DESIGN OF LEARNING ENVIRONMENTS: A ROOM AFFECTING WHAT WE DO AND HOW WE FEEL

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Abstract

The conversion of traditional classrooms into new innovative learning environments (ILE) has been increasingly investigated and implemented in many schools, mainly due to societal and technological developments [1]. Higher Education Institutions are no exception, and the design of learning environments to support the development of technology-enhanced learning, centred on students and pedagogic theory, have also been studied [2], [3]. These learning spaces are generally technologically rich spaces, with different screens for visualisation and a spatial configuration aiming to promote collaboration [4]. Nevertheless, attempts to incorporate active learning pedagogies in spaces that are not tuned in to the needs of active learning have yielded suboptimal outcomes and much dissatisfaction for both teachers and students [5].
In this paper, we study the relation between built environments with wellbeing in mind and their use in an innovative learning space. Following [6] we implement the SALIENT checklist in a prototype classroom at NOVA University. The SALIENT checklist recognises that behaviour is context-dependent and consists of seven dimensions to be considered in the design of environments with wellbeing in mind: 1) Sound, 2) Air, 3) Light, 4) Image, 5) Ergonomics, 6) Nature and 7) Tint.
These seven dimensions can impact the learning process, and we hypothesise that a space considering the SALIENT checklist will allow for better students' performances and satisfaction.
We conducted qualitative research using a design thinking approach [7] to understand better how to implement the SALIENT checklist in the context of education and what alternatives were more adapted to active learning.
We promoted two design-thinking workshops involving students and professors to propose design ideas for the learning environment. Through these design-thinking workshops, students and teachers reflected on the implementation of each SALIENT dimension and discussed its role and possible impact on integrating new pedagogical strategies.

Keywords: Innovative Learning Environments, Higher Education, Built environments, Design Thinking.

1 INTRODUCTION

The conversion of traditional classrooms into new innovative learning environments (ILEs) has been increasingly investigated and implemented in many schools, mainly due to societal and technological developments [1]. These ILEs support a variety of teaching and learning opportunities. However, they can present relevant pedagogic challenges for teachers who must balance the space designed to enhance student learning while simultaneously managing the complexities of innovative open spaces [8]. In [9], the authors examined teachers adaptations to new buildings designed and built on the concept of openness, concluding that the nature of classrooms might result in some friction between routine and new teaching practices.
ILEs are proposed by [10] to respond to the digital transformation in the classroom and has presented a rich collection of new visions for education. Technology is at the core of the possible transformations to redesign teaching and learning, and its integration has been a critical area of research in education [11]. These enhanced learning environments usually facilitate active learning through evidence-based argumentation [12]. However, this type of environments is more than just technology and combine flexible use of spaces, furniture and technology with greater collaboration and flexibility concerning teaching and the curriculum [1]. In [13], the author analysed the consequences of poor environments in learning and the benefits of improving inadequate environments. From the literature, poor environments main factors include noise [14], air quality [15], space available [13], temperature [16], lighting [17] and maintenance and renovation of spaces.
Noise is associated with distracting behaviour that impacts some parts of language processing. Especially in the case of young children, noise is also associated with deficits in reading. Thus, a better acoustic in classrooms, not allowing noise from other rooms or external environment, is associated with

better academic performance [13]. Regarding air quality, research seems to show it might affect students' attention and concentration, suggesting that improving air quality can decrease child absence and have implications for learning and academic achievement [18]. Space available in the classroom impacts the students' mobility, and some associations can be made with the student's attitude and social relationships. The lack of space in a classroom is also likely to be noisier and more difficult to ventilate, impacting learning. The temperature in the classroom is also usually associated with complaints in schools being thermal comfort one diver for attention and concentration in the class. Good lighting conditions and the use as possible of natural light seems to have some effect on mood and attitude which can influence students' performance which can be more easily associeted with some health issues such as headaches, eyestrain and fatigue [13]. Finnaly, the lack of maintenance and renovation of spaces can lead to a school building degradation which seems to be associated with a negative perception among staff and students promoting problematic behaviours and worse academic achievements.

Behavioural science can help us explore the impact of built environments on behaviour and wellbeing, and following the work of [6] a checklist for design with wellbeing in mind was proposed (SALIENT). The SALIENT checklist recognises seven dimensions to be considered in the design of environments with wellbeing in mind: 1) Sound, 2) Air, 3) Light, 4) Image, 5) Ergonomics, 6) Nature and 7) Tint.

Sound and noise reduction promote concentration and calmness. Using specific sounds associated with nature can be linked to higher levels of concentration [19] in line with the research in academic context [13]. Also, the *air* item from the checklist, which includes airflow, air quality and temperature, is in line with previous research [13], showing that airflow is associated with work absence, and different fragrances, such as citrus, can affect the unconscious behaviour [20].

The *light* affects our behaviour, being natural light preferable to artificial. Research also shows that dim environments seem to promote creativity and reduce calorie intake, while brighter environments improve alertness, perceived happiness and promote concentration [6].

Image is related to the use of visual art to promote health and wellbeing. Research shows that the use of too many images may result in levels of distraction and the use of classrooms without decorations seems to present learning gains compared with those with decorations [21].

Ergonomics is related to furniture and how the comfort, functionality and adaptability of well-designed furniture and equipment impacts productivity, concentration and wellbeing.

Nature is known to impact wellbeing, and the use of nature indoors is considered beneficial. They are usually associated with other Salient dimensions since they promote better air quality by absorbing carbon dioxide and toxins, better visual since nature is often used to promote the image.

Finally, *Tint* is associated with the use of colour to impact our behaviour and how the type of task to be developed (more detail-oriented or more creative) can be impacted by the use of a different dominant colour [22].

In this paper, we implemented the SALIENT checklist in a prototype classroom at NOVA University by conducting two workshops with professors and students. In the first workshop, the SALIENT checklist was presented, and a nominal group technique was implemented to brainstorm on possible ideas to implement in the room. The ideas were then categorised according to feasibility and impact and voted by the group. We then prototyped thirteen ideas and conducted a second workshop where feedback and assessment were collected.

The remainder of this paper is structured as follows: the following section presents the methodology used; namely, we used design thinking to conduct the whole experiment. Section 3 then presents the results for each step of the methodology, including discussing some evidence achieved. Finally, section 4 closes with a conclusion and future work.

2 METHODOLOGY

The development of innovative learning spaces that promote wellbeing involves complex constructs. The issue is broad and will need to meet the interests of various stakeholders (e.g., students, faculty members, and staff members), and it will almost certainly require considerable resources to set up. Design Thinking is a creative and problem-solving methodology [23] that implies different cognitive stages that could enhance innovation by focusing on the user’s needs and stakeholder’s collaboration. We believe that design thinking will provide a new lens to the topic, given relevant results in addressing complex situations in a variety of fields, including in the design of pedagogical interventions [24]. In this paper, we used a design thinking three-stage approach [25]: inspiration to create empathy with the topic; ideation in a formal co-creative process; and implementation, with iterative testing and refinement of outputs. Table 1 presents the goals and research methods used at each Design Thinking stage.

Table 1. Design Thinking Research Methods.

Stage	INSPIRE	IDEATE	IMPLEMENT
Goals	To capture different stakeholder's perceptions of innovative learning environments and diverge into different opportunity spaces.	Brainstorm specific interventions regarding each dimension of the SALIENT checklist and the opportunity spaces identified in the previous stage.	Evaluate the potential of the ideas and refine the final design of the room.
Methods	Inspiration mood board (open call to the community with 50 contributions) and synthesis of Design Principles	Ideation Workshop (Nominal Group Technique) with four master students and four professors	Pilot Room Workshop (Feedback Grid)

2.1 Inspire

The Inspiration Stage aims to promote a divergent and explorative mindset widening the problem space. The goal is to define and explain the problem that needs to be solved and engage stakeholders to learn about their perspective. We used different techniques (Table 2) from IDEO's Design Kit [26] to develop a comprehensive understanding of the challenge [27]. We have sent an open call to our academic community (professors, students, alumni, staff, partner institutions) to share the following topics:

Table 2. Techniques used in the inspire stage.

Techniques	Task
Trend analysis	Find a news piece or article about a relevant and disruptive recent innovation in higher education at the national or international level.
Empathy	Share a comment from a professor, student or staff member about a limitation resulting from space constraints or facilities that negatively affect the pedagogical process**.**
Benchmark	Share photos of a particular space that represents an ideal or perfect learning space.
Parallel worlds	Identify a brand or company that could, in a hypothetical situation, manage the university building and explain why

2.2 Ideate

The second step of the design thinking process is ideation. Divergent thinking processes are applied to maximise the capacity for producing as many alternative learning spaces interventions as possible during the ideation period. We have invited a group of four students and five professors to an online ideation workshop (Figure 1) using the Zoom platform and Mural Software for idea capture. It was a two-hour workshop, with the first part being the presentation of the main insights and opportunity spaces from the Inspire Stage, followed by a brainstorm using the nominal group technique (NGT) [28] to get group consensus amongst possible interventions in the different SALIENT checklist dimensions.

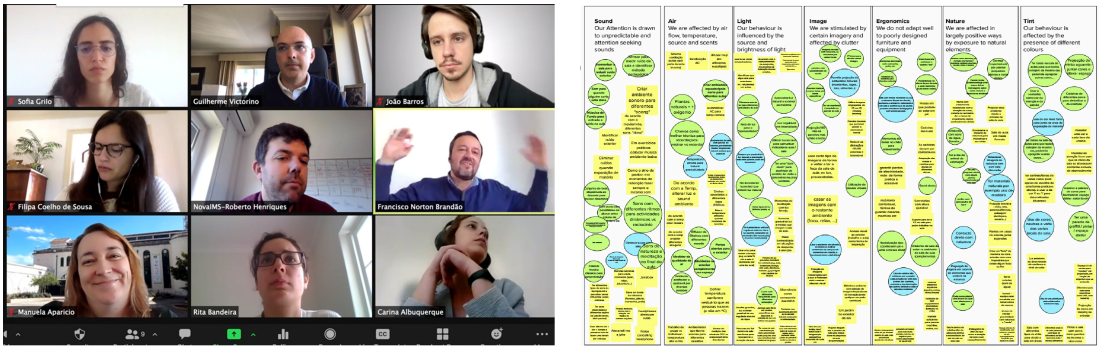

Figure 1. Ideation Workshop using Zoom and Mural software.

We conducted the NGT in a four-step process [29]:
(1) Generating Ideas: The moderator presented each SALIENT dimension to the group and asked everyone to work silently and independently and to write ideas in brief phrases or statements using the MURAL software.
(2) Recording Ideas: without debate at this point, a round-robin sharing process began to share each suggestion succinctly until all of the participants' proposals have been shared;
(3) Discussing Ideas: Each proposal was debated to assess its clarity and significance.
(4) Voting on Ideas: each individual voted privately to prioritise the ideas (three votes for the best idea, two votes for the second best and one vote for the last). In the end, we had a prioritised list of interventions that were democratically elected, and that allowed us to decide which one should be prioritised in the implementation stage.

2.3 Implement

At this last stage, we have concentrated on convergent thinking seeking to evaluate the proposals' potential and check whether they can adequately solve the problem at the end of the project.
First, we have plotted the ideas generated in the ideation workshop in the how-now-wow matrix [30], a two-by-two matrix based on originality and desirability of the idea versus the feasibility and complexity of implementation. The ideas were then categorised in NOW (normal ideas and easily feasible), WOW (highly desirable ideas and easily feasible), HOW (highly desirable and very complex to implement).
For the NOW and HOW ideas, we have developed a full-scale learning space prototype trying to validate the assumptions behind the ideas proposed, and we have encouraged participant feedback through a structured feedback grid [31] on an on-site feedback workshop.

The participants in the ideation workshop visited and interacted with the prototyped room and gave feedback regarding the overall perception of the room (feedback grid) and the different dimensions of the SALIENT checklist by answering two questions:

- How close is the prototype to the ideas presented in the brainstorming session?
- How close is this dimension to the full potential of a perfect learning space?

3 RESULTS

In this section, we will present the main results for the three stages of the design thinking process: inspire, ideate and prototype.

3.1 Inspire

The higher-education community (students, professors, staff and industry partners) contributed by answering our email with relevant insights. We have compiled all the educational trends mentioned; we synthesised all the relevant comments about space constraints; we have built a mood board [32] with a visual representation of all the photos submitted (**Error! Reference source not found.**) with learning spaces best practices.

The community's interest and participation in contributing to the design of a future "learning space" counted with more than 50 contributions.

- ***Trend analysis*****:** the main trends identified were related to artificial intelligence applications and learning analytics, green and social spaces as classrooms, multi-purpose peer learning areas, predictive analytics to target learner interventions and the use of virtual reality in education.

- ***Empathy*****:** the main topics presented about a limitation resulting from space constraints that negatively impact pedagogical process were related with the impact of group workspaces on class identity and cohesion; the impact of technology and the professor proficiency in its use on the class flow; class temperature affecting concentration; ergonomics and inclusive in class equipment; the impact of light (natural and artificial on class mood); class layout and versatility and its impact on students motivation and new teaching/learning opportunities.

- ***Benchmark*****:** in terms of references of ideal learning space, the contributions were related to the integration of natural elements, colourful and diverse set of equipment for learning spaces (more choices and more flexible layouts); smooth integration of in-class technology; importance of the

visualisation of data (NASA control room type); moveable furniture and dynamic/changeable class layout.

- ***Parallel worlds*:** finally, the reference institutions presented in this projection exercise were mainly related to the digital technologies and e-commerce companies like Microsoft, Amazon, or Open AI, and on a second layer, Team Building and Wellness Companies like Holmes Place. The reasons presented were mainly related to the need for education to integrate innovative business models, technology, fun and exciting work environments that promote mental and physical wellbeing.

With all the contributions above, we have developed a mood board (Figure 2) and synthesised a set of design principles (innovative, technological and inspiring learning spaces). This mood board was used as an inspiration boost in our first workshop.

Figure 2. Mood board created from the community contributions.

3.2 Ideate (nominal group technique)

The SALIENT checklist was perceived as highly innovative by students and professors and an ideation boost for the space design. The final ideas selected offer a high alignment with the wellbeing dimensions considered and active learning activities. By encouraging participants to perform a constructive problem-solving technique and allowing the group to prioritise ideas democratically, we observed a high sense of belonging to the final ideas. The group came up with one hundred and seventy-eight ideas, then merged and clustered in one hundred and two original ideas that were voted and prioritised by the workshop participants (Table 3).

Table 3. Ideation outcomes using NGT applied to the salient checklist.

Dimension	# ideas	Top 3 ideas	# votes
SOUND	31	• Soundproofing the room to reduce outside noise	10
		• Measure room noise and automatically identify the pedagogical method	8
		• Background music according to context (e.g. beginning and end of class, rhythms to mark dynamics, nature and relaxation, soundtracks)	6
AIR	29	• Smell diffusor and Specific scents to record pedagogical memories	10
		• Air quality and CO2 level monitor - correlate with student status	10
		• The temperature automatically aligned with productivity, pedagogical activity and season	8
LIGHT	29	• Adjustable lights, including signalling class moments or room indicators	13
		• Light pre-sets (e.g., lecture, brainstorm, lounge, Star Wars, disco, forest) and link with music playlists	10
		• Natural lighting and shutters that automatically raise/lower depending on the brightness of the room	7
IMAGE	22	• Writable Walls	17
		• White walls and intense colours in specific areas (learning/innovation manifest) (11 votes)	11
		• Automatic Projection of images related to lecture discourse	6
ERGONOMICS	23	• Informal furniture: cafe style with sofas, puffs, high table and "bar" chair for the teacher	17
		• Possibility to change the layout of the room at any time (all on wheels)	9
		• Kitchen-type socialisation (standing and with high tables)	3
NATURE	25	• Green (brainstorming) Wall where I can leave messages on	11
		• Classroom in immersive nature mode (forest, savanna, countryside): e.g. projection + breeze + smell + sound	10
		• Outdoor social space, with both shade and sun with relaxation stone loungers that absorb heat	10
TINT	19	• Diversity Corner: Chairs of different colours to symbolise diversity	13
		• Use red as a colour of energy and passion	7
		• Having a graffiti wall/painting/atelier space	5

The Now, How and Wow Matrix allowed us to filter and rank the ideas. Thirteen possible immediate interventions were selected to the prototype stage (Table 4) from the “Now” and “How” Quadrants, and three further interventions (How Quadrant) for a more complex pilot project to implement in a subsequent phase (360º projection, professor cockpit and fragrance diffusion).

The central interventions were selected based on the priorities defined in the workshop and with the feasibility and viability filters regarding the set-up time (3 months), available partners and suppliers and budget (5000 euros) defined for the intervention.

Table 4. Prototyped Interventions.

SOUND	(1) Installation of a new soundproof roof + (2) Alexa Speakers
AIR	(3) Room Sensors and (4) Air Conditioning Installation
LIGHT	(5) Installation of new adjustable lights and sensor-activated smart lightening
IMAGE	(6) Smart Board + (7) Writable Surfaces + (8) Projection Wall
ERGONOMICS	(9) Partnership with Steelcase for the classroom chairs and tables + (10) Kitchen Style Furniture for individual and small group work
NATURE	(11) Green Wall and natural plants
TINT	(12) Room Manifest Wall and (13) diversity corner (multicolour chairs)

3.3 Implement

3.3.1 Set-up of the Prototype

The prototype was implemented in an empty warehouse in the NOVA University Campus in Lisbon. The interventions for the prototype were sequenced for three months and involved (1) furniture selection for the different areas of the room (peer learning, group and individual work); (2) installation of a new soundproof roof; (3) set-up of the smart lightning sensors and equipment; (4) installation of the multimedia equipment (screens, projections, sound); (5) writable walls and whiteboards (Figure 3).

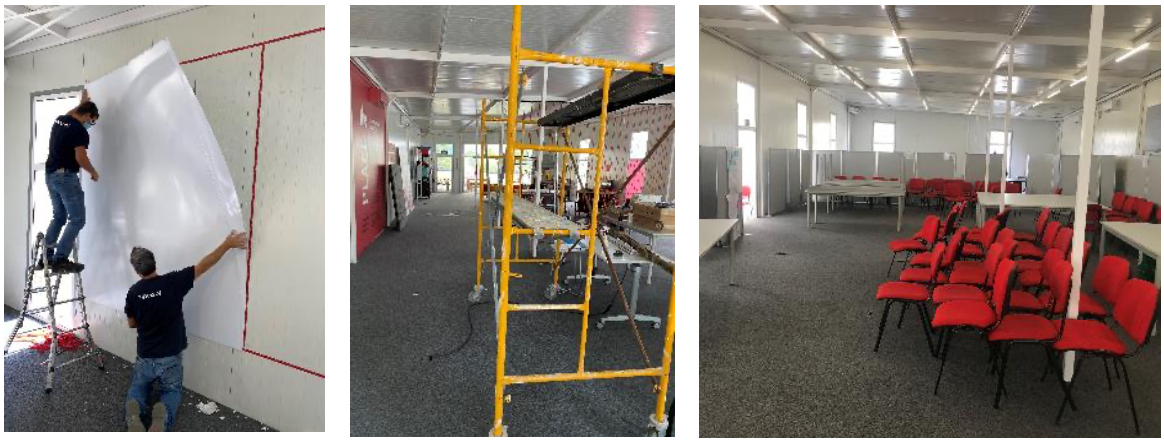

Figure 3. Empty warehouse transformed in Pilot Innovative Learning Space.

3.3.2 Results of the Feedback Grid (Workshop 2)

The participants from the ideation stage were invited to an on-site workshop where they had the chance to interact with the thirteen interventions prototyped. Each participant had to fill out the feedback grid (

Table 5) individually.

Table 5. Feedback Grid.

Based on the ideation session and the prototyped interventions, what things do you consider that have worked well	**In your opinion, what needs to be changed or could be improved in the room?**
• *The new (movable) chairs* • *The ability to create multiple workspaces* • *Light in the room* • *The best intervention was the Installation of a new soundproof roof* • *The TV/Board is amazing* • *Several dedicated and diverse spaces* • *Moveable classroom furniture: versatile and quick to move around for different class activities* • *Also, the Alexa Speakers are great to promote a calm atmosphere* • *The green (plant) wall,* • *Write on the walls: super important for letting ideas flow* • *The Projection Wall is also improving the interaction with students.* • *The lights with sensors* • *Manifesto wall and red/blue pillow doors create the mood for the room* • *The natural plants will also be my favourite since they provide the sensation of being grounded*	• *Better sound isolation* • *I think the natural light conditions can be improved Open spaces are agreeable, and however, when different activities are taking place at the same time, people might be distracted by the other groups' activities* • *The Installation of new adjustable lights need some improvements (Light switch closer to the door; adjust by section, by colour)* • *A way to control the light or visibility from the windows (if needed, be able to cut the outside/natural light)* • *I think more color can be added to the room* • *More sitting space outside* • *Bringing to the room more plants, I think it would make it even a great place to work (feel surrounded by nature)* • *a flexible/modular way to create "private" separate areas (in the classroom area), so multiple groups can work with some privacy and get the open space again.* • *Be in an open space and very quickly be able to create a couple of divisions so small groups could debate and afterwards get back to open space* • *Clearly see where to change air conditioning intensity and temperature*
Looking at all the interventions, what questions come to your mind that you might still have or that were raised by interacting with the room?	**Finally, what new ideas came to your mind that could benefit the space?**
• How would be the temperature on hot days, and if the AC will take long or not • Some spots are different looking, but the tasks being done on them are the same. I think making a better distinction between spaces or tasks to be performed at a specific space would help • Is there a place to include wood materials? • How can I interact with Alexa? • How much can the students move with the chairs? • How to maintain the ideal temperature, the room is big (was good when was there) • How do I change the air conditioning temperature? • Could the lights provide a calming sensation? • Could the sounds stimulate the learning?	• Controlling the lighting scenes according to the moods, or other triggers • Having a charging hub at the entrance of the room so that students would stay far from their phones • More open windows for the air to flow • A designated place (shelves/cabinets) for students to leave their physical project materials (e.g. project boards) alternation between learning a new subject or memorising an old one, by changing the room lights and sounds. • Create multiple scenes (light, sound, temp, ...) in a dynamic and automatic way • Presence of water • Multiple screens/computers interaction on the new digital board

3.3.3 Participants Perceptions on the Pilot Implementation

We wanted to see if the participants identify themselves with the interventions that were prototyped and how they perceived the impact of the pilot. We asked them for each dimension of the SALIENT checklist, on a scale from 0 to 10 where 0 is (very different) and 10 is (very close), how close the prototype is to the ideas that came out of the brainstorming session. The results from the survey are presented in Figure 4. The “Ergonomics” and “Light” interventions are the ones closer to the ideas generated in the brainstorm, whereas “Nature” and “Air” are the dimensions that are considered a little different from the ideation session. Furthermore, we asked participants how close we were, on a scale from 0 to 10 where 0 is (very far away), and 10 is (very close) to the full impact potential of this SALIENT dimension on a perfect learning space? The dimensions were ranked from “Ergonomics”, “Image” and “Light” being very close (above 8); and “Sound”, “Tint”, “Air” and “Nature” between 6 and 8.

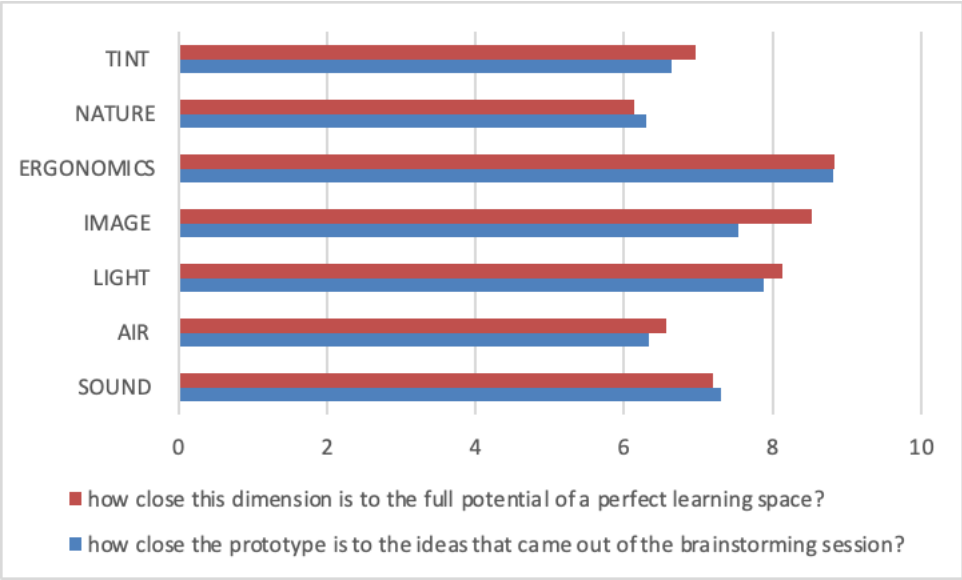

Figure 4. Workshop 2 Participants Feedback on the SALIENT Checklist Interventions.

4 CONCLUSIONS

In this paper, we implemented the SALIENT checklist to prototype a classroom at NOVA University. The seven dimensions considered (Sound, Air, Light, Image, Ergonomics, Nature and Tint) helped ideation, guiding the participants to include behavioural and wellbeing aspects in the learning environment.

The Design Thinking methodology was selected to help develop a new learning space that should consider the interests and needs of various stakeholders such as students and faculty. This approach involved the classroom users early on in the development process, and the techniques revealed excellent engagement in reflecting the complexity, flexibility, and social nature of each intervention. The tacit experiences provided by the prototype allowed us to identify surprising solutions and reveal productive failures that need to be refined. Figure 5 presents the final prototype for the new learning space.

As future work, we plan to implement some of the “HOW” ideas, namely, the professor cockpit to control the classroom environment, the 360º data arena projection and the diffusion of different fragrances. We will also consider the integration of the feedback from the second workshop to improve the current prototype. Finally, we should develop experiments to measure the impact of space on different pedagogical approaches and academic achievements.

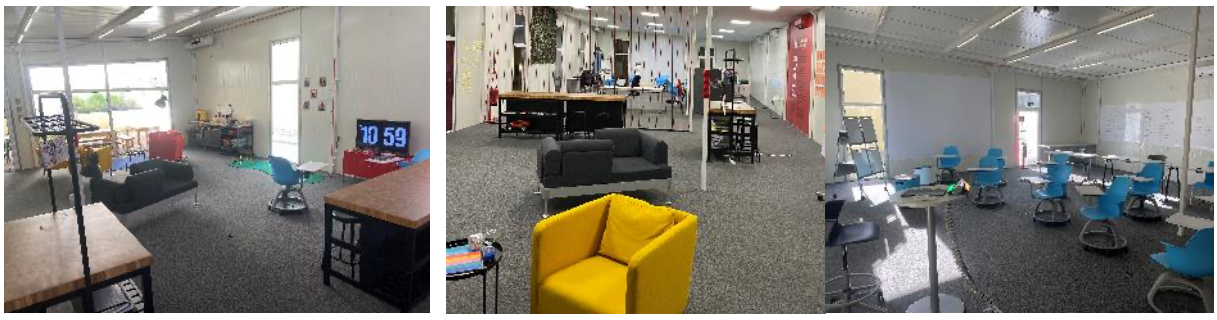

Figure 5. Final prototype of the innovative learning environment.

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