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Bridging approaches: Classroom Physical Space as a learning ecosystem

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Abstract. The classroom physical space enfolds several dimensions, beyond the learning one, as the social, cultural, architectural and technological. The current digitally classrooms scenario, calls for the need to rethink these spaces. Despite the already existence of some new classroom spaces, we argue that there might be lacking an innovative interior design strategy encompassing and fulfilling the classroom physical space dimensions. This paper aims to: 1) discuss the classroom physical space as a learning ecosystem and to argue the emergency of building the bridges between different approaches on this topic; 2) to understand how the Future Classroom Learning Labs (FCLL) were created and how they are currently being used by different actors, based on some results of an European web survey which was applied. The survey results show that the physical space of the FCLL is perceived as positive, although its potential could be better exploited, namely using an innovative interior design strategy.

Keywords: classroom physical space, smart learning ecosystems, classroom orchestration, enabling spaces, human-building interaction, smart classroom, spatial semiotics, spatial pedagogy.

1 Introduction

During the last years, there has been a boost of educational models based on the Technology Enhanced Learning approaches. Alongside, learning spaces have been under discussion in order to follow these educational models. Learning spaces - like the Future Classroom Lab [1], the SCALE UP [2, 3] or the TEAL [4] - were created.

By November 2016, there was a total of 26 Future Classroom Learning Labs (FCLL) registered as members on the European Schoolnet website. This paper aims to: 1) discuss the classroom physical space as a learning ecosystem and to argue the emergency of building the bridges between different approaches on this topic and 2) understand how the FCLL were created and how they are currently being used. This is an initial phase of an ongoing research that intends to define and investigate the role of innovative interior design strategies to create inclusive classroom spaces.

Acknowledging that the Classroom Physical Space interacts and depends directly on several different dimensions among which the social, cultural and digital, a new space [5] is going to be designed on a later phase aiming to promote the inclusion of specific populations, namely the youngsters that are Not in Education, Employment or Training (NEET) and Refugees. The research is mainly exploratory, and based on grounded theory [6–8] using mixed methods [9, 10].

Several approaches to the space are introduced: spatial semiotics and spatial pedagogy, enabling spaces, Dillenbourg's classroom orchestration, Human-Building Interaction (HBI), the smart learning ecosystem and smart classrooms, in order to start creating bridges among them. These different but bridging approaches are in the basis of the conceptual and theoretical framework of this research and is indented to support the analysis perspectives to be held along the further stages of this study.

Some of the data already collected through an European web survey regarding the use of the FCLL is also presented. This web survey aims to understand how the FCLL were created and how they are currently being used; a descriptive study based on quantitative methods of data collection is thereby presented.

2 The classroom physical space

The recent creation of spaces like the Future Classroom Lab [1], the SCALE UP [2] [3] or the TEAL [4] is grounded on the pedagogy-technology-space concept [11, 12] valuing its ecosystemic dimension. Nevertheless, the space itself - the Euclidean space [13] or the built space [14], its characteristics, its layout, its statics or dynamics resources [14] – have not always been in the centre of the discussion.

To develop research on the Classroom Physical Space involves a multidisciplinary approach, considering different dimensions and contributions from several domains as the classroom orchestration [15, 16], the enabling spaces approach [13], the HBI [17, 18] and the spatial semiotics and spatial pedagogy [19]. In our perspective, all these have in common the valuing of the social dimension of the Classroom Physical Space that, together with the technological one, alongside with the spatial semiotics and the spatial pedagogy, play a relevant role in the creation of a smart learning ecosystem.

When considering the social dimension, it seems relevant to better understand how can these dimensions shape a new context and help to create smart spaces that might potentially enhance a more inclusive and better Classroom Physical Space, i. e, "*a context where the human capital(and more in general each individual) owns not only a high level of skills, but is also strongly motivated by continuous and adequate challenges, while its primary needs are reasonably satisfied*" [20, 21].

2.1 A brief history of the classroom physical space layout

According to Park and Choi [22] the classroom physical space has been connected to the educational approaches through time. In ancient Greece there was a rhetorical/dialogical system and there were neither a specific space for the classes to happen, nor a rigid setting for the teacher and the students to be. These latter would place themselves around the teacher in no particular order.

When a more formal education appeared with the medieval Universities, often located in Cathedrals, a more rigid layout set place. This evolved to a very strict layout with the spreading of Universities and their detachment from the religious institutions. During this time, the educational system was teacher-centred, and the classroom layout reflected this centrism, occupying the teacher a featured place in the classroom. With the expansion of Universities and schools, the medieval layout remained, however adapted to a bigger space [22].

In the last century the pedagogical approaches started to change, although the classroom space and layout, in general, did not reflect these changes. Towards the end of the 20th century and, in particular, in the beginning of the present one, the classroom physical space started to be reconfigured. Not only is this change of paradigm due to the technological penetration in the classrooms, but also to new pedagogical approaches that came with it. The SCALE-UP [2, 3] space, the Future classroom Lab (FCL) [23] as others are good examples which translate this educational shift (figure 1).

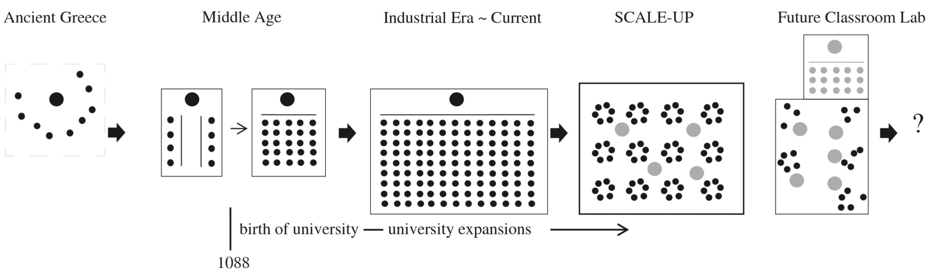

Fig. 1. Adaptation of the figure "Historical changes in classroom design" by Park and Choi [22].

2.2 The space approaches to create bridges

In our perspective, and alongside with some other investigators [24, 25], the classroom is a complex system that combines different dimensions as the social, cultural, architectural and digital, among others. Even if there is a mental image of "four delimiting walls" connected to the classroom space, we approach this latter as going further and outside the walls. Thus, the way the inside walls is thought and designed should broaden it across its physical boundaries. In order to comply this, digital technologies can play a very important role in creating new scenarios that can better enable the learning processes, through a technological enhanced environment [20].

It is, therefore, necessary to create bridges between different approaches considering the cumulative importance of: 1) the Spatial Semiotics and Spatial Pedagogy, through the interaction students and teachers have between themselves and space, and their positioning and movement meanings athwart space; 2) the Enabling

Spaces approach, for its multidimensional space approach; 3) the Dillenbourgs' Classroom Orchestration perspective as apart from the instructional design relevance, as it brings forward its relation with Computer Supported Collaborative Learning (CSCL) and for scaffolding teachers' importance in a technological enhanced environment; 4) the Human-Building Interaction approach, for enhancing the relation and interaction between digital and physical through a social-cultural perspective; 5) and of the smart learning ecosystem and smart classrooms approaches, due to its' aggregating perspective nature.

Spatial Semiotics and Spatial Pedagogy

Space is a way of communication and in order to understand the way it flows through space distance [26] and its dynamics [14], it is important to master its language. Different approaches to the built edification are stood for different authors. Some define it through an Euclidean perspective as the architectural space [27] or the built space [14] relying, in part, in static and dynamic resources [14]. Others argue that the "constructed" space between walls cannot be detached from a social dimension brought up by the interaction and interpersonal relations between its users [19, 14, 27, 28]. This social dimension together with a cultural one reflects on how space is organized [26] as each culture has its own way of experiencing space [29].

In what concerns to Classroom Physical Space, and more specifically to the classroom spaces conceived meanings, one can argue that the way of experiencing space is oftentimes present in the interactions between teachers and students and space itself, or spatial semiotics [19]. This latter is perceived through the way they move athwart space and its signification and their paths [19]. The different paths and their quality constructed through movement across the space may measure its fluidity.

From the study of the movements and of both teacher and students' different positions and directions, patterns emerge allowing the analysis of the dynamic of the physical space. However, the positioning and directionality of movement in a classroom usually are not random, having a meaning even as face expressions, gestures and the different voice intensities. These encompass semiotic means which, alongside with language and pedagogical materials, among others, define spatial pedagogy [19].

The Enabling Spaces approach

Peschl and Fundneider (2012) define Enabling Spaces as multidimensional spaces (architectural, social, emotional and technological dimension spaces, among others), which enable, facilitate and support the knowledge creation and innovation processes. For the authors, the optimization of new knowledge creation is empowered by the multidimensional spaces, each one corresponding to a different dimension, which must be "orchestrated in an integrated manner" [13], as well as in an interdisciplinary way overcoming the possible constraints and conditions [13].

Specific environments, like the social, cultural and physical ones, are the setting for innovation and knowledge creation and are inextricable from a particular context and space which springs from cognitive processes [13].

When applied to the educational context, the Enabling Spaces approach also encompasses the pedagogical choices and the didactical environment, as well as the teachers' personality (beliefs and thoughts) alongside with the different spaces/dimensions mentioned above [25].

Therefore, in the Enabling Spaces approach "the integration and orchestration of different spaces/ dimensions (…) is one of the most challenging problems, yet powerful features" [13][1]. In order to overcome this challenges, Peschl and Fundneider stress the importance of supporting and leading the Enabling Space interdisciplinary through a well-founded design process [13].

Dillenbourg's classroom orchestration

In 2006, Fischer and Dillenbourg use the term orchestration in the context of collaborative learning [15]. These authors stress the importance of the teacher's role in education, especially in CSCL context through integrated learning approaches bringing him back "*to the foreground*" as they face a complex environment, full of "*multi-layered activities and practical dimensions in real time*" (p.122) [15]. Hence "*orchestration refers to cognitive, pedagogical and practical dimensions of a distributed CSCL environment*" (p.122) [15] where teachers have to adjust different types of students' knowledge acquisition (individual, small groups and class). Moreover, the unforeseeable dynamics during the classroom activities that might ask for real time adaptation as well as the management of the interactions with the technology in use in the classroom [15].

Dillenbourg's classroom orchestration, ensue from the ability of managing a technological enhanced environment (like the CSCL environment), not only through the core of instructional design (kernel) but also through observing learners during their activities ("student modelling") and making the necessary adjustments to learners instructions whenever needed (personalization) [24]. To Dillenbourg, the "rings around the kernel" cannot be neglected, even those that might look out of place as the rings which address logistics. Nevertheless, he considers that constraints exist to both kernel and rings, being the kernel constraints related to: what (the curriculum), what is inside (the contents), and who (how people learn as well as the learners themselves). To what regards the rings constraints, or the "designing for orchestration", Dillenbourg considers these to be constraints related to the assessment, time, discipline, energy and space [24]. All these constraints (both kernels' and rings') have a deep influence on the teacher's work. So, he contemplates the teacher's role as one of his main focuses in classroom orchestration. Dillenbourg states that, in order to increase student's achievements via problem solving situations and group discussions, there is the need to empower the teacher. This empowerment does not aim to place the teacher as the commanding agent, but as the one that, through the design factors (leadership, flexibility, control, awareness, etc.), scaffolds and enhances students' motivation towards successful achievements.

Dillenbourg's classroom orchestration aims to provide a better environment (physical, technological, social, personal and emotional) to students in order to scaffold and enhance their knowledge acquisition.

[1] "Orchestration" here is used in a different meaning than the one related to classroom orchestration even though a similar one.

Human-Building Interaction

HBI brings forward the relation between Human-Computer Interaction and buildings. As these latter are becoming more and more technological based, like in the Smart Homes, Alavi et al. [17] argue that buildings ought to be developed and designed with a dialogical relation between its users (either in the social and individual levels) and their “digital and physical interactive daily experiences” [17].

HBI approaches buildings through Hillier’s perspective [17, 18] in which besides the physical and spatial form these also have a social-cultural function [30].

According to the HBI authors, “Designing HBI (…) consists of providing interactive opportunities for the occupants to shape the physical, spatial, and social impacts of their built environment” [17].

Smart Learning ecosystems and the Smart Classroom

Smart learning ecosystems encompasses not only the students, teachers and school staff as “individual actors of the learning process” [31] but also the stakeholders, surrounding community (with a *glocal* perspective), family, “services, social life, challenges, skills” [31] inherent to the learning environment. Smart learning ecosystems, apart from the smart technology, devices, applications and its infrastructures, relies also in “help[ing] towards achieving a people centred smartness, through streamlining mundane organisational tasks, and enhancing the skills of all actors involved in learning processes” [32].

Bautista and Borges state that the concept of smart classroom arises from the intersection between “classroom’s architectural design and its ergonomy”, smart technology and pedagogical approaches “as collaborative learning, project-based learning, (…) students’ autonomy, educational co-responsibility, etc.” [33] relying also on the actors’ learning processes.

Bridging the space approaches

In our perspective, physical spaces when detached from their social and cultural dimensions might be at risk of losing their meaning.

Therefore, when approaching the Classroom Physical Space, we intend to create bridges between the space dimensions presented above and to investigate an innovative interior design strategy to the Classroom Physical Space. These space dimensions (the social, cultural, technological and architectural ones) are those that we face as the bed stones of bridging creation, being the pedagogical dimension the unifying one between them, considering that it is inherent to a learning space (a Classroom Physical Space). In this process, we intend not only to give relevance to the social and cultural meanings of the physical space, but also to enhance the interaction opportunities and the state of flow of all the agents involved with the Classroom Physical Space. To study these interaction opportunities is of most importance and we must consider three main dynamics: between users and technology, between users and space and between users themselves.

For this reason, we have chosen to study the FCLL as a starting point, as these have in their genesis pedagogical approaches like collaborative learning or project-based learning [34] in a technological enhanced environment, and also considering that these spaces (figure 2) are distinct from traditional classroom and still quite recent (the first FCL created in Brussels, opened its doors in 2012).

Fig. 2. FCL layout and learning zones [23]

3. The web survey

In order to better understand the current scenario, a web survey was created and applied aiming to understand how the Future Classroom Learning Labs (FCLL) from the European Schoolnet FCL network members [35] were thought and conceived and how they are being used. It targeted different groups of respondents: the Decision Makers (DM), the Decision Makers that are also Teachers (DMT), Teachers (T) and Students (S). Each of these four groups answered different sections of the questionnaire as table 1 shows.

The 37 questions of section 3 to 5 have a 5-point Likert scale (from ‘strongly disagree - 1point to ‘strongly agree’ – 5 points). The questions were categorized in six dimensions: physical space, space communication, emotional space, teaching/learning space, social space and technological space.

A reliability test was conducted and an excellent alpha was found (Cronbach’s α= .954).

Table 1. Questionnaire sections, participants, objectives and type of questions

<table>
<tr><th rowspan="2">sections</th><th colspan="4">participants</th><th rowspan="2">objective</th><th rowspan="2">type of questions
example</th></tr>
<tr><th>DM</th><th>DMT</th><th>T</th><th>S</th></tr>
<tr><td>section 1</td><td>x</td><td>x</td><td>x</td><td>x</td><td>characterization of the participants</td><td>semi-closed
SCHOOL | My school is a
(please choose only one of the following
_ Early Childhood School
_ Elementary School
_ Middle School
_ High School
_ University
_ Other: ______________________________</td></tr>
<tr><td>section 2</td><td></td><td></td><td></td><td></td><td>Understand which factors lead to a decision of implementing a FCLL</td><td>semi-closed
Which factors led you to the decision of implementing a Future Classroom in your School?
(please choose only one of the following:)
_ Students with learning difficulties
_ School philosophy
_ Future Classroom pedagogical approaches
_ Other: ________________________</td></tr>
<tr><td>section 3</td><td></td><td>x</td><td></td><td></td><td rowspan="3">understand how the FCLL are being used by teachers and students and their perception of it</td><td>closed / 5 points Lickert Scale
Please select the best answer that fits your opinion.
(please choose the appropriate response for each item)
Strongly disagree
Disagree
Neither agree nor disagree
Agree
Strongly agree</td></tr>
<tr><td>section 4</td><td></td><td></td><td>x</td><td></td><td rowspan="2">It was easy to adapt to the Future Classroom space.</td></tr>
<tr><td>section 5</td><td></td><td></td><td></td><td>x</td></tr>
<tr><td>section 6</td><td>x</td><td>x</td><td>x</td><td>x</td><td>gather a list of the technological solutions in use in the FCLL, as well as to understand how the FCLL layout is being displaced</td><td>semi-closed
Which equipment exists in your School Future Classroom?
(please choose all that apply:)
_ Interactive whiteboard
_ Tablets
_ PDAs
_ Smartphones / iPhones
(...)
_ Animation software
_ Streaming software
_ Other: ______________________________</td></tr>
</table>

3.1. The participants

The web survey dissemination was made on-line, by email and through Facebook. An email was sent to all the contacts available on the FCL website in November 2016 and to the European Schoolnet organization. There were 26 FCLL from 12 countries of which: 9 FCLL's from Portugal; 4 from Belgium; 2 from Germany, Israel and Norway; and 1 from Croatia, Cyprus, Czech Republic, France, Italy, Slovakia and United Kingdom. No sample procedures were taken, as it was not possible to know how many people we would be targeting with the web survey. All the 26 FCLL were considered and contacted. They were asked to spread the web survey to all the decision makers, DMT, teachers and students using the FCLL's. The European Schoolnet posted the link to the web survey on their Facebook page.

107 complete questionnaires were collected, from which: 3 decision makers (3%), 10 DMT (9%), 11 teachers (10%) and 83 students (78%). To what concerns the gender, despite 82% being male, if we consider the decision makers, DMT and teachers alone, then we have 67% being female. The age mean is 23 years old with a standard deviation (SD) of 12; however, the age mean concerning the decision makers, DMT and teachers is 44 years old (SD= 9,16), being the oldest 66 years old and the youngest 32 years old. The students' age mean is 17 years old (SD= 1,59), being the oldest 25 years old and the youngest 15 years old.

Most of the participants, 94%, are from Portugal (101) including all the students, being the other 6 participants from Belgium (1), France (1), Israel (1), Italy (2) and Norway (1). In what concerns the type of school where the FCLL are located is worth to mention that 82% (89/107) of the respondents, of which 82 students, are from the same school – a Portuguese VET School[2]. The others are: Elementary School (1), Middle School (4), High School (4), University (4), Norwegian Education Government (1), Showcase (1), ICT Centre (1), Teacher Training Centre (1) and a Schools cluster (1).

3.2. Results and discussion

In this section we present some results, based on descriptive statistics, which concern to the relative frequency of the quantitative data collected which are organized according to two main items: factors leading to a decision of implementing a FCLL and the use of the FCLL (section 2), and users' perception of it (section 3, 4,5).

In order to complement these first results, we also present the analysis of differences between the groups in order to identify different perceptions among different actors (decision makers, teachers and students) so we may understand how the FCLL were created and how they are currently being used, through analysis of variances procedures(ANOVA). Other obtained results are not detailed in this paper.

Factors leading to a decision of implementing a FCLL

The analysis of the factors that led to the decision-making concerning the FCLL implementation was made considering the answers given by the decision makers and the DMT (13/107) from 12 different FCLL.

According to our data, the principal factor that led the decision makers to implement the FCLL in their school was the *Future Classroom pedagogical approaches* (6) followed by the reason of the schools' *Students with learning*

[2] The FCLL from this school opened in September 2016 and the person responsible has shown quite some enthusiasm for participating in this study.

difficulties (3) and the *School philosophy* (2). Two other factors have been pointed out: the *Pedagogical needs* (1) and the fact of *Taken part of ITEC Project* (1).

Regardless of what 11 decision makers have said that the FCLL of their school is inspired by the Brussels FCL layout[3], only 9 of these are based on the Brussels FCL layout despite having quite some differences. 6 of the 13 decision makers also stated that their FCLL has an area that differs from the Brussels FCL like a playing/gaming area. Nevertheless, the identified main reasons for their FCLL being different from the one in Brussels were: the budget (7), the chosen physical space not being the most suitable (6), the school culture (5) and the specificity of the school's students (5).

The use of the FCLL and users' perception of it

Some questions of the web survey regard the physical and communicative space. The participants (104/107)[4] have an overall positive perception of the initial use of the FCLL: 83% of the participants considered being easy to adapt to the FCLL space (table 2), 77% consider the FCLL space to be intuitive (table 3), and 81% think that was easy to identify its different areas (table 4).

Table 2. Perceptions towards the easiness in adapting to use the FCLL space (Q001)

	count	negative perception (1and 2 points)	neutral perception (3 points)	positive perception (4 and 5 points)
DMT	10	40.0%	20.0%	40.0%
T	11	0.0%	18.2%	81.8%
S	83	4.8%	7.2%	88.0%
DMT&T&S	104	7.7%	9.6%	82.7%

Table 3. Perceptions towards the FCLL space being intuitive (Q002)

	count	negative perception (1and 2 points)	neutral perception (3 points)	positive perception (4 and 5 points)
DMT	10	20.0%	30.0%	50.0%
T	11	9.1%	18.2%	72.7%
S	83	4.8%	14.5%	80.7%
DMT&T&S	104	6.7%	16.3%	76.9%

[3]The Brussels FCL layout comprises six learning zones in two different spaces: 1) one space based on the traditional classroom furniture setting, the interact learning zone, and 2) the remaining five learning zones (create, present, investigate, exchange and develop) are organized through an open space equipped with different type of technology.

[4] The decision makers have not answered these questions as they do not give classes in the FCLLs.

Table 4. Perceptions towards the easiness in identifying the different areas in the FCLL (Q004)

	count	negative perception (1and 2 points)	neutral perception (3 points)	positive perception (4 and 5 points)
DMT	10	20.0%	10.0%	70.0%
T	11	0.0%	18.2%	81.8%
S	83	4.8%	13.3%	81.9%
DMT&T&S	104	5.8%	13.5%	80.8%

However, even though 83% of the participants think that it was easy to adapt to the use the space (table 1) is interesting to notice that 40% of the DMT had a negative perception of it, the exactly same amount for the positive perception stated by them.

Nevertheless, only 56% say that there was no need to have an explanation on how to use the FCLL space against 21% of a negative perception (table 5). It is also interesting to notice that students (83/104) was the group with the fewer need of an explanation on how to use the FCLL space against 40% of the DMT (10/104) and 37% of the teachers (11/104).

Table 5. Perceptions towards the absence of need to have an explanation on how to use the FCLL space (Q003)

	count	negative perception (1and 2 points)	neutral perception (3 points)	positive perception (4 and 5 points)
DMT	10	40.0%	30.0%	30.0%
T	11	36.4%	9.1%	54.5%
S	83	16.9%	24.1%	59.0%
DMT&T&S	104	21.2%	23.1%	55.8%

When focusing questions on the FCLL layout organization, the results are, in general, also positive: when asked about if *it is easy to pass from an activity area to another without disturbing the students/classmates* (Q010), 90% of the DMT have a positive perception, in comparison with a lower, yet still positive perception, of the teachers and students' groups with 64% and 67% namely. Concerning the perceptions that the students group has towards the *spatial FCLL organization allowing them to understand which kind of activity they are about to start* (Q012) they present a 73% of positive perception, and the teachers and DMT groups when asked if *the spatial FCLL organization allows them to explain which kind of activity they are about to start* (Q012) present 73% and 80%, respectively. Yet, when questioned if *the spatial FCLL organization is suitable for different kind of activities* (Q011), the opinions between the students and the other two groups show a bigger difference – 75% of the students had a positive perception of this statement against 100% of the DMT and 91% of the teachers.

Regarding the existing furniture in the FCLL, when the question refers to the *facility of moving the FCLL furniture according to the different activities* (Q017), the students and teachers' positive perception presents a decrease to 66% and 64%, namely, and the DMT present the same 100%. In which regards the *ease to transform* *the FCLL layout (furniture displacement)* (Q016), the students and teachers' positive perceptions are very alike: 68% (S), 64% (T) having the DMT presented a positive perception of 90%. A slight increase of the positive perception from two of the three groups was observed to 74% (S) and 90% (DMT) and 82% (T), when asked about *the activities being enabled by the existing furniture in the FCLL* (Q026). In what concerns *the furniture used in the FCLL enabling the teaching improvement* (Q020) *and learning improvement* (Q021), the perceptions differ between the questions, especially for the teachers' group as in the first they have presented a more neutral perception (54,4%) than a positive one (45,5%) against the 73% of positive perception related to the learning improvement. The DMT presented 90% of positive perception regarding the teacher improvement against 70% presented in the learning improvement; the students' group, 72% against 66% respectively to the same questions. In what regards *the FCLL existing furniture being the most suitable for teaching* (Q032), the DMT positive perception drops to 50%, the teachers to 64% and the students' to 58%. When questioned about *the FCLL furniture being the most suitable for learning* (Q033), the positive perceptions are alike and set in 50% (DMT), 64% (T) and 66% (S). Still, when enquired if *the activities were enabled by the FCLL existing layout* (Q027) the positive perceptions increase to 90% (DMT), 82% (T) and 70% (S).

Some results differ to what concerns *the FCLL layout enabling* 1a) *the teaching improvement* (Q022) (table 6) and 1b) the *student improvement* (table 7) and to what regards *the FCLL layout being the most suitable* 2a) *for teaching* (table 8) and 2b) *for learning* (Q029) (table 9). It is worth to notice the difference of positive perceptions not only between the three groups but also between 1ab) and 2ab).

Table 6. Perceptions on how the FCLL layout enables the teaching improvement (Q022)

	count	negative perception (1and 2 points)	neutral perception (3 points)	positive perception (4 and 5 points)
DMT	10	0.0%	20.0%	80.0%
T	11	0.0%	9.1%	90.9%
S	83	2.4%	37.3%	60.2%
DMT&T&S	104	1.9%	32.7%	65.4%

Table 7. Perceptions on how the FCLL layout enables the learning improvement (Q023)

	count	negative perception (1and 2 points)	neutral perception (3 points)	positive perception (4 and 5 points)
DMT	10	0.0%	20.0%	80.0%
T	11	9.1%	18.2%	72.7%
S	83	6.0%	27.7%	66.3%
DMT&T&S	104	5.8%	26.0%	68.3%

Table 8. Perceptions on how the FCLL layout is the most suitable for teaching (Q028)

	count	negative perception (1and 2 points)	neutral perception (3 points)	positive perception (4 and 5 points)
DMT	10	0.0%	40.0%	60.0%
T	11	0.0%	27.3%	72.7%
S	83	2.4%	37.3%	60.2%
DMT&T&S	104	1.9%	36.5%	61.5%

Table 9. Perceptions on the FCLL layout is the most suitable for learning (Q029)

	count	negative perception (1and 2 points)	neutral perception (3 points)	positive perception (4 and 5 points)
DMT	10	0.0%	30.0%	70.0%
T	11	9.1%	45.5%	45.5%
S	83	2.4%	30.1%	67.5%
DMT&T&S	104	2.9%	31.7%	65.4%

A better positive perception is shown by the participants regarding the same range of questions but instead of the layout or the furniture, they are questioned about the existing technology in the FCLL, still being noticed some differences between the three groups: *enabling the teaching improvement* (Q018) the positive perceptions are of 77% (S), 82% (T) and 90% (DMT); *enabling the learning improvement* (Q019), 65% (S), 64% (T) and 90% (DMT); t*he activities being enabled by the existing technology in the FCLL* (Q025) present a positive perception from the students of 70%, from the teachers of 82% and from the DMT of 90% and it what regards *the FCLL existing technology being the most suitable for teaching* (Q030) and *for learning* (Q031) we have positive perceptions of 70% (S), 82% (T) and 80% (DMT) for the teaching. For the learning the students' positive perception is the same however the DMT and teachers groups' positive perception decreases for 70% and 73%, respectively.

Despite the FCLL being designed to allow different spatial configurations in a regular basis, only 42% of the participants (45/107) of the web survey say that *in their FCLL the layout changes*, and from these, 49% is occasionally and 26% once a week to daily; being usually either the teachers (40%) or the students together with the teachers (40%) changing the layout.

As mentioned above, we have also analysed the existence of differences between the groups, through a comparative analysis of means (ANOVA) in which: i) the calculation of the mean values to the presented items (negative perception: [1-2,5]; neutral perception: [2,6- 3,5]; positive perception: [3,6- 5]; ii) three groups were taken in consideration for this comparison: DMT, teachers and students; iii) the assumptions of normality of distribution and homogeneity of variances for the application of the ANOVA test were guaranteed; nevertheless, even though same problems with groups homogeneity were detected in same items, parametric test were still used as they are more robust to apply than nonparametric ones [36, 37] (table 10).

Table 10. Means, standard deviation and ANOVA test for the DMT, T and S groups

		N	M	SD	F	*p*
Q001_It was easy to adapt to the Future Classroom Learning Lab space.	DMT	10	3.00	1.247		
	T	11	4.00	0.632	7.918	**0.001**
	S	83	4.07	0.762		
	Total	104	3.96	0.858		
Q002_The Future Classroom Learning Lab space is intuitive.	DMT	10	3.40	0.966		
	T	11	3.73	0.786	2.845	0.063
	S	83	3.99	0.757		
	Total	104	3.90	0.795		
Q003_There was no need to have an explanation on how to use the Future Classroom Learning Lab space.	DMT	10	2.80	1.033		
	T	11	4.09	0.701	4.900	**0.009**
	S	83	3.55	0.966		
	Total	104	3.54	0.985		
Q004_It was easy to identify the different areas in the Future Classroom Learning Lab.	DMT	10	3.50	0.850		
	T	11	4.09	0.701	2.506	0.087
	S	83	4.10	0.806		
	Total	104	4.04	0.812		
Q010_ In the Future Classroom Learning Lab it is easy to pass from an activity area to another without disturbing my students/classmates.	DMT	10	4.40	0.966		
	T	11	3.82	0.751	3.297	**0.041**
	S	83	3.70	0.808		
	Total	104	3.78	0.836		
Q011_The spatial Future Classroom Learning Lab organization is suitable for different kind of activities.	DMT	10	4.80	0.422		
	T	11	4.36	0.674	9.299	**0.000**
	S	83	3.92	0.684		
	Total	104	4.05	0.716		
Q012_ The spatial Future Classroom Learning Lab organization allows me to explain/understand which kind of activity we are about to start.	DMT	10	4.30	0.823		
	T	11	3.91	0.701	1.668	0.194
	S	83	3.87	0.694		
	Total	104	3.91	0.712		
Q016_It is easy to transform the Future Classroom Learning Lab layout (furniture displacement).	DMT	10	4.40	0.699		
	T	11	4.00	0.894	3.860	**0.024**
	S	83	3.75	0.713		
	Total	104	3.84	0.752		
Q017_It is easy to move the Future Classroom Learning Lab furniture according to the different activities.	DMT	10	4.60	0.516		
	T	11	4.00	0.894	5.470	**0.006**
	S	83	3.78	0.750		
	Total	104	3.88	0.780		
Q018_The technology used in the Future Classroom Learning Lab enables the teaching improvement.	DMT	10	4.50	0.707		
	T	11	4.00	0.632	2.390	0.097
	S	83	3.94	0.786		
	Total	104	4.00	0.776		
Q019_The technology used in the Future Classroom Learning Lab enables the learning improvement.	DMT	10	4.50	0.707		
	T	11	3.73	0.905	3.134	**0.048**
	S	83	3.82	0.843		
	Total	104	3.88	0.855		
Q020_The furniture used in the Future	DMT	10	4.30	0.675		

Classroom Learning Lab enables the teaching improvement.	T	11	3.55	0.688	2.513	0.086
	S	83	3.78	0.827		
	Total	104	3.81	0.813		
Q021_The furniture used in the Future Classroom Learning Lab enables the learning improvement.	DMT	10	3.90	0.738		
	T	11	3.82	0.874	0.131	0.877
	S	83	3.77	0.770		
	Total	104	3.79	0.772		
Q022_The Future Classroom Learning Lab layout enables the teaching improvement.	DMT	10	4.10	0.738		
	T	11	4.09	0.539	3.571	**0.032**
	S	83	3.66	0.668		
	Total	104	3.75	0.679		
023_The Future Classroom Learning Lab layout enables the learning improvement.	DMT	10	4.10	0.738		
	T	11	3.82	0.874	1.347	0.265
	S	83	3.70	0.728		
	Total	104	3.75	0.747		
Q025_The activities are enabled by the existing technology in the Future Classroom Learning Lab.	DMT	10	4.30	0.675		
	T	11	4.09	0.944	2.430	0.093
	S	83	3.81	0.723		
	Total	104	3.88	0.754		
Q026_The activities are enabled by the existing furniture in the Future Classroom Learning Lab.	DMT	10	4.40	0.699		
	T	11	3.91	0.831	3.222	**0.044**
	S	83	3.76	0.759		
	Total	104	3.84	0.777		
Q027_The activities are enabled by the existing layout of the Future Classroom Learning Lab.	DMT	10	4.30	0.675		
	T	11	3.91	0.831	2.616	0.078
	S	83	3.75	0.730		
	Total	104	3.82	0.747		
Q028_The Future Classroom Learning Lab layout is the most suitable for teaching.	DMT	10	4.00	0.943		
	T	11	3.91	0.701	0.813	0.447
	S	83	3.72	0.738		
	Total	104	3.77	0.753		
Q029_The Future Classroom Learning Lab layout is the most suitable for learning.	DMT	10	4.10	0.876		
	T	11	3.55	0.934	1.522	0.223
	S	83	3.77	0.687		
	Total	104	3.78	0.737		
Q030_The Future Classroom Learning Lab existing technology is the most suitable for teaching.	DMT	10	4.10	0.738		
	T	11	3.91	0.831	0.555	0.576
	S	83	3.84	0.724		
	Total	104	3.88	0.733		
Q031_The Future Classroom Learning Lab existing technology is the most suitable for learning.	DMT	10	3.90	0.738		
	T	11	3.82	0.874	0.054	0.947
	S	83	3.81	0.848		
	Total	104	3.82	0.833		
Q032_The Future Classroom Learning Lab existing furniture is the most suitable for teaching.	DMT	10	3.80	0.632		
	T	11	3.82	0.751	0.233	0.792
	S	83	3.69	0.748		
	Total	104	3.71	0.733		
Q033_The Future Classroom Learning	DMT	10	3.50	0.527		

Lab existing furniture is the most suitable for learning.	T	11	3.82	0.751	0.689	0.504
	S	83	3.76	0.709		
	Total	104	3.74	0.697		

Through the one-way ANOVA we may state that in some questions significant statistical differences were found (specifically 1, 10, 11, 16, 17, 19, 22 and 26). In order to verify between which groups these significant differences exist, we have applied a post-hoc test (Tukey) (table 11). For doing so, and as required in Tukey' test, harmonic means were used.

Table 11. Post-hoc comparison (Tukey HSD)

multiple comparisons

dependent variable		I	J	Mean difference (I-J)	Standard error	*p*
Q001_It was easy to adapt to the Future Classroom Learning Lab space.	Tukey HSD	DMT	T	-1,000*	0.352	**0.015**
			S	-1,072*	0.270	**0.000**
		T	DMT	1,000*	0.352	**0.015**
			S	-0.072	0.259	0.958
Q003_There was no need to have an explanation on how to use the Future Classroom Learning Lab space.	Tukey HSD	DMT	T	-1,291*	0.415	**0.007**
			S	-0.754	0.318	0.051
		T	DMT	1,291*	0.415	**0.007**
			S	0.537	0.305	0.188
Q010_ In the Future Classroom Learning Lab it is easy to pass from an activity area to another without disturbing my students/classmates.	Tukey HSD	DMT	T	0.582	0.357	0.238
			S	,701*	0.274	**0.032**
		T	DMT	-0.582	0.357	0.238
			S	0.119	0.262	0.892
Q011_The spatial Future Classroom Learning Lab organization is suitable for different kind of activities.	Tukey HSD	DMT	T	0.436	0.290	0.294
			S	,884*	0.222	**0.000**
		T	DMT	-0.436	0.290	0.294
			S	0.448	0.213	0.095
Q016_It is easy to transform the Future Classroom Learning Lab layout (furniture displacement).	Tukey HSD	DMT	T	0.400	0.320	0.426
			S	,653*	0.245	**0.024**
		T	DMT	-0.400	0.320	0.426
			S	0.253	0.235	0.530
Q017_It is easy to move the Future Classroom Learning Lab furniture according to the different activities.	Tukey HSD	DMT	T	0.600	0.327	0.163
			S	,817*	0.250	**0.004**
		T	DMT	-0.600	0.327	0.163
			S	0.217	0.240	0.639
Q019_The technology used in the Future Classroom Learning Lab enables the learning improvement.	Tukey HSD	DMT	T	0.773	0.366	0.093
			S	,681*	0.281	**0.045**
		T	DMT	-0.773	0.366	0.093
			S	-0.092	0.269	0.938
Q022_The Future Classroom Learning Lab layout enables the teaching improvement.	Tukey HSD	DMT	T	0.009	0.290	0.999
			S	0.437	0.222	0.125
		T	DMT	-0.009	0.290	0.999

			S	0.428	0.213	0.114
Q026_The activities are enabled by the existing furniture in the Future Classroom Learning Lab.	Tukey HSD	DMT	T	0.491	0.333	0.307
			S	,641*	0.255	**0.036**
		T	DMT	-0.491	0.333	0.307
			S	0.150	0.244	0.813

*. The mean difference is significant at the 0.05 level.

From these tests we may state that the main differences exist most often between the DMT's and the students' perceptions towards the FCLL, specifically in the items Q001, Q010, Q011; Q016 Q17, Q019 and Q026. At item Q001 significant differences were also detected between DMT and teachers.

Discussion

In general, and from this initial web survey, we may say that the current scenario regarding the FCLL physical space is positive as their users have a positive perception of it. However, from the results, we may infer that the potential of the FCLL physical space is not at its best. Results show that the options made by the decision makers took into consideration the pedagogical, the technological and the social dimensions: the CSCL and project-based learning approaches present in the Future Classroom project [34] as well as a social concern regarding the school's population. Nevertheless, and even if the decision makers have taken into account the community, families, stakeholders, as in a smart learning ecosystem, none of the results support this aspect.

Regarding the physical space, its communication and use, results are irregular, particularly if we consider the students and the decision makers who are also teachers and the teachers groups separately. Through a HBI perspective [17, 18], the dialogical relations as well as the users' built environment shaping through interactive opportunities seem not to be completely adjusted as the perceptions users have, despite being positive, present incongruities: 77% of the FCLL users state that the space is intuitive, however 56% said that an explanation how to use the space was required. Considering, as well, that space communication [26] is important in order to understand its use and dynamics [14], we may also infer from these results that the FCLL spaces are not yet designed at its best for its purpose.

The disparities concerning the furniture and the space layout mentioned above lead us also to infer that the constructed paths are probably not yet the most suitable and not enabling at its best the space fluidity and, therefore, interfering with its spatial semiotics [19]. From these results we also might argue that the "balance" between the different space dimensions and, in particular, the architectural and the technological ones, is not the most consistent. It is also important to highlight the differences in the perceptions presented by the three groups in what concerns the teaching improvement and the learning improvement. In our perspective, these objectives should be fulfilled equally in the Classroom Physical Space.

Therefore, we argue that an innovative interior design strategy regarding the Classroom Physical Space and bridging the different presented approaches is in order.

4. Future work

Interviews are being conducted, in order to gather more grounded information and to create the scripts for the workshop/focus group. The semi-structured interviews' scripts were created grounded on the web survey data analysis. The participants of these interviews are key-elements connected to the Portuguese FCLL: apart from decision makers who are also teachers, teachers and students, we will also interview architects/designers involved in the FCLL projects, as its objective is to consolidate some of the data already collected, as well as to gather more data regarding the classroom physical space and how it is being used. The final phase of data collection, is the one in which NEET/Refugee population will participate in the workshop/focus group where they will be asked to design classroom spaces followed by a group discussion.

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