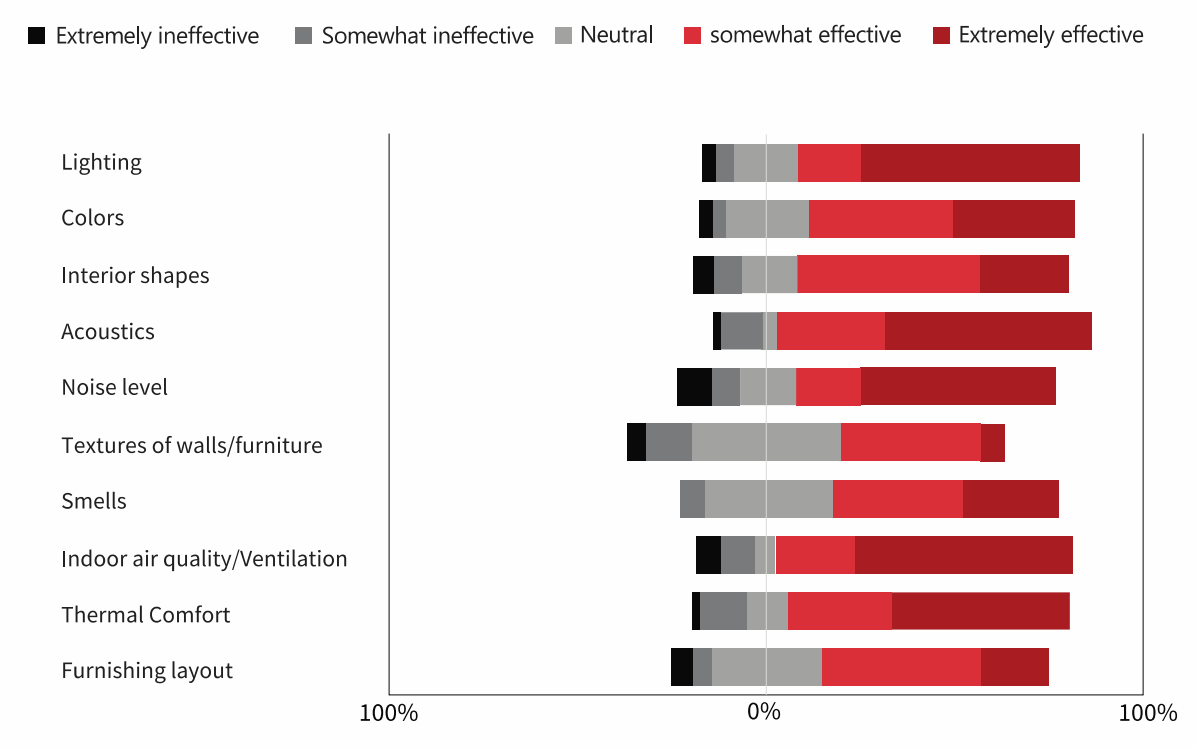

Figure 5: The rating scale results for interior elements that impact the sensory experience in the learning environment. Source: figure created by the authors

The following question asked the participants if other elements should be added to the previous list to enhance the sensory experience. The results showed that 48 out of 55 respondents answered "none". Two respondents noted the technological factor, and two others mentioned the interaction between users of the learning space. The classroom infrastructure, environmental factors, movement, furniture quality, and shape were also mentioned.

The tenth question focused on the sensory assessment of the respondent's chosen classroom. The respondent was asked to rate the space on a scale of extremely poor, poor, fair, average, and good, as shown in Figure 6. The results revealed that "fair" is the predominant rating for all categories of evaluation, including visual (38.2%), olfactory (41.4%), tactile (49.1%), auditory (32.7%), and taste (56.4%).

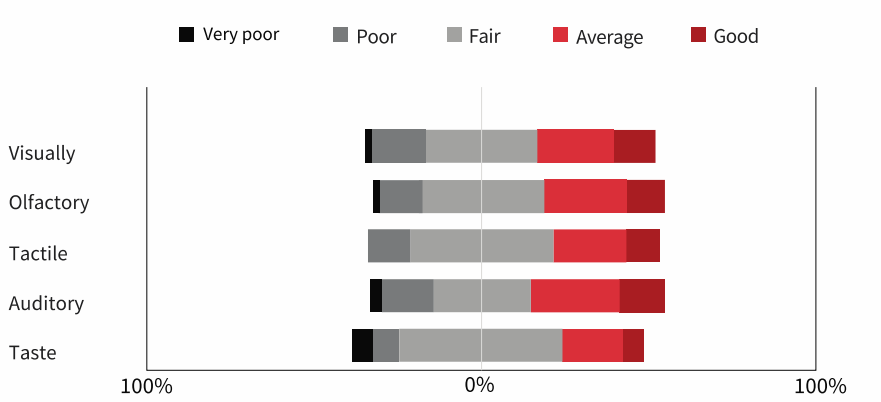

Figure 6: The results of the respondent's selected classroom's sensory evaluation
Source: figure created by the authors

In the last question, the 55 participants were given a chance to mention the sensory elements they believed could be improved. Sixteen respondents highlighted how noisy classrooms are, commenting, "When we work in groups during studio time, the noise inside the class is annoying if we have to stay for many hours." A different respondent continued that it is important not to hear sounds from outside or from other classes. Nine out of the fourteen comments submitted for improving the visual aspect dealt with lighting-related problems, such as lighting tone, glare, and the need for more natural light. A respondent explained: "After a long time watching the board screen, my eyes start to get tired from that light and to get annoyed by the other lights." "I hate when we have to close the curtains because, without natural light, we lose space-time perception," another respondent noted.

In addition, nine respondents brought up the issue of poor indoor air quality, particularly during the winter, which one of them described as having a "stuffy air" feeling accompanied by unpleasant smells. Also, the temperature in the classroom is too warm, which promotes sleepiness and lack of concentration, as seven participants commented. Another respondent suggested that the classroom interior design reflects a design studio by using stimulating colors, a furniture layout that encourages both individual and collaborative work, and more comfortable seating.

Observation Method and Analysis

A prepared form (see Appendix B) was used for the observation and filled out with the data collected. It is divided into two sections: the first covers the key information of the observed space, including the observed classroom number, degree program, user number, and a drawing of the design of the learning space. The second part of the essay includes the observational aspects of the space's features, educational activities, and sensory qualities. The observed classrooms are the same ones evaluated by the survey to reinforce the research data. Four classrooms—B2.0.1, B2.1.2, B2.1.3, and B2.2.4—have been observed during a design studio lesson.

The observation findings matched the survey outcomes regarding auditory and olfactory issues in particular. Figure 7 illustrates the sound circulation in two different classrooms with the same linear interior layout; the classroom on the left (B2.1.3) featured a frontal lecture in which the sound source was only focused on the class users. In contrast, there were group tutorials in the classroom to the right (B2.2.4), where the noise level was extremely

distracting due to the abundance of sources for the chattering sounds across the room. On the other hand, the lack of fresh air entering the classroom made it obvious that the air quality was poor, accompanied by the space's uncomfortable temperature.

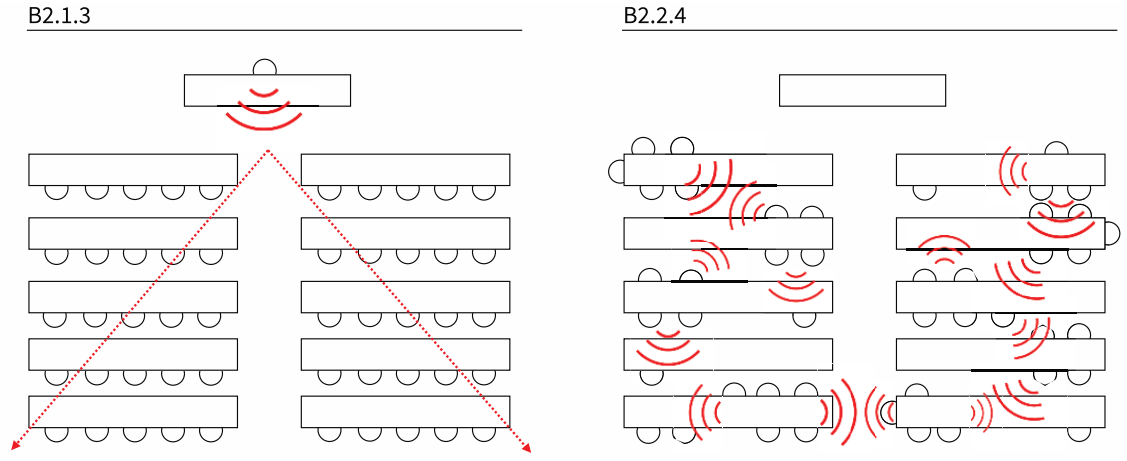

Figure 7: The sound diffusion in two selected classrooms
Source: figure created by the authors

Conclusion

This paper conducted a two-phase mixed-methods research to investigate the sensory needs and preferences of users in learning spaces, particularly in higher education institutions. The study explored the impact of interior design elements on behavior, learning outcomes, and well-being. The initial phase involved a literature review to establish sensory characteristics and assessment criteria. The subsequent field research collected data from 55 participants at Politecnico di Milano School of Design, including surveys and direct observations.

The findings highlighted that sight was the most crucial sensory factor, followed by sound, smell, touch, and taste. Interior design elements like lighting, indoor air quality, and ventilation were identified as the most important, with acoustics and noise levels close behind. The study revealed that noisy environments hinder focus and raise anxiety, while poor air quality and temperature can lead to headaches. Consequently, the research emphasized the necessity of incorporating sensory preferences into the design process to enhance the quality of learning spaces and promote better educational performance and well-being.

Appendices

Appendix A
Survey form

1. Profession *

- ◯ Bachelor Student
- ◯ MSc Student
- ◯ Teaching Assistant
- ◯ PhD Cadidate/Researcher
- ◯ Professor

2. Gender *

- ◯ Female
- ◯ Male
- ◯ Non-binary
- ◯ Prefer not to say

3. Field of study *

- ◯ Interior Design
- ◯ Product Design
- ◯ Service Design
- ◯ Fashion Design
- ◯ Communication Design
- ◯ Digital and Interaction Design
- ◯ Design and Engineering

4. Could you please indicate the classroom number where y ou had/have your design studio? *

- ◯ B1 Aula F.LLI CASTIGLIONI
- ◯ B2.1.2
- ◯ B2.1.3
- ◯ B2.1.5
- ◯ B2.1.6
- ◯ B2.1.8
- ◯ B2.1.10
- ◯ B2.1.13
- ◯ B2.1.15
- ◯ B2.2.2
- ◯ B2.2.4
- ◯ B2.2.6
- ◯ B2.2.7
- ◯ B2.2.10
- ◯ B2.3.1
- ◯ B8 2.3

5. How do you feel while staying in this classroom? *

Feel free to choose more than one answer!

- ☐ Focused and inspired
- ☐ Unfocused
- ☐ Anxious
- ☐ Out of mood
- ☐ Safe and secure
- ☐ Productive and motivated
- ☐ Calm
- ☐ Cannot wait to leave
- ☐ Other

6. Which senses affect your overall mood/performance in the learning space? Please order y our responses from most important to least important. *

- Sight
- Sound
- Smell
- Touch
- Taste

7. Could you please explain the connection between the interior space elements and the feeling/s you choose in the previous question?

8. From your opinion, how does each of the f ollowing elements affect your sensorial experience in the learning space? *

	Extremely ineffective	Somewhat ineffective	Neutral	somewhat effective	Extremely effective
Lighting	◯	◯	◯	◯	◯
Colors	◯	◯	◯	◯	◯
Interior shapes	◯	◯	◯	◯	◯
Acoustics	◯	◯	◯	◯	◯
Noise level	◯	◯	◯	◯	◯
Textures of walls/furnitur es	◯	◯	◯	◯	◯
Smells	◯	◯	◯	◯	◯
Indoor air quality/Ventil ation	◯	◯	◯	◯	◯
Thermal Comfort	◯	◯	◯	◯	◯
Furnishing layout	◯	◯	◯	◯	◯

9. Do you think other elements should be added to the previous list f or enhancing the sensory experience? *

10. How can you evaluate the classroom from a sensorial perspectiv e? *

	Very poor	Poor	Fair	Average	Good
Visually	◯	◯	◯	◯	◯
Olfactory	◯	◯	◯	◯	◯
Tactile	◯	◯	◯	◯	◯
Auditory	◯	◯	◯	◯	◯
Taste	◯	◯	◯	◯	◯

11. What are one or more sensory elements that y ou believe should be improved? And how? *

Appendix B
Field observation sheet

Observation form – Politecnico di Milano	
Date of observation:	Classroom number:
Degree level:	Design program:
Number of students and staff:	Lesson type/topic:
Start time:	Finish time:
Drawing of learning space	
Observation	Reflections
Space Atmosphere (Formal – informal – Flexible) Layout type:	
Activities Class task: Used tools: (manual/digital)	
Sensorial Qualities Lighting (natural & artificial) Colors: Interior shapes: Acoustics: Noise level: Textures of walls/furnitures Smells: Indoor air quality/Ventilation: Thermal Comfort: Furnishing layout:	
Pictures: (yes – no) Notes:	

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Contact emails: reejyatef.mikhail@polimi.it
anna.barbara@polimi.it