Spaces for learning

An empirical model for measuring the effect of the built environment on learning

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ABSTRACT

The development and design of learning spaces is receiving more attention because of a cultural shift in educational practices. By studying the effect of the physical space on the learner, this article develops a learner centered framework that can be applied in the design of a learning space. The design of learning spaces is evaluated by studying statistics and research on learning, creating the basis for the concept of *spatial moderators*; elements of the built environment that have a significant positive effect on learning. These moderators have been developed to provide evidence-based, practical guidelines that can inform the design of learning spaces.

KEYWORDS

Learning space, spatial moderators, student centered education

1. INTRODUCTION

> "The context of education is changing. […] the focus has moved away from more traditional methods of teaching to embracing a totality of experiences that will equip young people to meet the challenges of the 21st century» (Scotland, 2015).

The shift from passive to active learning emphasising student participation, as well as new educational initiatives of the 21st century are challenging the educational institutions, from secondary school to university level. Meanwhile, educational institutions are accommodating societal needs of competencies and skills in a time of rapid technological advances, globalisation of the economy and shifting demographics (*The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution*, 2016).

From an outside point of view, a 'Learning environment' is an educational approach, cultural context, or physical setting in which teaching and learning occur ("Learning Environment," 2013). As mentioned in the abstract, one of the key factors that determines the configuration of a learning space is the educational philosophy, which often materialises in seating arrangements, learning resources, teaching strategies. Evidently, these choices shape the activities that take place in any learning space.

With a shift toward a student-centered education, it is compelling to define the learning environment from the perspective of the learner. Research on schools suggests that social factors like having friends, having a high

learning pressure and the engagement of parents and their attitudes towards the school are among the most influential factors in a learning environment (Amundsen, 2015). Consequently, we should be aware of the limitations of the physical space, and keep in mind the context in which students interact with it.

So, are the physical spaces keeping up with the societal requirements emphasising complex problem solving, critical thinking and creativity (*The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution*, 2016)? Some initiatives, including architectural projects and design pilots, have attempted to create spaces that address this new educational framework. This involves designing a variety of spaces that support different learning activities, thus providing a network of spaces that gives the learner freedom in balancing individual studies with group projects (Van Merriënboer, McKenney, Cullinan, & Heuer, 2017).

Still, it remains unclear whether these initiatives are simply the physical manifestations of a new educational mentality, and whether the activities that take place are in fact supporting the learning requirements and goals of the educational institution.

Some work in recent years address the relationship between the physical environment and learning, including research linking attributes of the physical learning environment to cognitive load (Choi, 2014) and mental health and well-being (Ettema, 2015). There is, however, limited research on how physical spaces affect learning, and the research that exists is not necessarily focused on the learning process.

This article will explore the effects of spatial characteristics on the learner, and investigate whether these can be quantified and categorised. Research on factors in the physical environment and their influence on the learner is the basis for the development of spatial moderators. The development and concept of spatial moderators will be explained in the research section.

There are several factors that influence the activities in a learning environment; in this article, we will look at learning environments from a broad perspective, focusing on common themes and conclusions that can be drawn with the purpose of creating effective learning spaces.

2. METHODS

This article is a literature review, with sources from reports, articles and web sites. The research topic deals with physical learning environments and their influence on various aspects of learning.

The search criteria were divided between theoretical aspects of learning – i.e. learning theories, subcategories of learning, etc. – and practical aspects of learning –i.e. the design of learning spaces, influences on the learning process, etc.

The article research was conducted between September 7th and November 20th. Most of the articles, including ones that deal with empirical studies about the influence of learning spaces, were found through Oria and Google Scholar. Reports and other sources were found through internet searches.

Important keywords in searches include:

Learning space, spatial characteristics, influence, empirical research, guidelines.

The empirical evidence cited is based on findings in research papers and research-based reports. Although a limited amount of empirical research exists on the relation between space and its influence on learning, findings that were time-sensitive or that had a narrow application were excluded. Findings that deal with learning theories have been selected based on their relevance to the physical learning environment.

3. RESEARCH

3.1 Ideologies affect the design of learning spaces

> 'The student-centred learning environment has the student need satisfaction as its primary focus whereas the subject-centred environment has the transmission of a body of knowledge as the primary focus.' (Clasen & Bowman, 1974)

The concept of student-centred learning is gaining momentum, and has been shown to be effective, especially in higher education (Wright, 2011). Here, the curriculum and the learning activities are determined by the student, enabling pursuit of their own learning interests, developing problem solving skills, and equipping them with the tools to become lifelong learners (Nanney, 2004).

In many ways, it is the antithesis of the prevailing teacher-centered, authoritarian model that dominated in the 20th century. Arguably, the classroom interior archetype – in which all the students have an appointed desk facing the teacher and the blackboard - embodies an educational philosophy that is modelled on the industrial principles of the early 20th century, favouring efficiency and uniformity.

The teacher's passing of knowledge is still a core activity in modern schools, but in a student-centered environment the teacher acts more like a facilitator, supporting students in their self-directed learning processes. Data from OECD shows that on average, teaching time is highest at primary school, and decreases for higher levels of education (OECD, 2017), correlating with higher degrees of learner autonomy and influence on the learning process. These are characteristics that are associated with *active* learning environments.

The architectural framework of student-centered learning has a lot in common with the *activity based working* office model (hereby called ABW), which brings together elements from the social democratic open plan model whilst providing flexibility through spatial differentiation, often measured in terms of focus and collaboration (source). However, statistics on work satisfaction indicates that for ABW to be effective for workers, the work culture should be aligned with the work environment:

> 'Statistically at face value, the benefits of ABW environments are difficult to see. Comparing them to a control group of non-ABW spaces, they show lower Leesman effectiveness scores and average satisfaction agreement against both productivity and pride key indicators. Presented with these results in isolation, it would be difficult to build a case for ABW adoption. However, those averages mask a dramatically diverse picture that is concealing how ABW environments deliver significant performance improvements on multiple measurement lines for those employees who adapt to their new surroundings. But a number of these spaces are populated by large numbers of employees stuck in traditional workstyles, in effect, in conflict with their new setting.' (Leesman, 2016)

To conclude, the functioning of a learning environment relies on the successful alignment of the learning culture, the pedagogical ideology and the learning space. This is especially important in a time when education is responding to rapid technological and societal changes.

In the following chapters, we study how learning spaces support various learning activities, with an emphasis on skills and competencies that have been established as essential for the future work force.

3. 2 The function of learning spaces

> 'The [learning environment] also encompasses the culture of a school or class—its presiding ethos and characteristics, including how individuals interact with and treat one another—as well as the ways in which teachers may organise an educational setting to facilitate learning—e.g., by

conducting classes in relevant natural ecosystems, grouping desks in specific ways, decorating the walls with learning materials, or utilising audio, visual, and digital technologies' ("Learning Environment," 2013).

Learning spaces provide a wide range of learning experiences for different learner groups, with a diverse set of goals for learning outcomes. Therefore, it is not straight forward to determine what the general function of a learning space should include. Still, we may point to certain forms of learning, as well as aspects of learning processes, that are facilitated by or rely upon the built environment.

Situated learning is a learning theory that emphasises the role of physical and social surroundings in the learning process, originally proposed as a model of learning in a community of practice (Lave & Wenger, 1991). Learning activities that apply this theory include workshops, role playing, field trips and music practice. In addition to providing an alternative to the traditional classroom, this theory stresses the role of contextual factors in learning processes. In the words of Paula Vincini, "Learners must use tools as practitioners use them and become 'cognitive apprentices' in that discipline's community and its culture" (Vincini, 2003).

The theory of situated cognition relates interaction with the environment to skill training and execution, arguing that knowing is inseparable from doing (Brown, Collins, & Duguid, 1989). Going one step further, *distributed* cognition argues that "cognition and knowledge are not confined to an individual; rather, it is distributed across objects, individuals, artefacts, and tools in the environment (Hollan, Hutchins, Kirsh, & Grudin, 2000). This perspective acts as a theoretical basis for understanding the importance of the physical environment in any learning activity.

Interestingly, digital media represents its own ecosystem of distributed cognition, as it allows people to interact and coordinate socially to perform tasks in a shared mental space.

Cognitive research indicates that the best learning takes place in a close simulation of the realistic environment, which has been shown to be effective in medical training (Lateef, 2010). This also has important applications to learning environments in general, with benefits reaching beyond the cognitive realm of learning. Furthermore, it is widely acknowledged that a cognitive model alone cannot explain the complex process of learning.

In the following chapter, we will introduce research that attempts to determine the effectiveness of practices within a learning environment.

3.3 Measuring learning

In a report by the SCRI, principles from SCRI's Senses, Brain and Spaces (SBS) research work "suggest direct connections between sensory stimulations, learning and physical space." (Peter Barrett, 2009).

The report states three design principles to inform the development of effective learning environments in primary schools:

- **Naturalness** – addressing biological requirements for light, air and safety.
- **Individualisatio***n* – each person perceives and responds to environmental stimulus differently.
- **Stimulation** – by providing peripheral sensory stimulation, the surrounding space can engage without diverting attention.

In a 2012 article by Barrett et al., the impact of school building design was measured across ten design parameters in seven different schools. Of all the factors influencing learning progression, factors of the *built environment*

were estimated to account for around 25% (Barrett, Zhang, Moffat, & Kobbacy, 2013).

Among the attempts to characterise good learning environments, one of the most comprehensive studies is by the school researcher John Hattie. In his *Visible learning* (Hattie, 2009), the relative effect of learning practices is measured based on meta-analyses of schools, relating to the influences on achievement in school-aged students (Miller, 2010). John Hattie defines a moderator as an 'effectual measure known to have a positive effect on learning' (Hattie, 2015).

Influence	Effect (d)
Teacher estimates of achievement	1.62
Collective teacher efficacy	1.57
Self-reported grades	1.33
Piagetian programs	1.28
Conceptual change programs	1.16
Response to intervention	1.07
Teacher credibility	0.90
Micro teaching	0.88
Cognitive task analysis	0.87
Classroom discussion	0.82

***Fig. 1** - List of influences that have been shown to have the largest positive effect on learning (Hattie, 2017). Here, d is the effect size (Cohen's d) defined as the standardised difference between two means.*

This statistical overview links a practical measure in the learning environment with its relative effect on learning, providing a fact-based overview of the most successful measures that can be taken to facilitate learning. As such, it is independent of any specific pedagogy, as it may point to certain universal truths about how learning happens. It also provides an informed basis for prioritisation of teaching resources.

For example, the high rank of 'Formative Evaluation' suggests that informal and ungraded settings facilitate student learning (Learning, 2017). A key characteristic of these moderators is their relative definition; for example, the implementation of formative evaluation can be interpreted and customised to suit a specific learning environment. Furthermore, as a strategy to facilitate learning, it can be backed up by research and statistical data.

This is the theoretical basis that inspires the concept of a spatial moderator; an aspect of the physical surroundings known to have a positive effect on learning. There are some challenges related to the description and effect measuring of spatial moderators, which will be addressed in the following chapters.

3.4 Developing spatial moderators

First, it is crucial to understand the educational framework that affects behaviour and activities in physical learning spaces. To implement any of these spatial moderators is not necessarily going to ensure better learning by itself; every learning environment is different.

Second, some of the attributes that characterise good learning environments are not restricted to learning, but influence other aspects – i.e. wellbeing and physiological needs – that have an indirect influence on learning.

Third, there is no comprehensive statistic linking spatial characteristics with their relative influence on a learning environment. Nor does this article attempt to develop one; instead, we will look at some spatial attributes that have a proven effect –directly or indirectly – on learning. We will use this list as a theoretical framework for understanding and developing spatial moderators.

The formal characteristics of a (learning) space consists of temperature, ventilation, views, natural light, light, acoustics and finishes (Wikipedia, 2017). While this describes the elements that constitute a physical environment, it does not provide information about how the learner experiences their environment. Within the scope of spatial moderators, components in the learning

environment – e.g. colour, displays, furniture – are also included.

In the following section, we will present a list of findings that address various aspects of spaces and their influence on the learner. This list is a collection of research findings from disciplines such as neuroscience, environmental and developmental psychology, social anthropology and cognitive science. The purpose of this list is to exemplify how multidisciplinary research could act as a foundation for developing spatial moderators.

- Availability of green space corresponds with lower frequency of mental health problems (van Den Berg et al., 2016). This finding could be generalised to an innate orientation to all living things, often referred to as *biophilia*.

- 'Computer and video games are suggested to increase the motivation and engagement of players because they include elements such as play, fantasy, curiosity, challenge, competition, cooperation, and learner-control' (Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005). "Game-based environments afford activities for experiential, situated, problem-based, and active learning.' (Boyle, Connolly, & Hainey, 2011)

- 'In times of declining resources and increasing public demands, schools are often tempted to reduce or abandon aesthetic experiences in the curriculum. These experiences (e.g., art, music, movement, etc.) offer the most obvious opportunities for children to play. Because play appears to affect other desirable patterns of intellectual functioning like divergent thinking and problem solving, we argue that play may have a more basic function in education than many educators believe. The concept of basic education perhaps should include aesthetic experiences that encourage play.' (Christie & Johnsen, 1983)

- 'The learning environment should incorporate the actions and practices of real life environments.' (Vincini, 2003)

- 'Generally, teachers who want to maximise the on-task behaviour of their students during independent work should consider utilising rows rather than groups as their primary seating arrangement and moving desks into other positions to facilitate interaction when it is desired.' (Wannarka & Ruhl, 2008)

- 'Although exposure levels at schools were below 60 dB […] multilevel analyses revealed that increasing exposure was linearly associated with less positive ratings of quality of life, increasing noise annoyance, and decreasing reading performance.' (Klatte et al., 2017)

3.5 Categories of spatial moderators

Spatial moderators affect several factors that must be present in a good learning environment, addressing physiological needs as well as social interaction and cognitive requirements.

It is also worth pointing out that some spatial moderators are easily introduced to existing learning spaces, i.e. introducing plants in the environment or rearranging furniture. Others require changes in infrastructure or learning material, which could be resource intensive. Nonetheless, spatial moderators are only concerned with the relationship between spatial factors and their relative effect on learning.

Further, a comprehensive list of moderators listed in order of *effect type* and relative effectiveness could provide a framework for evaluating and developing learning spaces. This would require meta-analyses in which elements of the physical learning environment were defined as influences on learning. Below is an *example* of how items in a list of spatial moderators could be structured:

Influence	Learning activity	Effect (d)
Natural light	Processing, thinking	0.6

Fig. 2 – *Example of influence categorised according to learning activity and relative effect. Here, the effect size (d = 0.6) is assumed to be calculated as Cohen's d (see Fig. 1)*

3.6 Towards a holistic understanding of learning spaces

The motivation for developing spatial moderators is not to formulate a definitive answer to what constitutes the optimal learning space, but to provide information that links specific elements of the space to specific influences on the learner and, by extension, their learning process. Research on spatial moderators can complement research on other aspects of learning, from teacher-student interaction to the learning strategies of students.

By looking at learning spaces through the lens of spatial moderators, there is an inherent focus on the effectiveness of learning environments, as opposed to the traditional paradigm of measuring learning. Also, by approaching the subject from a multidisciplinary research point of view, we can identify subtle aspects of learning spaces - like levels of noise and the extent to which the physical environment provides mobility - that have a profound effect on learning.

Some spatial characteristics, such as colour and choice of furniture, have influences which are difficult to assess in a rigorous, quantitative manner, although we know that these are crucial factors in the perception of space, and what we experience as the atmosphere of a space. Thus, learning environments should not only accommodate and facilitate learning, they should be settings for a broad range of experiences that support personal development beyond the realm of academic achievement and curricula.

3.7 Technology and its impact on learning spaces

'Mobile internet and cloud technology' has been listed as the primary technological driver of change toward 2020 (*The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution*, 2016). The mobility and connectivity that comes with this change has implications for the function of physical learning spaces.

Over the last decades, technology has evolved from presentation mediums (monitors, projectors) to research, generative and collaborative tools (Wikipedia, 2017). With virtual learning environments, there is a sense of *augmented* cognition, in which huge amounts of information is accessible. This development is consolidated by *augmented reality* technology, giving us access to new layers of information integrated in our physical environment.

Mobility in learning is also a direct result of this technological shift. Computer rooms are becoming obsolete, as mobile devices offer freedom in study space. Through mobility and connectivity, there is an opportunity for customising the learning experience, to accommodate different learning styles and different learning trajectories. Although there exists a lot of software for e-learning today, there is work to be done bridging the gap between the physical and the virtual world.

In a personalised learning environment, the progression is based on interests and competence, not a predetermined curriculum or assessment. In the ecosystem of a learning environment, technology can provide the traditional knowledge transmission while providing new platforms for collaboration and communication.

This provides opportunities for restructuring the layout of classrooms for other purposes. A natural way for learning spaces to respond to this change would be to specialise on social platforms of different kinds. As discussed previously, the acquisition of skills and competencies is often bound to the physical

and social context in which the learning activities take place.

3.8 Future work requirements

It is estimated that the majority of the jobs of the future do not yet exist (Scott McLeod, 2017). Along with the fact that changing jobs is increasingly common (*Number of jobs, labor market experience, and earnings growth among Americans at 50; results from a longitudinal study*, 2017), there are compelling arguments for emphasising interdisciplinary skills and competencies in educational strategies.

Below are the skills families expected to be most important in 2020, according to the 2016 *Future of Jobs* report by World Economic Forum:

SKILL	%
Complex Problem Solving	36
Social Skills	19
Process Skills	18
Systems Skills	17
Resource Management Skills	13
Technical Skills	12
Cognitive Abilities	15
Content Skills	10
Physical Abilities	4

Fig. 3 - *Demand for skills: industry overall | 2020 (The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution, 2016). Here, the percentage (%) indicates the share of jobs requiring skills family as part of their core skill set.*

In the larger perspective, we may consider the main function of learning as preparing for the future. One of the challenges for educational institutions is to adapt to shifting societal needs. Regardless of any specific skillset, it is evident that even the near future holds a lot of insecurity, especially related to what sort of things we will work with.

Consequently, being able to support a variety of learning activities appears to be a requirement for the future. Whether the focus will be on facilitating complex problem solving, developing social skills or something else, learning spaces should be flexible enough to respond to changes in society, changes in learning activity and changes in technology.

As mentioned in the introduction, new skills and competencies make their way into the curriculum, many of which are difficult to assess by traditional means. When moving away from a highly formalised and structured learning space, one of the challenges is to measure the learning outcomes of activities like collaborative problem solving. This problem has been addressed in 'The Nature of Problem Solving', which provides a research-based overview of problem solving in general and assessment in particular (Griffin, 2017). Studies like these are necessary to understand how new learning activities can be implemented effectively in learning environments.

3.9 The future of learning spaces

From an outside point of view, a learning environment is 'an educational approach, cultural context, or physical setting in which teaching and learning occur' ("Learning Environment," 2013). In this article, we have dealt with learning spaces as a physical setting, looking at how they are designed, how they are used, and how they influence learning.

The increasing presence of virtual environments, as well as increased mobility in learners is the context in which future settings for learning will take place. Perhaps one of the main challenges of the digital age is to balance things that happen in the digital world with things that happen in the physical world.

One experimental approach to incorporating information in the physical surroundings was developed by the MIT Media Lab in 1997:

> ‘The *ambientROOM* allows users to be aware of background bits using ambient display media such as ambient light, shadow, sound, airflow, water movement in an augmented architectural space.’ (Hiroshi Ishii, 1997)

Whether this is a realistic interpretation of how the virtual and the physical world might integrate, can be discussed, but it certainly provides an original viewpoint, reconceptualising the function of the built environment by providing information directly to the senses.

A more recent attempt to create social and immersive experiences is the phenomenon of escape rooms, in which elements from game design is applied in a setting for collaborative problem solving. Efforts to create engaging and immersive spaces could be beneficial when applied in a learning environment.

4. DISCUSSION

4.1 About the research material and definitions used

This article gathers research from multiple disciplines, combining studies that are related to the influence of the physical environment on the learner. In this context, the learner is a generic term that covers any person involved in a learning activity.

Because children and their requirements change over time, it is essential to understand the influence of spatial moderators in the context of age as well as learning activity and the overall learning environment. As such, the research findings are not universal truths that apply to everyone; information about the demographic and learning activity used in the studies is provided when available.

Importantly, we should also emphasise the role of positive learning, which happens in a collaborative (rather than competitive) environment that encourages self-directed learning and wellbeing among learners (Chen & McNamee, 2011). The implementation of effective learning should not be on the expense of the wellbeing and motivation of the learner, as these have been shown to be integral factors in cultivating learning.

Lastly, learning is a term with multiple definitions and subcategories, which this article does not go to great lengths to distinguish. It becomes important, however, to determine the type of learning activity that is involved, when describing how the physical environment affects various aspects of learning.

4.2 The essence of the article

By looking at factors influencing the design of learning spaces, both external (societal and technological changes) and internal (learning ideologies and strategies), the aim is to contextualise the role of the learning space in a modern educational reality. Evidently, a successful and effective learning environment relies on a holistic approach to learning strategies, that may inform the physical space as well as learning activities and objectives.

Efforts to reconceptualise the meaning and function of a learning space, whether they be reflexes to external changes or explorations of possible future scenarios, can be useful discussion points for the development of learning spaces.

Through the development of spatial moderators, this article proposes an informed discussion about the influence of the physical environment on learning, as well as the function of a learning space in different learning activities and processes, now and in the future.

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