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Phygital learning ecosystems and places beyond 2030

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Abstract. The aim of this article is to provide designers of future smart learning ecosystems with a cultural framework of reference, and a set of inspirational principles consistent with it, that can act as stimulus and guide. The framework is introduced by a critical analysis of the evolution that educational spaces have undergone in recent centuries in function of both pedagogical requirements and process optimisation, up to the most recent experiments. It is then illustrated the meaning, sense and purpose that should be attached to a *smart learning ecosystem (SLE)* identified with: a) the development of the competences needed by the students to find their place in the society and playing a propositive role, and b) the wellbeing of the actors involved in the learning process. Finally the cultural paradigm (*people in place centred design*), the pedagogical framework of reference (*learning by being*) and the didactic approach (*P3BL: problem-project-process based learning*) that should serve as a source of inspiration for the design of future learning places, and/or for the renovation of existing ones, are discussed. Four the guiding principles, discussed in the article, that are expected to be followed: *centrality and openness of the spaces to the territory of reference, functional specificity, flexibility, affordance*. Also discussed are the qualities - *sensitive, enabling, engaging* - that should characterise the integration of new technologies within the spaces of SLEs to make them *phygital*, together with the trends that are expected to characterise the phygital transformation in the future.

Keywords: smart learning ecosystems, future educational place, phygital spaces, people in place centred design, smartness, wellbeing, learning by being. P3BL.

1 Introduction

How many readers of this article remember exactly the shape of the walls of the classrooms they attended or what hung there? How many remember classroom objects besides desks, chairs and blackboards? Probably very few. It is not uncommon, in fact, for people to be unable to describe in detail the school spaces they are occupying, especially if they are sitting in standardised classrooms, whose design and organisation of space derive from the rigidly standardised mass education that started to develop from the XV century [1] in certain European countries. It is much easier to meet people

who remember better how a gymnasium, an open space for play activities, or a laboratory were structured.

In fact, since the beginning of *designing spaces for education*, the focus has not been on the needs of the people involved (hence the little attention paid by students to the classroom spaces they attend, even for a long time) but, rather, on organisational ones and, more generally, on the expectations of society. Classrooms were created to optimise the use of human resources i.e., to increase the learner/teacher ratio and to ensure that knowledge can be transmitted simultaneously to a sufficiently large number of learners with a similar level of education [2]. Individualised education [3, 1] dominated in earlier centuries, a time when dedicated educational spaces did not exist. Instead, learning often took place informally in various settings, including public streets. [4,5]. Furthermore, education focused mainly on what today are called basic skills/competences: reading, writing and counting [6,7]. Instructional processes that did not require any special equipment [8,4]: a comfortable chair for the teacher and a desk where the lectern could be placed to support the texts used (pupils rarely had their own); seats that allowed for writing on wax-covered tablets for the students, seats that over time turned into desks when the students also began to need more space to stand. Since then, and up to the present day, very little has changed in the vast majority of places of education, so that teaching, from primary to university, is still taught *ex-cathedra* in a *transmissive* and *depersonalised* manner. Sole exception is the development of those skills/competences - mostly vertical ones - required by the job market, which need the use of other spaces such as laboratories, workshops, gyms, etc.

The later subdivision of the space into smaller classes (initiated in Paris and the Flanders between the end of the 15th and the 16th century [2]) - caused by a more precise definition of the levels of instruction (progressive pedagogy) and/or of the subject being taught - is also related to organisational aspects, in particular the efficiency of the process [9,2]. Much later, in the 19th century, was realized the association among education levels and age groups, an association that coincided with the acquisition of a greater awareness of the various developmental stages of the individual [9]. Those above are transformations that also generated a tightening of the school organisation that has been handed down to us and that has been accompanied, over the years, by increasingly detailed regulatory prescriptions and led to the so called school factory [10]. A process that was initiated by the "*Compagnia di Gesù*", whose actions were inspired by the application of a rigid discipline that required constant control of the pupils [11,12]. These latter were also subjected to hierarchisation and selection in the perspective to educate the future ruling class. In such hierarchical organization, the best were also used to assist the teachers and support the weakest (peer education *ante litteram*).

Parallel to the reforms operated by the Jesuits, the work carried out at the turn of the 17th and 18th centuries by the *Brothers of the Christian Schools*, a congregation founded by Jean-Baptiste de La Salle, should be noted [13-15]. In support of the education of the poorer classes, the congregation set up what we can consider the first example of vocational schools in which skills/competences - which today we could define as vertical - were no longer acquired by working in a workshop but within specially adapted educational spaces (together with the rudiments of basic competencies and more technical disciplines). In these schools, one can observe an initial shift from

learning by knowing to *learning by doing* with the consequent partial redefinition of the spaces.

Still to be noted in this evolutionary phase, mid 17th century, is an early concern for classroom walls. Such concern, however, was more aesthetic than functional: Comenius stated that they should be adorned with portraits, maps, bas-reliefs, etc. [16]. With the advent of different and more advanced pedagogical approaches and teaching strategies, it was realised that the space in which learning processes were taking place no longer had to be considered neutral, but could/should play an *educating role*, as a third teacher (see, for example, Rousseau's Emile on the role of things that fill space) [17,18]. New approaches and strategies require new tools and a redesigning of space and its occupation.

A critical analysis of the factory school model was already more or less consciously undertaken as early as the 19th century by pedagogists like Pestalozzi and Froebel that focused particularly on the early age of development [19], criticisms reinforced by the Piaget's [20] and Maria Montessori's [21] studies on the cognitive development of children and by Vygotsky's studies [22,23] that contributed, together with those of other colleagues [24,25], to the enunciation of constructivist theories [26,27]. Already in the early years of the 20th century, it was theorised that kindergarten spaces should be designed to foster activities that support the development of all modes of human interaction - physical, intellectual, social and affective - and all potential talents (think of the Steinerian principles and schools [28,29]); this by allowing children to interact with peers of other ages and having the time necessary for their own development (the reference is again to the Steinerian schools), while respecting human rights and the environment. An approach that even then favoured interaction between indoor and outdoor spaces (also understood as occasions for human relations and taking social responsibility, e.g. fostering family participation).

At that time we started to move into a new terrain, that of *active schools* [30-32] and educational processes supported by spaces with specific and integrated functions (see, for example, Godin's design hypotheses) [33]. Moreover it emerged, as in the case of the so called *country schools* [34], the need to reconnect with the territory, to open the spaces also to social activities in order to make them take on the role of cultural centres as well. It was the time during which the reflection on the relationship between indoor and outdoor spaces met the demands of comfort (lighting, ventilation), together with those of hygiene and health, and has led, over the decades, to very daring experiments such as that of the Open air school in Amsterdam, built in 1929-1930 by Duiker and Bijouet [35]. A reflection on active schools and the relationship between indoor and outdoor spaces that has found a privileged ground for discussion and exploration in the spaces designed to accompany the growth of the individual in the transition from family to school: preschools and infant schools. Many scholars have put their design effort in trying to annul the trauma of the transition, such as Montessori ("*casa dei bambini*") [21] who advocated the use of child-sized furniture capable of stimulating meaningful experiences and making children active; or like Dewey who, with the *ideal home* [36], focused more on the functionality of spaces and furniture in order to encourage learning by doing, starting from spaces and activities capable of reproducing familiar environments and situations; or, finally, like the Agazzi sisters who believed that furniture should reflect the family environment to stimulate collaboration between childrens and adults [37]. It is interesting to note that it is in this cultural context that

empty space begins to acquire its own relevance, as it is recognized as necessary for children to move and act autonomously, also with the aim to participate in the organisation of their own activities [38]. And it is also in this cultural milieu that the relationship between space, the objects that fill it and the role that this latter can play in the sensorial development of the individual has been considered. A very fertile ground for experimentation and fruitful confrontations between pedagogues and architects have certainly been schools for infancy and childhood. However, since this topic is too specific for this article's purpose, it will not be explored further in this and the following paragraphs. What is relevant in this context is the recognition of the need to reflect on a *progressive design* of spaces inspired by the various developmental stages of the individual [8,4].

At this point it is certainly worth emphasising how, over the centuries, we have witnessed, in parallel, on the one hand the transmission of a dominant (still today) model of a rigid and passive organisation of the school and, on the other the development of a debate and experimentations - that we could define as niche due to the small number of practical realisations - characterised by a circular path that has taken us back, through various steps, to the origin, i.e., to personalization. After World War II, in fact, despite the focus on standardisation that had characterised the Modern Movement [39], spaces begin to fluidify, to acquire that character of functional flexibility that will be one of the key themes of the most advanced research in the years to come, together with the functional division of spaces (laboratories, ateliers, libraries, etc.). This fluidification of spaces, which finds one of its greatest expressions in the Hellerup school [40,41], is in fact accompanied by a renewed personalisation of teaching in which teachers develop personalised plans and operate as tutors, meeting individually or in small groups with pupils, as was the case originally. It is not clear, however, whether in the case of the Hellerup school, the pedagogical and didactic choices influenced the co-designing (with the community of reference) of the spaces, or whether it was the design of the latter that induced the choice to personalise education, that in turns implied making the children responsible about the way how the spaces have to be used. Another element of circularity can be identified in the attempt to re-propose within schools the structuring of a city, i.e., of its public space in which the development of educational processes originated, albeit with a not insignificant difference: originally the informal spaces were used out of necessity to group together and develop the educational process, whereas now planners attempt to recover the informality of spaces within buildings designed and intended exclusively to deliver educational processes. One of the earliest examples of this trend was a never realised project by Hans Scharoun (1951) [42,43] in which various districts (neighbourhoods corresponding to different age groups) were connected by a street, defined '*meeting path*'. Much more recent and even more explicit are the projects of Herman Hertzberger in which he proposes a school as a city with corridors transformed into learning streets and atriums into squares with the function of learning environments; in other words environments capable of offering multiple stimuli and of hosting more or less informal activities (see as examples the Montessori schools in Delft and Amsterdam) [44,45].

In the debate that developed in the post-war period, and which was very lively, the relationship with the territory was developed not only in terms of imitation of the urban space but also in relational terms. In fact the school, anticipating the idea of learning ecosystems - which is at the root of the ASLERD vision [46] and will be discussed in

the next section - started to be considered as a driving force and an aggregation point for the community's cultural activities and for developing social exchanges. In other words, schools started to be imagined as possible civic centres (community centres) [47-52] capable of replacing and/or flanking, in a secular key, the role played for a long time by parishes and which has recently waned considerably. Civic centres, however, to be integrated in a city that can be considered an 'educating' one [53-55].
As we have seen up to now, many are the stimuli and suggestions coming from a more or less recent past, as well as the directions of possible development and change indicated. The debate that has guided the experiments that have taken place in the last century, and which are still in search of full implementation, have been constantly accompanied by requests for interdisciplinary collaboration, first and foremost between pedagogues and architects, and for the involvement of all stakeholders, as well as by the request for the definition of a reference framework that clearly identifies cultural paradigms, pedagogical references and didactic approaches. These are the needs that have stimulated the realization of this contribution, which aims to offer to the still ongoing debate a possible framework of reference, in the hope that it may guide the development of the learning ecosystems of the future, well beyond 2030, taking also into due consideration the influence of the twin transition on the digitisation and sustainability of spaces.

In the next sections, therefore, a brief description of what is meant by a learning ecosystem will be provided, before moving on to the identification and description of the constituents of the reference framework - cultural paradigm, pedagogical reference and didactic approaches - that will serve as a guideline to update the lessons of the past to account also for last developments, particularly technological ones.

2 Smart Learning Ecosystems

The brief historical introduction contained in the previous section showed us how, already in the past, the school had been imagined as the hub of social and civic activity and had been placed in relation to the territory, identified with its educating function. These are all elements that foreshadow the concepts of *smart learning ecosystems* [56,57] and *smart city learning* [53-55] that have emerged in recent years; elements that are also at the basis of the development of initiatives such as those on the Collective Impact [36], the Schools as Community Hubs [49, 58-62], and the proposal of Community Pacts [63,64].

With respect to the concept of smart learning ecosystems, the anticipatory visions described in the introduction lack, in a certain sense, of definition, and this is the criticality on which we will concentrate in this section in the attempt to find a remedy.

A learning ecosystem is defined not only through spaces, functionalities and relationships (albeit designed to support a given pedagogical vision) but first and foremost through people and processes. Indeed, it is crucial to recognize, first of all, the centrality of the learner (see fig. 1), with respect to processes, spaces and relationships. The latter, moreover, implies the involvement of other actors whose well-being and expectations must also be met. This is because they are expected to be directly involved in the performance of the learning processes, albeit with different and complementary roles: school personnel (teachers, principals and technical staff), families, territory

stakeholders, to whom, in recent years, we have to add the stakeholders of the almost borderless territory defined by the web. And it is thanks to all these actors that learning processes can be designed, developed and delivered to meet the expectations of students and society.

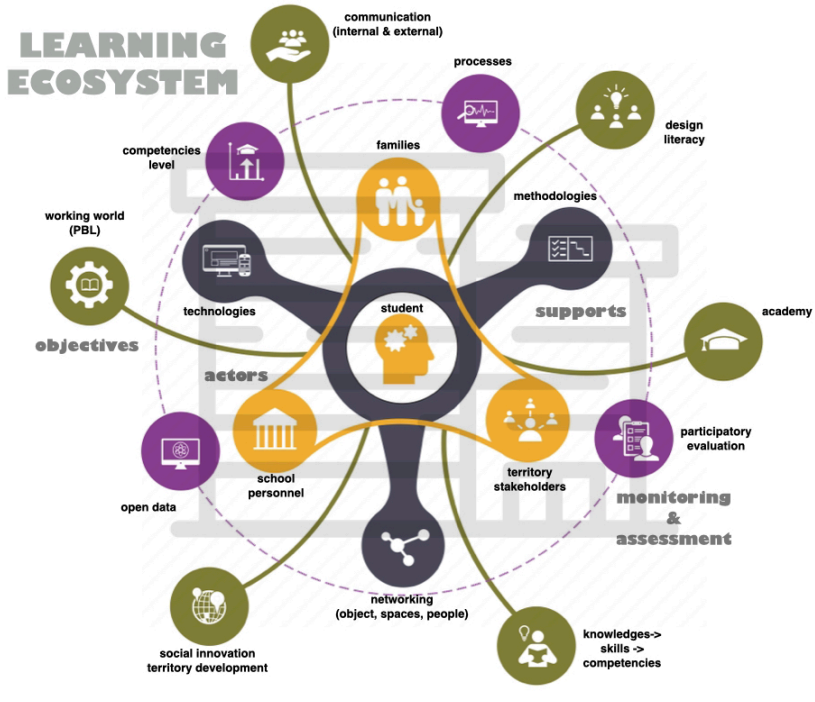

Fig. 1. Schematic representation of a smart learning ecosystem centred on the student and on the collaboration of all educational agencies - teachers, families territorial stakeholders -, characterised by various types of resources, relationships and objectives and by a necessary monitoring and assessment layer.

The learning processes, then, are expected to *shape the spaces* hosting them, insofar as they are the offspring of a pedagogical vision and related methodological approaches, which today it is difficult to imagine without the support of advanced digital technologies. A contribution to space shaping, of course, is also expected by the system of relationships that will develop and that - also exploiting technologies - is capable of connecting objects, places and people.

However, no learning process - as well as no learning ecosystem - can be defined as *meaningful* if a set of objectives are not identified that can meet the expectations of the actors involved in the process: in fig. 1, as an example, are symbolically represented the development of knowledge/skills and competences combined with that of an adequate design literacy; the ability to connect students with the academic world and the job market, to stimulate project-based learning and to provide students with adequate orientation; the relationship with the territory, also to support its development and

social innovation; the establishment of effective communication between all actors involved in the learning process.

Moreover, an ecosystem can be said to be *relevant* if, in addition to the process objectives, it is possible to determine its effectiveness and capacity to generate impact (essential aspects to determine its survival). This implies the need for constant monitoring of the outcomes of the process, as well as the deployment of an evaluation process capable of gathering the perceptions of all the actors involved in the process. This is also strictly necessary for the production of evidence-based and open social reporting (hence the relevance of open data).

Process monitoring and participatory evaluation of outcomes, however, imply the definition of a *learning ecosystem model*. This need, over the past few years, has led us to develop the definition of smart learning ecosystems [56,57] together with a macro-objective characterising these ecosystems and the dimensions to be taken into account in the realisation of participatory evaluation processes [65-69], the ultimate aim of which is to nurture reflection and the production of ecosystems improvement plans [68,69].

All in all, the macro-objective of learning ecosystems is to increase their level of smartness over time, which coincides with the ability to foster the well-being of the actors participating in the process. The term *smart*, therefore, is not to be identified with the integration of technologies to support the process, but with the possibility of the actors involved in the process to develop a state of complete well-being understood as well-being inducible from the characteristics of the context and the process *(extrinsic well-being)*, integrated with the well-being developed and perceived at a personal level that leads also to full self-realisation (*intrinsic well-being*), see figures 2 and 3.

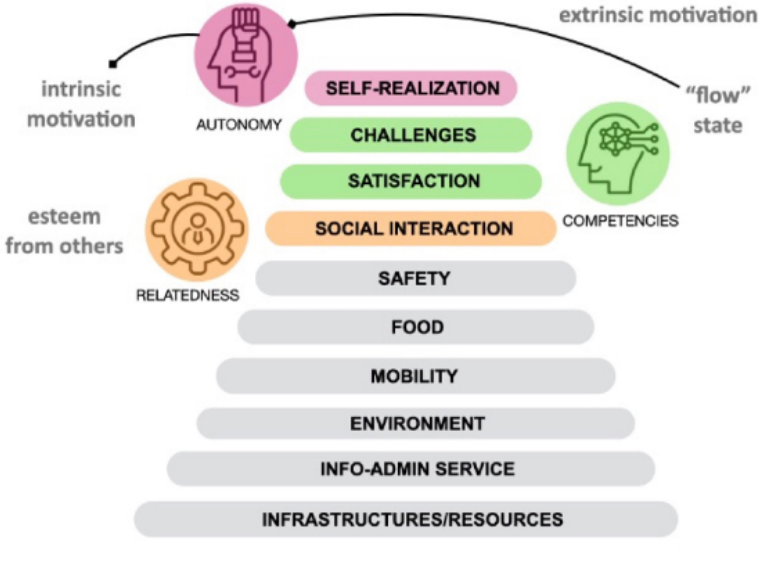

Fig. 2. ASLERD pyramid of the smartness/well-being of a people-centred ecosystem, from which it is possible to design a participatory evaluation process of any learning ecosystem [65,67], such as schools [66].

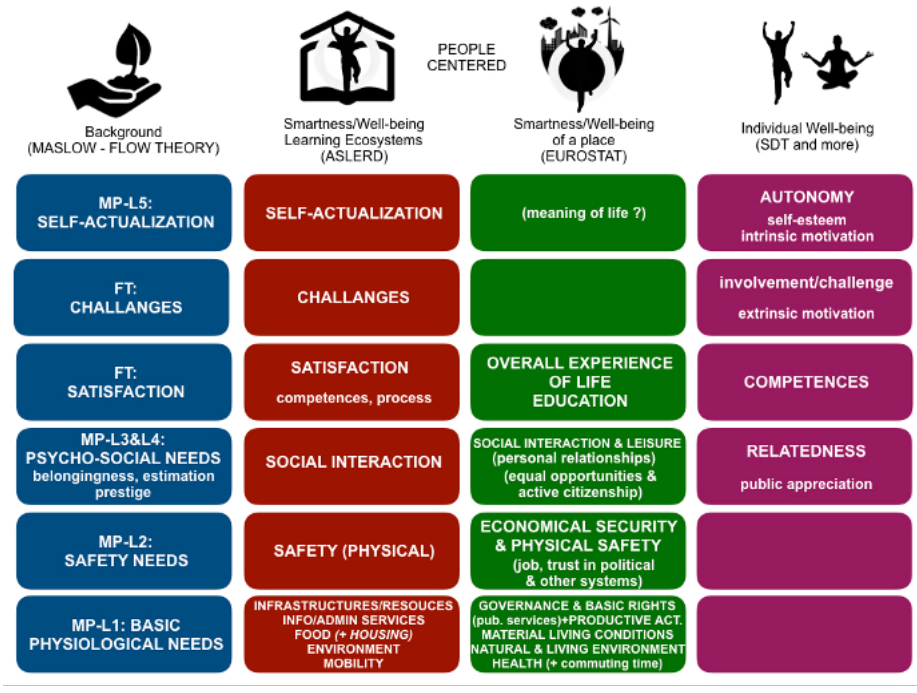

Fig. 3. ASLERD pyramid of *smartness/well-being* (amaranth boxes) compared with a) the constituents of the Maslow pyramid [70] and of the *flow* theory [71] (blue boxes); b) the elements considered by the EUROSTAT [72] to define the well-being generated in a person by a context/place (green boxes); and the pillar of the *Self-Determination Theory* [73] (purple boxes) to determine the individual psychological well-being (in particular in a working environment).

The ASLERD pyramid (fig.2) shows all the levels that should be taken into account in the design and evaluation of smart learning ecosystems and that derive from the integration of Maslow's pyramid of needs and Czisikszentmihalyi's flow theory. Fig. 2 also shows the relationship between the ASLERD pyramid and the SDT theory that identifies autonomy - competences - relatedness as the three components of individual well-being. In addition, in fig. 3, taken from ref [74], a comparison is made between the levels that contribute to the definition of the smartness of a learning ecosystem and the elements that, according to EUROSTAT [72], define the smartness of a place and the wellbeing that can be generated by it.

The use of this evaluation framework has been tested in numerous situations involving schools and universities [65-69].

Up to now the model of smart learning ecosystem and the ASLERD pyramid of smartness have not yet been used to design spaces. At present, their use in design practices, has been limited to the use of the results of the participatory evaluation to design apps prototype and realize improvements plans [68,69]. Nevertheless, the SLE model and the ASLERD pyramid are particularly useful for the purposes of this contribution because this framework sets very precise conditions on the needs that spaces for education must satisfy: a) must offer infrastructures that enable the development of

educational processes capable of ensuring the well-being of the actors involved, as well as the services necessary for such processes; b) must satisfy the basic needs of the actors involved, such as those relating to food, mobility and the perception of safety; c) must satisfy the needs of sustainability, particularly environmental sustainability; d) must support and guarantee social interaction whose relevance has been further emphasised by the recent pandemic; e) must offer adequate stimuli and challenges useful to support and foster the complete development of the student (i.e., of their space of competencies) and, ultimately, their self-realisation.

At the end of this section it is also worth pointing out one last aspect, not of little importance, which barely emerges from the historical reconstruction of the previous section, but which needs to be clearly highlighted: the need to involve all the players potentially involved in the operation and development of a smart learning ecosystem in its initial design and, then, in the co-design of improvement plans. Undoubtedly, a principal that owns very sharp goals assisted by a group of highly motivated collaborators - teachers and technical staff - can influence the transformation of the school environment (see, for example, the case of the Modena school [75], a school where the transformation did not start from scratch as in the case of the Vittra school [76,77] or the Hellerup school [40,41]) but it is only by involving all the stakeholders and the community of reference that the expectations of all players can be integrated to stimulate the necessary sense of identification and belonging. In fact, the teachers‘ and families’ visions on the purpose of opening up school spaces to the territory and the development of relations with the territorial stakeholders (as well as the expectations and objectives of the latter) could be quite different from each other [78] and it is therefore necessary to identify the most suitable strategies and methodologies to build a cohesive community sharing common objectives [79-81]. Without involvement and mediation, the spaces and processes provided by a smart learning ecosystem, however well they may be designed and implemented to accompany the students' development path, will never be fully supported by the community of reference. This is a topic on which debates and in-depth studies [82-84] have been developed in the recent past. The risk associated with the failure to involve the community is that the smart learning ecosystem does not become a value shared by the community. If so, a change in the school leadership or a cut in funding could render all efforts made to generate a change only a fluctuation destined to recompose itself within a ‘traditional’ school organisation. One should recognize that a systemic change can occur only if supported by very enlightened government directives. Otherwise, any change would appear always as “confined” experimentations, outcomes of the efforts produced by enlightened individuals and communities.

All of this leads us to understand how the creation, development and maintenance of smart learning ecosystems would require both: a) top-down processes that do not focus on measures with limited horizons but, rather, are able to provide a constant driving force, at least on a cultural level; b) bottom-up processes that stimulate co-participation, co-planning and the assumption of co-responsibility on the part of the entire community in order to create the basis for continuous and lasting support and ensure that smart learning ecosystems could operate on a long-term basis.

The definition of a smart learning ecosystem model illustrated in this section and the associated possibility of using it for participatory evaluation practices represent an important step forward for the possible development of bottom-up processes.

3 Cultural paradigm, pedagogical framework and teaching approaches

The introductory section of this article has served, among other things, to make it clear how one cannot imagine the phygital spaces [120-121] of the future SLEs without defining a cultural paradigm and, as well, a pedagogical framework that can direct the design of both educational processes and spaces.

The cultural paradigm we intend to take as a reference is the so called '*people in place centred design*' [85] while the pedagogical framework to be combined with it is the '*learning by being*' [86]. This latter can be supported by multiple didactic approaches among which we tend to favour *P3BL* (*problem-project-process based learning*) [87,88]. Before going into the details of the above paradigm, pedagogical framework and didactic approaches and, of course, of their relation to the educational space, it is important to clarify the meaning ascribed by us to the term '*people*' in the context of this article. It is well known, in fact, that in some pedagogical domains a particular attention is paid to the distinction between the terms people, person, human, also in order to claim the cultural background that has determined the use of each of these terms [89-93]. In this specific context we do not intend to make any difference between them. From our point of view, the *person* is a unicum - in which there is no distinction between biological and spiritual dimensions - defined by the multiplicity of dimensions that determine its experiences and well-being, also in relation to the environment in which it is located and/or operates. Because of this it is also worth to clarify the relation between individuals and society, pointing out that one cannot think of the individuals as an entities whose freedom of choice makes them detached and unconditioned by society. They will always experience a conditioned and conditioning freedom, so that individual and context will necessarily tend to influence each other and co-evolve. It is to this state of things that individuals need to be made aware, in particular the young generations. The absolute freedom of choice, or the rejection of social conventions, can only lead to extremes such as, for example, the don Quixote, the terrorist, the martyr or the hermit. The first identifies and fights imaginary enemies and tends to be tolerated by the system because he is not considered dangerous; the second identifies and fights real enemies but is usually crushed by the dominant system; the third identifies and fights the system peacefully, usually remaining crushed by it because he is not willing to react by force; the fourth renounces fighting and isolates himself, becoming irrelevant to the system. In order to fit within a social context and be able to influence it - i.e., co-evolving with it - it is necessary to get aware of and accept possible limitations to one's freedom while, at the same time, developing one's own critical mind and other life skills, to try to influence the co-evolution of the system and of the conventions in the desired direction.

This brief digression should help the reader to understand why the cultural paradigm we have indicated as reference is the *people in place centred design*: the person, in their entirety and complexity [94], is placed at the centre of a relational system that does not only involve the people who participate in the learning processes provided by the learning place, but all the components - both internal and external (including the spatial ones) - that characterise them. In other words, the person is placed at the centre of the design and implementation of the learning ecosystems. All this in a perspective of

multidimensional interaction which at the beginning of the training pathway experienced by the individuals may appear unbalanced in the direction of influencing the learners. However, as time goes by, it shall increasingly tend to rebalance itself towards the co-evolution of learner and place, a rebalancing that hopefully reaches its apex with the learners' entry into society (that includes also their entry in the job market) and, then, will continue throughout their whole life (as already recommended by Comenius) [16].

It is important to emphasise, however, that identifying one's own place in the job market should not be the ultimate goal but only one component of identifying one's own place in society, even though finding a job is necessary for the individual to attain independence and thus maintain their dignity.

In order to be able to identify and occupy one's own place in society, however, it is of paramount relevance to develop an adequate set of competencies to accompany the parallel development of one's abilities and the emergence and satisfaction of one's own propensities. This, as extensively discussed in a recent article [86], corresponds to overcoming learning models based on the transmission of knowledge and, as well as, learning models based on the transmission of knowledge and know-how, i.e., the ability to reproduce more or less standardised procedures. The pedagogical framework should be that of *learning by being*, i.e., the parallel development of base, vertical and transversal competencies, accompanied by digital competencies that can act as an amplifiers of all the other competencies. Being competent is what still distinguishes us from the machines, from AI. It means, for instance, being able to critically analyse information to adapt it to the context of use. It means, as well, being able to produce new objects of knowledge from which the machines of the future will be trained. In other words, it means being able to mobilise one's own knowledge and skills to address unfamiliar problems and/or situations and/or contexts by identifying appropriate explanations and solutions that are the product of one's own critical reasoning and creativity. Inevitably, spaces will have to be designed to produce continuous stimuli capable of supporting the development of the entire bouquet of competencies needed by the individuals. Educational spaces should not be designed any longer as assembly lines where students are passed from one classroom to another according to their age (i.e., should no longer reproduce, as an example, the school factory model).

As written above, there are many didactic approaches that can be integrated to support the pedagogical strategy of *learning by being*, however we believe that the methodological backbone should be represented by the P3BL (problem-project-process based learning) [87,88], to be applied, possibly, in an interdisciplinary manner. Broadly speaking, without dwelling on the benefits of such a methodology for the development of individual competencies, we can state that a problem-based didactics, in which problem setting/posing precedes problem solving, is the basis of both the *scientific method* and *design thinking*, i.e., the critical approach to knowledge and the logical and/or creative approach to the identification of optimal solutions to ill-defined problems [86]. A project-based didactics is necessary to develop the ability to deploy initiatives that might involve broad spatial horizons and long-term effects and, as well, to develop an aptitude toward concrete realisations and a propensity to achieve goals. While problem- and project-based teaching approaches are quite widespread, their integration with the process-based approach is very rare. Integrating the idea of process with that of problem and project not only helps to understand the nature of human experiences in their

continuous evolution and intersecting, but also enables learners to develop a propensity for planning, management and monitoring (in particular of progression and impact).

What it lasts now is to draw up, also by considering the avant-garde experiences conducted in the past, guidelines for the realisation of the smart learning places and ecosystems of the future - well beyond 2030 - capable also to support the use of methodologies and strategies described in this section. This is the goal of the next section.

4 Learning spaces beyond 2030

While the cultural paradigm, the pedagogical framework of reference and didactic approach described in the previous section have universal applicability, the design and realisation of spaces that can support them represent a big challenge because they must necessarily take into due account the constraints imposed by the boundary conditions. The first is the legacy of the existing building stock that has been passed down for decades, if not centuries. Except for a few experimental realisations, these are buildings imagined for the delivery of transmissive educational processes and on which one can only intervene to a limited extent although, as we shall see in the following, it is always possible to make some changes. The second constraint is the availability of resources, including economic ones, so that the principles we will describe in this section, most likely, are applicable differently in the high income countries and in the low income countries.

The third is urban positioning: being located in an historic centre, a suburb, a mountainous area or far from very active centres can determine differences of no small importance.

The fourth, partly but not exclusively related to the third, is the readiness of the community to be involved in and support the development of smart learning ecosystems.

Among the potential constraints we have not included the availability of a class of adequately trained and motivated teachers and principals, which, in the specific context of this article, we take for granted, although it is not so.

Despite the potential constraints listed above, we will try to enunciate principles that can be widely applied, albeit in very different ways depending on the specificities of the context.

Before plunging into the description and discussion of these principles, it is also worth emphasising how we cannot fail to take into account the lessons of the recent pandemic, which made emerge either the potential of technologies in optimising didactic processes and individual time, and the inescapable needs of human beings, such as that of a socialisation that cannot be surrogated by virtual interactions.

Centrality and openness of the spaces to the territory of reference. This first principle should be considered for its potentiality to act as an educating territory while the learning ecosystem should/could act also as a civic centre. This principle has as its consequences: the expansion outwards of the educational spaces to include informal ones that can also be used for educational purposes; the opening up of the learning ecosystem spaces to activities other and complementary to the curricular ones, with the possibility

to involve also members of the community; the multiplication and intensification of communication flows and interaction with the territory and its members.

In the case of newly built schools, or schools that possess outdoor spaces, this could mean setting up such spaces for outdoor learning activities such as, for example, those dedicated to the development of precision and sustainable cultivation (although such activities could be conducted also indoors), to the exploitation of clean energy, to archaeological exploration or the conservation of cultural heritage, to the recovery and maintenance of common spaces available to the community, to workshops to be held in underused working environments with specific educational potential, etc.. It is always possible, in fact, to identify spaces with educational potential that can become part - part-time or full-time - of the learning ecosystems and that can be kept in constant connection with it, for example through monitors installed within the school.

Ultimately, we could think of widespreaded learning ecosystems that, perhaps, can be more easily realised in small towns and villages rather than in the historical centres of large cities.

About opening up the spaces of a learning ecosystem to other activities, trivially, it is possible to imagine spaces that could be transformed into theatre and music workshops, with the particularity of being open to interaction with the outside world, so as to allow actors and musicians to interact remotely, as happened during the pandemic period. In the same way, it is possible to set up spaces in which one can get used to the new modes of remote collaborative work, or even to working processes typical of Industry 4.0 [95] in which distributed and integrated activities, automation and remote control/interaction dominate. These examples underline the more general need to open up learning ecosystems to interaction with the members of the communities of reference to take advantage of their experience and expertise. This implies the realization into the LEs of spaces where one can get in contact individually or in small groups (if needed in supervised manner) with external experts. Such contacts could be used also for remote support and assistance in the workshop activities thanks, for example, to the use of mini-robots capable of allowing for an agile visualisation of what is happening on the work tables [96], supplemented by appropriate ways of providing indications on how to proceed in such activities. Similar communication facilities and spaces could possibly be used for socialising, in order to maintain contact also with the more fragile members of the community, e.g. sick companions or the elderly, the latter could also make their wealth of experience and historical memory available.

It is worth emphasising that what has been described up to now aims at creating synergies and 'integrating' community members and outdoor spaces into the learning ecosystem rather than reproducing indoor spaces in imitation of the urban and social organisation of, say, a city. All this while keeping always the students and their education at the centre of every initiative.

Functional specificity. The second principle concerns the functional specificity, or diversification of spaces. In order to activate a pedagogical strategy that aims at *learning by being* and the use of P3BL didactic approaches, it is necessary to have specialised spaces to carry out activities related to the development of specific knowledge, skills and competences, whether vertical or horizontal. In fact, it is pointless to reproduce, as in traditional schools, spaces that look all the same (e.g. classrooms) for the sole purpose of imparting knowledge according to age. Spaces should be dedicated to specific

activities to be carried out not according to age, but according to skill levels, and be used by students according to the planning of activities. If it is quite easy to imagine and realise new spaces to fulfil specific functions (see the examples of Vittra school [76]) it is less easy to readapt pre-existing space structures. For instance, it will not always be easy to reorganise corridors or transit spaces as spaces useful for social interaction between students and/or teachers, although they could accommodate niches open to social interaction with the outside world (see above). It is not impossible, then, as is already the case in the so called Dada approach [97], to reorganise classrooms into functional spaces for brain storming, targeted research, open debate, workshop activities, etc., albeit with the constraints imposed by the rigidity of the wall structures that could prevent the creation of large structural openings.

It is important to stress that, in addition to political will and the availability of adequate economic resources, the functional reorganisation of spaces also requires a profound reorganisation of educational processes, like for example in the adoption of the *learning by being*, a pedagogical framework of reference which become easier to apply as the age of students increases.

In any case, it is very important that the *use of spaces would be perceived as meaningful* and would determine an added value with respect to domestic spaces, since also these latter allow a certain number of activities to be carried out in an equally efficient and more comfortable manner. This positive feeling with respect to the LE's spaces should be taken in consideration even more when the site of the LE is distant and difficult to reach. In such cases, the time spent within the learning ecosystem could be reduced to the minimum needed to carry outout meaningful activities and satisfying the need for social interaction.

Flexibility. The third principle is that of flexibility, to be applied at all scales. In newly built schools, it can also be applied at the macro level by designing structures that, as needs evolve, could give rise to expansions similar to those of some airports where new hubs can be added, or decommissioned, depending on the volume of the passenger traffic. An example is provided by the of the 4het Gymnasium in Amsterdam [50,51], a school composed of prefabricated modules that could take on different configurations.

With the availability of adequate structural spans, this principle can be applied - not in contrast but as a complement to the principle of diversification - to the realisation of spaces with variable functionality, taking inspiration from the organisation of the wings of a theatre in which equipped walls can slide to redefine the functionality of the spaces; similarly equipped ceilings can be used.

Where it is not possible to have suitable spaces, the principle of flexibility could be applied to the furniture and other elements that populate the physical space and that should be designed to favour the rapid functional reorganisation of the spaces themselves.

More in general, it is worth reflecting on the possibility that the behaviour, needs and demands of schools and their 'inhabitants' may change over time, with the consequence that space too may have to undergo modifications and/or additions to give rise to the 'production' of new spatial identities. In principle, applying the concept of flexibility more broadly, we could understand the spaces of an LE as service spaces, where one could move from *space for learning* to *space for learning as a service*. One consequence is that the design should be able to transcend the physical aspects and focus on

the performative aspects of a space: versatility, integrability, modifiability. Generally speaking, it can be observed that a new space identity revolves around the concept of *temporality*. In fact, while on the one hand a LE officially accommodates the existence of a group of people for a given time, on the other hand this process cyclically modifies, contracts and integrates with changes that are institutionally heterodirected or induced by particular events, as was the case during the recent pandemic or as may happen in the aftermath of a war. Moreover, the formal and informal use of space may not be crystallised in time but change and become contaminated even over a very short period of time. Responsibility for spaces would also be better if it were not centralised but shared by many and different actors (principle of co-responsibility). School buildings, in reality, already represent an asset at the disposal of the community, which are sometimes very quickly conformed to be used for other public services (e.g. elections-referendums); not to mention that school buildings have over the decades often assumed the identity of spaces for the exercise of civic and political criticism and discussion (e.g. protests and occupations).

Affordance. The fourth principle is that of *affordance*, or the *suggestion of use* that can go as far as the *stimulation of activities* to be performed by students. This principle, which in the world of design was introduced by Gibson [98] and in pedagogy, albeit not by this name, by the work of John Dewey and Maria Montessori [99-101], establishes that objects in space, teaching aids (including computer applications) and spaces themselves should suggest to users as much as possible how the artefacts and the space that includes them can/should be used. In pedagogical terms, one could say that artefacts and spaces should stimulate students' interest in interacting with them, even in a creative way. It is obvious that with the increasing complexity of topics to be dealt with one cannot expect that the use of artefacts and spaces to be left entirely to the autonomous initiative of the student, but it is certainly possible to design them in such a way that teacher intervention is minimised and the ‘door’ to experimentation by students is left open.

Having stated the four basic principles, the main question that remains to be answered is how to take account of IT and how to integrate them into LEs' spaces to transform these latter in phygital ones?

The ICT infrastructuring of an LE can only proceed step by step and requires a deep understanding of the interaction between physical and virtual spaces that goes beyond the streamlining and amplification of existing processes and fosters the emergence of new qualities from the integration of the two spaces that become only one: a phygital place [102].

Phygital design should be based on recurrent driving conditions, for example, responsiveness, usability, empowerment, and mostly interaction. The interactive role of space is, among all, the one that encompasses much of the qualities that were discussed in the scientific literature [103] about space design. Interaction is about the digital and physical exploration of spaces, throughout the five senses of human beings. In these terms, interaction generates an ontology of very different qualities that define an experience [104] which, in turn, requires that designers widen the common and traditional sense of space and time. The design of school factory education neglects phygitality or is laterally influenced by it.

The design should focus on at least three main dimensions that qualify phygital LEs:

- Sensitive: phygital spaces can embed sensors that collect info or react to human behaviors. Sensitive objects or materials can be connected and provide in real time that invisible network (Internet of Things) which is becoming the new "metabolism" of spaces.
- Enabling: phygital spaces can ease the implementation of numerous activities (social, working/ studying, or moving activities, as described above).
- Engaging: phygital spaces increase widely both the bidirectional information flows between the digital and the physical realm and the structure and nature of the information; this augments and amplifies engagement strategy and opportunities to interact with space and people, even if we are passive and choose not to interact.

These three dimensions occur simultaneously and can feed each other's purpose to provide a variety of configurations which will hopefully take to new models as fluid classrooms.

What are, thus, the possible trends towards the development of increasingly phygital spaces beyond 2030 ?

The first one concerns the sentient dimension of space. The most trivial applications are those that follow the definition of home automation, aimed at controlling the physical well-being (temperature, light, and its coloring, humidity level, sound intensity, etc.) and mechanical affordances (automated movement of components of physical space); less trivial, but now widely accessible, is the detection and elaboration, in particular in laboratory environments, of physical parameters of various kinds (also, for example, in the management of green spaces - precision farming [105,106]) and the detection of behaviors (e.g. students' attention by cameras [107]). The latter, especially when coupled with AI applications, entails ethical considerations but may stimulate in the students the acquisition of adequate data literacy [108-110] as well as a multidimensional perception of the self.

Another aspect, already mentioned above, is automation, especially in labs where sensors could be integrated with expert systems (e.g. AI-based applications on the cloud), to prepare students for the so-called Industry 4.0 [95].

A final and important aspect concerns the interaction with virtual objects in sentient and immersive spaces in which, for example, interactive games can be projected onto floors and walls, in which interaction between persons, physical objects and virtual objects can be developed to give rise to artistic performances, to telepresence meeting or to perform exploration of hardly accessible environments.

Immersive or sentient and interactive spaces [111,112] could be created either as independent specialised spaces or be integrated and disseminated in other spaces: occasional rehearsal halls, meeting recreation corridors/corners, virtual learning spots with protagonists of the past/future; social diachronic spaces, immersive meeting spaces with world heritage sites, etc. Spaces dedicated to debates and presentations could become caves for semi-immersive projections, laboratories could provide for the integration of real experiments with virtual calculation and representation tools, gyms could host the projection of virtual spaces and objects that could serve as support for

the execution of physical exercises or, reversing the information flow, tools could be used to show the level of performance in real time to aid self-correction, etc.

It is quite clear, therefore, how the transformation of physical spaces into sentient spaces can only go hand in hand with the development of new opportunities, i.e., an increase in the level of enabling, which inevitably leads to an increase in the potential for engagement.

In sentient spaces, the machine need not to be visible, it could disappear behind the physical spaces and in the bodies of the objects that populate them [113-115]. It may manifests itself only through computability and responsiveness, i.e., the capacity of spaces and objects to perceive a stimulus and to process a response [116].

A fully interactive immersiveness can also be experienced through the use of visors, and wearable sensors/actuators, but in such cases the individual's perception (including the proprioception) is decoupled from that of the physical space in which one finds oneself. Certainly useful in all cases of simulations (e.g. Lego construction [117]) and in the visualization of what cannot be explored in reality, e.g. [118,119]) but in such cases the phygital perception changes quite a lot and we can hardly refer to phygital spaces.

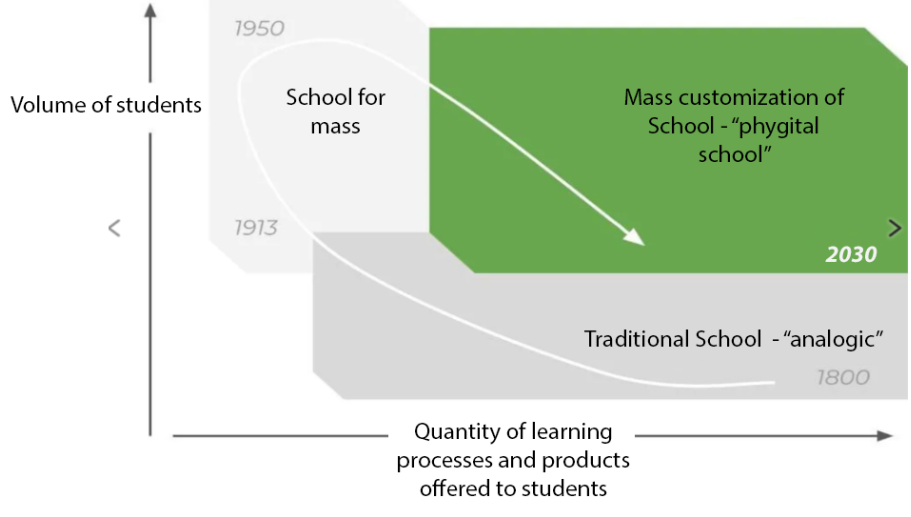

Fig. 4 Schematic view of learning demand-offer experience from the past to the next future

A final consideration deserves the change to which the contents of the educational offerings are subjected over time due to both the demands/expectations of students and families and the labour market, and that results in increasing fragmentation. New technologies can also play an important role in this process. As we have already seen above, the school of the past had fewer students doing many activities related to a multiplicity of disciplines that over the centuries have been standardised to originate the mass education. Today, new technologies offer the opportunity to return to personalising the educational experience at different points in the process. Because of this we are witnessing an enlargement of the educational offer in an attempt to accommodate new and

varied needs that could end up inducing a *mass customisation - from mass education to mass customisationg of learning* that would require a profound reflection on the flexibility of the contents that should be 'student-centred' and on the educational pathways that should be more open to customisation without a predefined target. A customisation of the content that could go very well with the *learning-by-being* approach based on competence development.

Finally, it is worth emphasising that the designer's perspective also changes with the transformation of spaces into sensitive spaces. Interaction with educational science experts becomes even more important to avoid transforming spaces from potential educational spaces to playgrounds. The members of the interdisciplinary design teams should be able to intuit as many evolutionary trajectories of the educational processes that might develop in the transformed spaces, also taking into account possible future technological developments and the potential needs of an evolving society. In other words, they should be able to read the evolutionary path that led from the past to the present and that could extend from today to tomorrow, always keeping in mind the well-being of the individuals who are at the centre of the learning ecosystems

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