SENSE. The New European Roadmap to STEAM Education

D5.1 – Scoping Report on Cross Cutting Issue: Space

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Abbreviations and acronyms

Abbreviation or acronym used in this document	Explanation
EU	European Union
ILE	Innovative Learning Environment
STEAM	Science, Technology, Engineering, Arts and Mathematics
STEM	Science, Technology, Engineering and Mathematics
OECD	Organisation for Economic Co-operation and Development

Glossary

Term	Definition used or meaning in the SENSE. project	Reference or source for the definition if applicable
Activity-Based-Layout	Activity-Based Working was originally coined by the Dutch consultant Erik Veldhoen in his 1994 book "The Demise of the Office". It describes a layout design that offers a variety of specialised settings geared towards different activities and tasks. The layout in itself is not flexible but provides the freedom of choice to the user.	Authors, (OECD 2017; 2013),

Affordance	Affordance is a term developed by J.J.Gibson and describes the dynamic relationship of individuum and physical environment. An affordance of an object or space defines the action possibilities it offers to the user.	(Lobo, Heras-Escribano, and Travieso 2018), (Norman 2013)
Open-plan layout	An open plan describes an arrangement that is characterised by an almost complete lack of internal partitions within the structural confines of a building or part of a building. This means there may be no significant physical or visual boundaries to delineate the various functional areas such as classrooms, workshops, library circulation areas, etc.	Construction Wiki ("Designing Buildings" n.d.)
Traditional classroom	A "traditional classroom" is a spatial typology that was developed in the 19th century. It describes a rectangular space within a school building, a group of students and typically one teacher. It features a display (for example, a blackboard) on the far end with rows of chairs and desks for the students directed towards it. It was created to support teacher-centred pedagogies spatially.	Authors, (Gislason 2011)

The SENSE. project

There is a widespread understanding that the future of a prosperous and sustainable Europe depends to a large extent on the quality of science education of its citizens. A science-literate society and a skilled workforce are essential for successfully tackling global environmental challenges, making informed use of digital technologies, counteracting disinformation, and critically debunking fake news campaigns. A future-proof Europe needs more young people to take up careers in science-related sectors.

Research shows that interest in STEM subjects declines with increasing age. This effect is particularly pronounced among girls and young women; even those of them who take up science studies gradually forfeit their motivation. But despite all image campaigns and efforts to remove the awe of science only “one in five young people graduates from STEM in tertiary education” and only half as many women as men, according to the European Skills Agenda.

The disinterest in science is striking and evokes the question of its causes. Stereotypes and lack of female role models seem to be only a part of the explanation. Nor is there a lack of career prospects that could explain a reorientation despite initial interest.

SENSE. has identified two major problems in current science education that need to be addressed: a) A distorted teaching logic that progresses from abstract models to procedural applications (“reverse ontology”) and b) The inability to implement a learner-centred pedagogy linking students’ everyday knowledge to science-based knowledge, thus promoting motivation, self-directed and life-long learning.

SENSE. advocates for the development of a high-quality future-making education that is equally accessible to all learners and promotes socially conscious and scientifically literate citizens and professionals. SENSE. aims at radically reshaping science education for a future-making society. By promoting the integration of all human senses into exploring and making sense of the world around us we will challenge conventional ideas of science and science education. Considering the pitfalls of current science education practices and the advantages of artistic and aesthetic activity, this innovative approach also considers social inclusion and spatial design as core components for a new STEAM education paradigm. With ‘SENSE.STEAM’, future science learning will be moving away from the standardised classroom shapes and furniture layout entering new learning landscapes.

The project seeks to develop an accessible educational roadmap promoting socially conscious and scientifically literate citizens and professionals. It addresses outdated perceptions of current science education as well as gender stereotypes by integrating the arts, social inclusion and spatial design as its core components. SENSE. will establish 13 ‘STEAM Labs’ across Europe to develop and evaluate the

‘SENSE. approach’ to STEAM subjects alongside students, educators, teachers, businesses, and other stakeholders.

The ‘New European Roadmap to STEAM Education’ will take the shape of a STEAM learning companion to support tomorrow’s educators and learners – be it in the classroom, in a museum or on a drilling rig. A digital hub will be established, where practitioners from all ages and backgrounds across Europe will be able to access tried and tested educational practices to increase engagement within these subjects.

The SENSE. consortium

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Executive Summary

D 5.1 explored the topic of the spatial conditions of STEAM education through multiple perspectives:

1. A wider review of academic literature looking at research analysing the impact of the built environment in general and educational spaces in particular

   Although a growing body of evidence shows that buildings impact human behaviour and influence educational outcomes, no common methodology, metric, or underlying theory is widely used or accepted. The field is very heterogeneous. However, a range of researchers postulate that a unified understanding of the impact of education architecture can be achieved, subject to the scale and rigour of future research.

   We disagree with this based on affordance theory, emphasising context and personal experience as important, making absolute objectivity impossible. In contrast, we suggest a discoursive model that creates spatial strategies based on context and mediates between objective conditions and subjective perceptions.

2. The Evolution of educational spaces with a focus on current STEAM practice

   The history of educational spaces is often described as an oscillating development from the traditional classroom towards innovative Learning Environments, often associated with multifunctional open-plan arrangements, with the classroom typology showing stubborn resistance to innovation. STEAM spaces and the conventional classroom are seen as incompatible.

   In this study, we highlighted that both spatial models, ope-plan and traditional classroom, have coexisted and that instead of describing the history of educational architecture towards “better” spatial solutions, we argue that the intense spatial work of the last 250 years has widened our choices and produced a wealth of design patterns that can be applied to specific contexts.

   We also highlighted that a critical dialogue between STEAM and the traditional classroom might be more fruitful than a simple rejection. Many current schools show a gradient of spatial conditions, which might be a good solution towards a deeper integration of STEAM into the curriculum.

3. Interviews with the SENSE. Research Consortium and Stakeholders

   The discussion with the Stakeholders reflected many aspects of the desktop research. STEAM spaces are described as mainly multifunctional large workshops that complement a more traditional curriculum. In this view, a STEAM space is, in essence, NOT a classroom. A flexible, open-plan space,

potentially with an open outdoor area, is seen as the ideal solution. Overall, the stakeholders feel that incorporating STEAM spaces into education is a massive improvement, especially for female students' attainment, as one interviewee highlighted. However, many practitioners described ongoing struggles with school culture, curriculum and exam pressures or missing resources.

Whilst the interviews with the research consortium mirrord many “real-life” aspects of the conversations with the stakeholder group, it was generally felt that widening the idea of what a STEAM space is, both in typology and underlying principles, would be beneficial and should be the aim of SENSE.

Many interviewees emphasised the potential of more inclusive spaces. The idea of an “ideal” space was rejected. Instead, all research partners favoured the focus on contextualised personal agency – “hacking a space” - over transferable design blueprints.

4. Key output: the Spatial Awareness Kit.

As a result of our research, we created a “Spatial Awareness Kit” that acknowledges the contextual, discoursive nature of space. Instead of producing a best practice manual, it is a loose guide to help structure an informed reflection on the impact of the physical environment, pivoting around the four dimensions: “Appearance”, “Environment”, “Space “, and “Function”.

This method will serve as a tool for the WP4 labs and be used as a common principle to gauge and understand the spatial aspect of the fieldwork.

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1. Introduction

1.1. Purpose of the document

This report aims to harness the knowledge of the partners and stakeholders regarding best practices in STEAM education with a particular focus on the activity's spatial needs and implications. The report provides a general overview of the development of school spaces and their opportunities for STEAM pedagogy. Consortia members and community-based actors were invited to explore and map structures and strategies across Europe that intersect STEAM educational theory and spatial design practices. Starting from this crowdsourced exploration by all partners and community-based actors, several good practices, experiences, or methods will be identified and characterised to inform general recommendations and guidelines when implementing spatial design strategies into the SENSE.STEAM educational model. The effort has brought out advice on how to address spatial settings of STEAM spaces to apply the SENSE.STEAM educational model and pedagogy.

As a general disclaimer at the outset of this document, it needs to be highlighted that the scoping report focuses on educational spaces in the "western" context, including Europe, North America, Australia and New Zealand.

1.2. Intended readership

The report will be publicly available and, as such, be accessed by the stakeholders and beneficiaries, as outlined in Deliverable 3.3. However, as a background document, it is predominantly directed at the consortium members in general and at the actors of the STEAM labs in particular to help design, reflect and develop the spatial setting of the STEAM practices. In each Lab, participants will co-create and share practices with other Labs, learning about and from each other. Two cross-cutting topics – Inclusion and Space, provide the basis for evaluating the reach and adaptability of the Labs across the different European sites. This report forms the basis of one of the cross-cutting subjects, i.e. the understanding of the spatial context.

1.3. Structure of the document

The report is structured in 4 parts. It commences with a short chapter about the research design, which, amongst others, explores the state of evidence-based design, followed by a background chapter on the evolution of educational spaces, including current "STEAM" spaces and their relationship to traditional classrooms. The central part of the research report consists of two chapters summarising two rounds of interviews: one with the research consortium members and the other with

stakeholders and educational Practitioners. The analysis of these primary sources is supported by case studies dealing with a range of educational spaces. The report concludes with a chapter that summarises the findings. Although in the appendix, the central output of the report is a short guide on how to analyse, use and operationalise the educational environment, which we will call the “Spatial Awareness Kit”. It is introduced in the summary chapter and appended.

1.4. Relationship with other deliverables

Similar to the cross-cutting delivery “D6.1- Scoping report on social inclusion and gender in STEAM,” the scoping report D5.1 will contribute to all STEAM labs. As the name suggests, it is a first step to collecting background knowledge and the knowledge of the research consortium, which will inform and shape the field studies in the STEAM labs.

Acknowledging the complexity of the subject and diversity of STEAM labs – and reflecting the diversity of the educational landscape in Europe, this report cannot - and does not want to - be a guide that provides highly defined recipes for the spatial arrangements of STEAM.SENSE environments. The conceptual impossibility of such an aspiration has been sufficiently explained in D 3.5. It is a base for an intense reflection process about STEAM and space.

The scoping report is a resource for the STEAM labs and will also be an initial intellectual base for the more targeted Deliveries 5.2-5.4 that will analyse the results of the fieldwork in WP4.

Furthermore, the report will not contain any lengthy explorations of SENSE. methodology in general or our understanding of how space relates to the user. This has been explored and summed up in deliverables 3.4 and 3.5.

1.5. Acknowledgement

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2. Methodology

2.1. The role of the physical environment

In the last 50 years, we have seen a growing body of research on how the physical environment impacts human beings. With the broadening scope of the social sciences since the 1960s and 1970s, the built environment has been identified as a key element in shaping human behaviour and social relationships. While the relationship between man-made physical environment – especially the urban form – and society has always been part of the evolving field of sociology (especially with the Chicago School but also already with Georg Simmel and Emile Durkheim (Schäfers 2015)), the particular interest in the exact mechanism of how architecture influences human behaviour and social structures has intensified in the 1970s – going hand in hand with a proliferation of architectural theory and environmental psychology. The works of Pioneers such as Adrian Leaman or Bill Hillier – to name only two - are still used and hugely influential today – one in the form of the BUS survey methodology (“BUS Methodology” n.d.) and the other in the form of space syntax analysis (Hillier et al. 1976). The last two decades have seen the growth of a Post Occupancy Evaluation industry that aims to research buildings' social and environmental performance. In the UK, for example, it is now mandatory for higher education buildings to be tested and evaluated after completion. However, this is far from a general industry practice (neither national nor international), let alone based on a widely accepted and standardised theory and methodology. (Leaman, Stevenson, and Bordass 2010)

Notwithstanding the vast spectrum of theories and methodologies, there is a wide and undisputed consensus amongst the many professionals and scholars dealing with the built environment's impact that its form plays a significant role in shaping human behaviour and society.

As educational buildings play a central role in society, it is almost natural that the relationship between school architecture and educational outcomes is part of this growing field of impact research, aiming ultimately at a better evidence base for new educational facilities. It is tempting to conceptualise the “perfect” school that supports the social transformation of society. While in the past, studies in this field often commenced with the caveat that the behavioural impact of the built environment is rarely analysed, this cannot be claimed any more. There is an

increasing awareness of the importance and availability of research, with affordance theory having entered the mainstream. However, as with the other architectural typologies, no accepted methodology exists. Studies that systematically analyse a larger number of buildings are rare. (Byers et al. 2018) Two of these kinds of more comprehensive research projects (Tanner 2000; Barrett et al. 2013), for example, have been recognised as exemplars (Morris, Imms, and Bradbeer 2023; Byers, Imms, and Hartnell-Young 2014) but are not without limitations. Both use quantified academic achievements as key indicators without looking at affective learning outcomes - a problem that applies to many studies in this field. Moreover, both rely on statistical, correlational analysis that leaves many questions about the concrete design impacts unanswered. Other more qualitative studies that address wider issues, such as soft skills, are often less transferable, usually derived from a limited number of case studies, and lack methodological rigour. (Byers, Imms, and Hartnell-Young 2014) It needs to be emphasised that this does not imply that this research is invalid; the contrary is the case. But its purpose is more that of an exchange of experience than transferable objective metrics.

A research project by the University of Melbourne has embarked on a DELPHI study to understand the gaps and scope of research in educational environments. The resulting White Paper describes our current understanding of research into educational spaces as follows:

> *Research into innovative learning environments has progressed in recent years, with good advancement in terms of initiating and understanding design innovations, developing more sophisticated evaluation techniques, and exploring the role of the teacher in using spaces well. However, one could argue that the field stands at a threshold. It lacks cohesion internationally, it recognises but does not necessarily service well the input and need of sectors other than education, and despite excellent smaller-scale studies, it has yet to really understand the experiences of students of all abilities in these spaces. (Imms et al. 2023, 1)*

The white paper identified several research gaps, with the evaluation of the effectiveness of design on academic and affective achievements taking the top 3 ranks. The white paper further suggested that

> *[...] a large-scale, international, crosssector project was required to build a robust evidence base and bring cohesion and direction to future ILE development. (Imms et al. 2023, 1)*

The researchers behind the DELPHI study seem to assume that this cohesion is possible, i.e., clear causation exists between the built environment and learning outcomes; however, better coordinated and more coherent research is necessary to come closer to a clear understanding of this link. However, the DELPHI study does not question the theoretical base for this assumption in depth and assumes a mostly Western-European context, which is already limiting. Although not expressed, it

implies an “ideal” school design is possible. Given the complexity of the subject, we might raise some doubts about this, especially since the definition of success is a similarly moving target like the evidence methodologies.

We can conclude that current research into educational spaces can be described as a grey area where most scholars agree that “space matters”. However, despite the expanding body of research, the potential impact of the physical form is more than ever heavily contested, as is the right criteria and method, with the pendulum periodically swinging in one or the other direction (Gislason 2011)

This scoping report is not the place to further elaborate on the methodological contradictions of building research or go into the depth of evidence-based design methodologies. The main reason we paint a broad brushed picture of the current research into the impact of school design is to highlight that the last 60 years produced an epistemological diversity which, to some degree, reflects the complex nature of the built environment. Certain themes have been evolving; however, no standardised model dominates. This diversity contrasts with the desire to quantify and standardise building research, i.e. reduce the “chaos” of current research. However, we would classify this desire as aspirational but less based on fundamental theoretical considerations.

In contrast, we suggest a different approach that – similar to our understanding of the SENSE. methodology– aims at living with ambiguity and complexity. For the SENSE. project, we propose to follow a more open route that promotes a structured, collaborative reflection of spatial conditions, specifically emphasising the specific context of the STEAM practice and personal experience. In short, there are no magic solutions, only magic conversations and contextualised reflections.

As outlined in Deliverables 3.5 and 3.4, the methodology underlying our research enquiry into the spatial conditions draws heavily on environmental psychology, namely the affordances concept, namely the affordances concept developed by J.J. Gibson in the 1970s and popularised by Donald Norman in the 1990s. This approach tries to combine subjective choice with objective conditions. It is well suited to capture the complexity and – at the same time – sufficiently pragmatic to be used for the concrete understanding of how space supports STEAM education by contextualising the spatial experience. Understanding and manipulating this context requires a continued reflection on how we interact with the physical environment.

However, it needs to be noted that with this method, it is difficult to impossible - and maybe unnecessary - to formalise and generalise STEAM Space design, as each context is different. Success also heavily depends on the teacher's and students' operational abilities – not to forget the array of socio-cultural influences. Moreover, each context - will define success differently. With so many variables, evidence-based design seems to be impossible. To deal with this pragmatically, we prefer to speak about spatially reflected design, i.e. an active engagement with the complexity of the process. Or, to cut a long story short, we need to talk about STEAM spaces.

2.2. How to talk about STEAM spaces?

We need to start this chapter with a disclaimer. It should be normal academic practice that the research subject is clearly defined. However, this is not necessarily the case for STEAM spaces as our understanding of their impact inherits multiple, definitory complexities.

One is the methodological heterogeneity of building impact research itself– as outlined in the preceding. There is simply no agreed way how to measure the impact of the built environment. The second one is that in neither academic nor grey literature is no clear agreement as to what STEM, let alone STEAM pedagogy is (Colucci-Gray et al. 2017). Consequently, it is difficult to impossible to define exactly what constitutes an appropriate, i.e. impactful STEAM space.

However, there is a general, one might say pragmatic consensus amongst educational practitioners that a workshop, lab, or other space for "hands -on" work - usually labelled as "maker space" are typical STEAM spaces. (Stakeholder Interviews-Appendix, 2023). There is by now a plethora of practical literature that deal with this new typology (Keane and Keane 2016; Brejcha 2021; Hudson and White 2019; Rendina 2015; Keane and Keane 2016; Morozova and Dukhanina 2020) and – as we see in our research – this is a reoccurring theme which we will not dismiss. Making as a form to unleash creativity is an essential part of current STEAM practice. Many practitioners we interviewed see "art" as the practical exploration that helps expand knowledge boundaries and unveils aspects of our thought process that plain words can never achieve. The line between creativity and creative thinking is easily blurred when the arts are applied across the subject spectrum. Using it as a tool of exploration rather than a method of producing a predictive outcome can help identify hidden strings, making the learning process transdisciplinary.

> *"I feel the arts and creativity are hands-on, like one of the best ways to kind of teach with young people or explore different topics with young people because it's a lot of it is practical. They're collaborating. They're kind of exploring and creative subjects. So I feel creativity can be really freeing, and especially for those who may have barriers or challenges and academically socially, I feel like the arts really kind of support them to flourish. There's no right or wrong way to be creative, or right or wrong way to do art, and I think that's the kind of joy and the like. There's so much freedom in it."*
>
> Interview O (Appendix), 2023

This quote above highlights two aspects: the practical application of creativity and the focus on the process of learning rather than the final factual takeaway. This ensures that concepts are completely understood. When this content is taught in spaces that encourage the free flow of information, these concepts are understood by every individual, and the opportunity to pick them apart and reconfigure them is also provided.

The first aspect, the practical application of creativity in the form of making, clearly connects STEAM practice with maker spaces. However, the second aspect, i.e. understanding of learning as a more informal process that permeates every aspect of the school building, can be understood as a reminder that reducing STEAM spaces to maker spaces might be slightly simplistic and does not reflect the extended idea of STEAM as formulated within the SENSE. approach.

Based on the theories of Christopher Alexander (Alexander 1978), architects Nair & Fielding (Nair, Fielding, and Lackney 2020) developed a series of design patterns that can be used as a toolkit for schools to extend capacities to accommodate a wide range of learning modalities. Working with "design patterns" was conceptualised by Alexander in the 1970s and has influenced many creative industry fields– especially webpage design and even engineering disciplines (Bhatt 2010). This scoping is not the place to discuss Alexander's seminal approach in detail; however, its adaption into the world of measuring the impact of educational architecture (Tanner 2000) has the potential to strike a balance between pragmatism, context and transferability. The concept of design patterns breaks down the complexity of design, making understanding its intricacy and context manageable and intelligible. Design patterns are created through observation, personal experiences and educational context, but not necessarily quantifiable evidence. The concept is more driven by observation of phenomena and often avoids a reductionist analysis. We have some reservations against the potentially formulaic nature of a fully pattern-based design approach. However, the method is relevant for our research as it highlights that we should not focus on "STEAM spaces" but a wider array of spatial constellations generated by experience and a reflected context. The STEAM labs will be instrumental in this respect.

To harvest this contextualised experience, the coping report contains in-depth interviews with researchers and practitioners to identify a range of ideas and patterns, which we see as an important base to start further investigations into the spatial conditions of STEAM. As outlined in deliverables 3.4 and 3.5, we understand the spatial conditions as a contextualised and negotiated field. This reflects the consortium's understanding of the SENSE. methodology as a dynamic concept, such as multi-sensory perception, process, and context, to challenge the epistemological base of science education as a whole.

The main output of this scoping report is, therefore, not a recipe guide for successful STEAM spaces. We want to highlight spatial aspects of STEAM education as part of a process. The resulting "Spatial Awareness Kit" aims to support this discursive, open-ended approach by creating a structure for an informed discussion that considers context and needs.

3. STEAM Spaces

3.1. The Evolution of Educational Spaces

It can be rightly assumed that knowledge transfer in some form of education has been a constant part of human culture. However, this is not the case when it comes to creating specialised educational spaces, although we often take this for granted.

The same applies to traditional classrooms as we know them: rectangular rooms with directed rows of desks and a blackboard – by now upgraded to a digital display – at the far end. There seems to be a common conflation of schools with this kind of "classroom", together with the somewhat negative connotation that classrooms are traditional relics of an older – yes ancient - time that must be overcome (Hnilica 2010; Nair 2011). In the context of this scoping report, it is worth reflecting on how school architecture arrived at this point. We will not provide an in-depth history of school architecture – others have done this much better (Gislason 2011; Seaborne and Lowe 2022; Silva 2018) – but a broad-brush description of the spatial evolution of Educational Spaces leading to current school layout principles.

What is generally described as the "traditional" closed classroom-based school is not much older than the mid-19th century. Before this time, schools for larger groups of students were mostly open-plan and multi-functional, without many (if any) specialist spaces. In pre-classroom schools, all students were taught in one space – in larger schools, maybe several large spaces on several floors - without much spatial differentiation. Students were not grouped by age but by ability. In English Grammar schools, for example, all students occupied one central room, sitting in pairs at desks that were bolted to the floor. A significant problem of this model was that the schoolmaster could offer only so much simultaneous instruction to the whole school, given the overall differences in student ability. As a result, most of the students were left to work independently or went unsupervised at any given time. This meant that groups of students were regularly left to self-directed learning, which often led "to disciplinary problems, the increased use of corporal punishment, boredom, and a lack of progress, particularly among the lower classes." (Gislason 2011, 231) The pre-19th century educational space was an organic – often messy affair with less social and educational control than one might assume. (Hnilica 2010)

Figure 1- Writing school of Christ's Hospital, City of London 1696 (Nicholas Hawksmoor) as example of an open-pan classroom pre-19th century. The building was demolished in 1902, (src.: (Harwood 2010))

To make this spatial arrangement more efficient and to deal with the growing number of students - following the introduction of compulsory schooling -, the classroom with large blackboards, specialised furniture and same-age classes was successfully introduced. (Buzbee 2014) This simple and rational spatial typology allowed standardised teaching contents to be taught by a single teacher to a relatively large number of students and efficient behaviour control. The Prussian school system at this time was the most innovative in Europe and was copied by many other countries, including the UK. (Seaborne and Lowe 2022, 24 Volume II) The development of the classroom system resulted from an intense research process. Especially in Prussia, a lot of effort went into designing the right school furniture that allowed to shape – and dominate - the student's bodies in what was considered appropriate (Hnilica 2010). Together with the classroom system, curricula were introduced that atomised knowledge into many subjects which were taught spatially disconnected – resulting in similarly disconnected epistemologies – a still dominant educational tradition that STEAM pedagogies aims to overcome.

However, it must be highlighted that the achievement of the classroom together with the school bench and blackboard in its spatial simplicity, cannot be overstated. It allowed society to leverage education across social classes and led to an unprecedented increase in literacy. Without the classroom, the Western/European

culture would be fundamentally different. Until now, this spatial arrangement has been at the core of the Western/European education culture. It is easy to dismiss the "traditional classroom" and ignore its success story that still forms the spatial basis of most contemporary educational spaces.

Almost from the onset, the classroom and its culture of social and educational control were subject to criticism. In 1895, John Dewey founded the Chicago Laboratory School, which tried to break with the contemporary learning model by rote and replace it with a student-centred pedagogy. This approach was reflected in the spatial configuration of the school building, which did not consist of traditional classrooms but a series of workshops – maker spaces, so to speak – which were "laboratories" of joined student-centred, hands-on enquiry. (Durst 2010; Hein 2004) Although not successful in all aspects, Dewey's break with 19th-century school architecture influenced a wide spectrum of other reform pedagogies that sought to express their educational philosophy in particular spatial arrangements. Steiner schools, Montessori schools, Bauhaus and so forth all aimed to facilitate and express their educational aspirations through a reconceptualization of the built environment. What unified most of these approaches was the rejection of the classroom, its teacher-centred education approach, and rigid furniture design. Especially school benches that aimed more at transforming and dominating the body were subject of Maria Montessori's ire. (Hnilica 2010)

The most radical spatial counter model to the classroom paradigm was the open-plan school concept, which developed in the USA and UK from the 1940s onwards, peaking in the 1970s. Early examples were the Crow Island School by Perkins/Will and Elo Saarinen (1940), which did not dissolve the classroom but deviated from the rectangular, directed spatial arrangement to create a more flexible space for multiple modes of learning and teaching. Especially smaller primary schools, like Finmere Primary School (1958-59), started experimenting with open-plan arrangements without classrooms as overarching principles (Franklin 2012). Finmere School incorporated three large spaces at its centre, which were complemented by a range of peripheral subspaces. The school layout avoided any corridor that might segment the free flow of the spatial continuum. Flexible partitions allowed a broad spectrum of learning modalities combined with a high degree of intervisibility, creating a SENSE. of community and acknowledging that learning and teaching are social activities. (Goodhart 2020). The architects David & Mary Medd went on to design many other schools where children-centred pedagogy went hand in hand with a free-floating layout, dissolving the classroom and avoiding any intersecting corridors. (Lacomba Montes and Campos Uribe 2018)

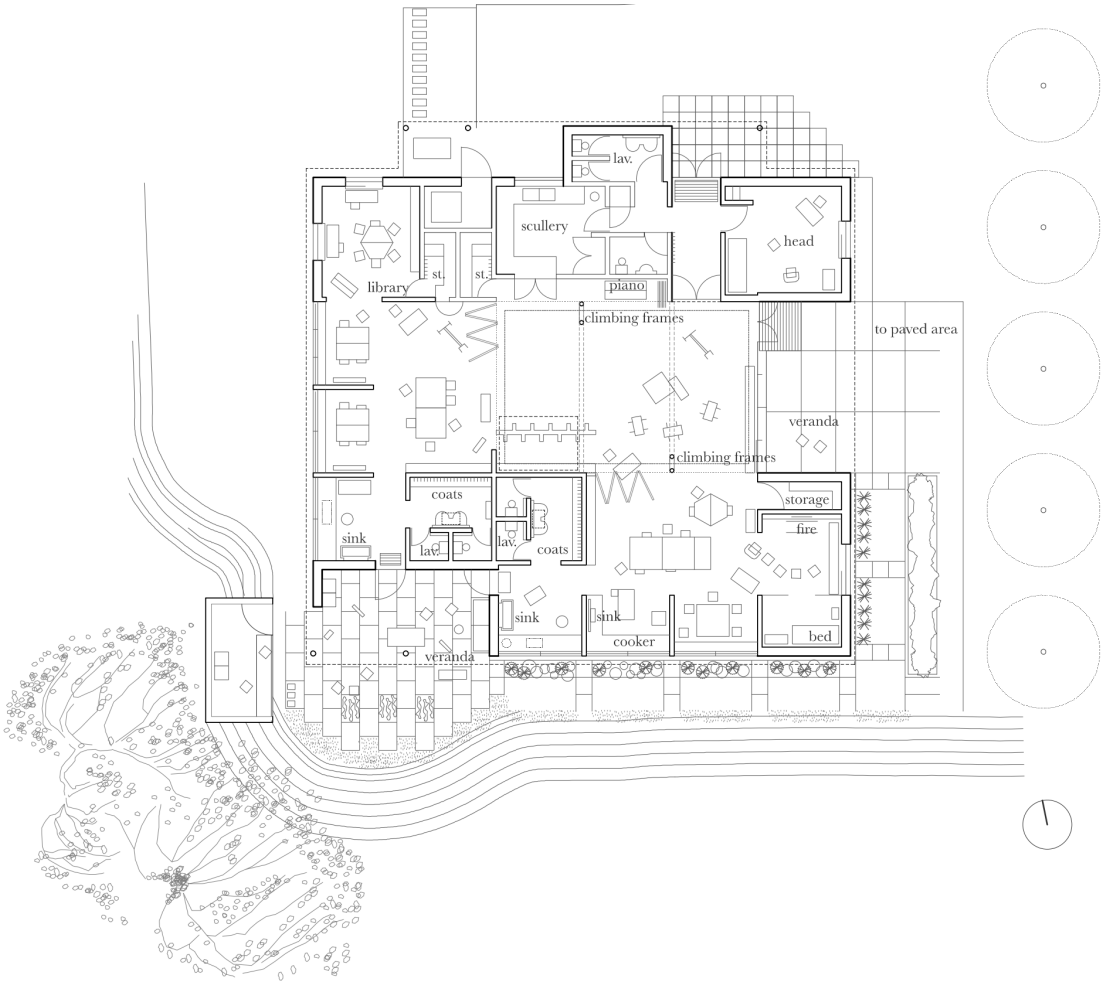

Figure 2- Finmere School, David and Mary Medd (1959), (src: Lacomba Montes and Campos Uribe 2018)

In the 1960s and 1970s, open-plan principles were developed further, resulting in schools with large mono-spaces with furniture or removable partitions becoming the main means of spatial organisation, such as for the Laborschule Bielefeld (1974), which consists of one large volume which is differentiated into sub volumes and sections; however, students always feel that they are in one big space (Zenke 2017).

Figure 3- Laborschule Bielefeld, Ludiwg Leo (1974). Open Plan School Layout , (src.: Zenke 2017)

By the 1970s the open-plan school had become an accepted alternative to the established classroom-based model – although still representing a small percentage of the overall stock. Open-plan schools were especially successful in the US and Canada, while the “pure” version was less common in Europe.

However, after curricula changes in the 1980s and 1990s the number of open-plan schools in the US and elsewhere decreased significantly, with many existing schools being converted and subdivided into classrooms. In some cases, this was caused by severe problems with acoustics, ventilation and daylighting, making operating the spaces challenging. (Zenke 2018)

However, the main reason for the development was that educational practices in many countries returned to more traditional teaching and quantitative performance assessment methods better supported by teacher-centred structures, followed by a change in teachers' and parents’ attitudes. (Gislason 2011) If teachers and parents do not buy the more complex principles of open-plan schools, they will perform inadequately.

Moreover, from the onset, the debate about the right school layout has always been political, with open-plan principles being labelled as “liberal” and traditional, teacher-directed classrooms as “conservative”. The increasing intensity of this “school culture war” has made a well-informed assessment of school layouts more complex than ever. School layout is not only educational but has also become a socio-political statement. (Cuban 2017; 2006)

However, it needs to be noted that the principle of a - at least partly - dissolution of the classroom and especially a flexible attitude towards furniture arrangement has become a part of the classic school design canon. While the traditional teacher-centred classroom somewhat saw a renaissance in the 1980s and 1990s, the open-plan approach continued in the form of specialist spaces – like workshops, labs or art spaces - and in the increasing use of communal areas for informal teaching and learning elements. This tendency has continued to grow steadily in recent decades (Harrison and Hutton 2013).

From today's perspective, it could be claimed that the last 80 years have seen a productive fusion of the open-plan and multifunctional pre-19th century school layout with the Prussian classroom culture. The history of education design has often been described as changing between informal, less determined open settings and formal classroom structures (Gislason 2011). However, we would argue that both approaches were always available, as dynamic design patterns with the constant development of new strategies often as rephrased old forms, resulting in the current diversity of spatial options.

Many new schools built in the last 20 years contain traditional, closed classrooms in combination with flexible furniture layouts and open-plan elements, such as specialist STEAM spaces. We picked three sample layouts to illustrate this mixed spatial mode. The three schools – all built or conceptualised in the last five years show a mix of open and flexible spaces and avoid any corridors. Circulation, communal areas and places for informal learning are combined, allowing for a wider range of educational settings.

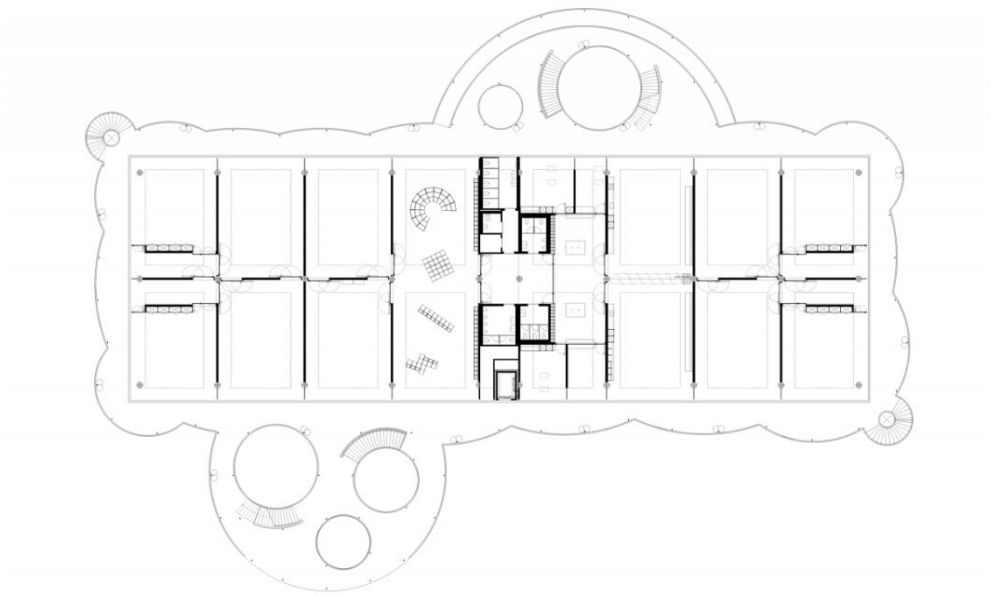

Figure 4- Schulhaus Wallrüti Schneider, Studer Primas Architekten (2022), (src.: baunetz.de)

Figure 5- Sekundarschule Laufen, Thomas Fischer Architekten (2021), (src.: baunetz.de)

Figure 6- Concept Design "Nuove Scuole", PPGA Architekten (2022), (src: PPGA)

There is also a tendency (for example, Figure 5, 6) towards a squarer form of the classroom for more flexible use – and to curb the directional affordance. Some schools also started including outdoor spaces as another form of "open-plan" approach in their extended spatial offer.

The described "mixed spatial" approach acknowledges an existing classroom culture that has proven successful and is a widely accepted and tested tool for education by simultaneously offering alternative models.

Whilst we see many schools trying to make the best of both worlds – as much as curriculum and financial constraints allow – the last decades have also been a renewed push towards open-plan schools, especially in Scandinavian countries (with Finland considering setting "classroom-less" schools as a new spatial standard see Fig 7). (Niemi 2021; O'Sullivan 2017). The OECD is supporting this trend with extensive research. (OECD 2017; 2013)

The arguments for this new push towards open-plan are similar to the original concepts: student-centred, hands-on and project-orientated education in spaces that allow a wider range of learning and teaching modalities than the traditional classroom. (Nair, Fielding, and Lackney 2020) In this context, STEM/STEAM is seen as

better supported by less formalised education environments. (Hudson and White 2019)

Figure 7- Kastelli School and Community Centre, Lahdelma & Mahlamäki architects (2014), (src. Lahdelma & Mahlamäki architects)

Another shift in education linked to a new wave of open-plan layouts is the introduction of digital technology into schools. While hybrid teaching methods such as the flipped classroom have become common in the Higher Education sector, the digitisation of schools has not yet similarly advanced beyond a supporting role. However, some schools have started to use the full potential of digital media to test a personalised, self-directed learning approach that comprehensively replaces traditional pedagogies. The Alemannenschule in Wutoeschingen is an interesting example of this new development. In contrast to conventional schools, it does not use classrooms, textbooks or collective timetables. Students can largely choose how, where, when and how they learn. The central tool for students and teachers is the laptop and (Institut für angewandte Kindermedienforschung iPad with a program called “DiLer”, the school’s digital learning platform, which sets and controls learning progress. Teachers have access to the student's data, are well informed about the individual progress, and can tailor the support individually. (Institut für angewandte Kindermedienforschung (IfaK 2022) The school layout uses a version of activity-based working (well-known from the commercial office world), offering a range of settings for specific activities. Students who want to learn alone and focus can use more confined niches in “mini houses” within a larger space. If help of a teacher is

needed, students can meet them in the centre of the large space. Other areas are more suitable for group work, there are specific spaces for “Input” etc. A characteristic of activity-based learning environments is that the physical environment is not flexible, but the student is. Each space has a clear purpose, and it is the free choice of the student which area is best for their current learning process. This setting is easy to operate as the layout needs less adjustments

Figure 8- Activity-Based Learning Environments in an open setting (src. Alemannenschule, Wutoeschingen)

A similar approach follows, for example, the Swedish Vittra schools designed by Rosan Bosch. Students freely use an elaborately designed learning landscape with very defined affordances. The learning progress is structured by the laptops every student has to use.(Rosan Bosch 2011)

Figure 9- Activity-Based Learning in Open Spatial Settings, Rosan Bosch (2011) (src: Vittra Telephonen, Sweden)

The Alemannenschule in Wutoeschingen is currently introducing a STEAM orientated curriculum with workshops labs etc., that follows similar activity-based learning principles. (Hohenloher 2021)

It is often claimed that digital technologies complement and extend STEAM education (Leavy et al. 2023). While we do not want to discuss this claim in the scoping report, we would like to highlight that it might be questionable if the digitally supported personalised learning method and the activity-based layout in the Frankenschule/Wutoeschingen are a natural match for STEAM. Especially the SENSE. approach, which relies on a sensual exploration, might be limited through the enhanced control of the digital medium. While current STEAM approaches can draw from a broad range of spatial knowledge and experience, which allowed schools to understand and overcome the limits of the 19th-century classroom, it might be that digitally dominated and, hence, controlled learning introduces an element of determinism and control that especially SENSE. strives to overcome. We currently benefit from a wealth of spatial experiences and knowledge. Will the trend to personalised digital learning render this unnecessary or even unwanted? Or, in other words, will digital devices of a personalised learning approach become the Prussian school benches of the 21st century?

3.2. Current STEAM Practice or: The Classroom Conundrum

Acknowledging that STEM education and its extension as STEAM eludes a clear-cut definition, there are nevertheless two points most involved professionals agree on:

- STEAM education uses hands-on approaches – project-based, student-centred, interdisciplinary "learning by doing".
- The traditional classroom is not ideal for this, and a large, flexible workshop type of open-plan space is preferable.
  (Hudson and White 2019, 73)

There are diverging opinions about what STEAM spaces are, but generally, it is agreed that this cannot be the traditional classroom.

> *"The classroom the most visible symbol of an educational philosophy. It is a philosophy that starts with the assumption that a predetermined number of students will all learn the same thing at the same time from the same person in the same way in the same place for several hours each day. A classroom's simplistic design also assumes that a significant part of a student's learning occurs in the transmission of knowledge from the teacher in a somewhat linear fashion. [...] This makes eminent sense if that is, indeed, what learning is all about."*
>
> (Nair and Fielding 2013, p.13)

This quote is the departing point of Nair, Fielding et al to dismiss the classroom as a limited and outdated typology, suggesting the need for a greater variety and complexity of educational design. This opinion is echoed in the many interviews we conducted for the scoping report – on both functional and symbolic grounds, with the classroom being a "symbol" for a particular educational approach. A STEAM space is essentially a "not-a-classroom" space.

So why is the classroom still with us? Nair and Fielding blame many countries' outdated regulatory and budgetary frameworks (p.14). We can confirm this to a certain degree from our professional experience as architectural practitioners. However, blaming "stifling regulations" hides the fact that the classroom and blackboard are ingeniously effective spatial inventions that survived many reform attempts. Traditional classrooms allow one person to multiply their knowledge easily; simple affordances like closed walls and directed seating support efficient behavioural control by embedding social control into a physical environment that reduces the sensory input to facilitate a linear knowledge intake. Classrooms are comparably easy to operate and deeply embedded in the European schooling tradition as they come with well-rehearsed standardised behavioural patterns. The personal value of this might be disputed – but the traditional classroom is a solution that has seen stubborn resistance against change. In comparison, other spatial modes

of teaching require a higher operational complexity, which not every teacher or student – let alone parents - is willing to accept.

However, from a more differentiated, learner-centred educational perspective such as Sense., the traditional classroom appears fundamentally unsuitable.

So what to do? One of the most common answers to this conundrum of 'we can't live with or without classrooms' is to create a new specialised room typology, the STEAM workshop or other facilities like labs or outdoor spaces, including a whole suite of new STEAM-oriented furniture. While this "add-on" approach is a pragmatic solution that works more or less well within most European curricula, it does not address the situation fundamentally. As many interviewees mentioned, it creates a STEAM realm that coexists and competes within a more formal spatial environment. As one of the interviewed design and technology teachers stated (Interview K and P- Appendix, 2023), a true school-wide STEAM collaboration is difficult as long as there is no spatial intersection. Some schools, like the UCL Academy, have integrated their STEAM spaces more centrally. However, clashes between teaching principles and spatial settings persist to a certain degree in many other schools. STEAM spaces often remain an addition.

However, the ambition of the SENSE. methodology is to go beyond STEAM as an add-on but as a principle that permeates every aspect of the school. Does this mean that closed classrooms have to be abolished? This could be one possibility, but as highlighted in D3.4 and D3.5, there are no golden formulas. Making a certain type of space mandatory might not help either.

Many educationalists acknowledge the quality of the classroom as a defined space that gives students social identity, which might improve learning outcomes and social competence. Even if a "class" does not have a dedicated room, i.e., changing location throughout the day, the socio-spatial relationship, a group of people in an enclosed space, creates a strong bond – potentially stronger than in a less defined spatial environment with varying group compositions. Removing the classroom might alter the social dynamics and opportunities. However, the relationship between social identity and layouts is a less researched field. (Watkins 2005)

Many attempts have been made to extend and develop the traditional classroom as a learning landscape with L shapes, niches, flexible furniture, etc. Originally conceptualised by Perkins and Will in 1941, with many iterations throughout the 20th century, traditional classrooms have been relaunched as "learning suites" or "studios" often in combination with semi-transparent large doors or moveable walls (Nair 2011), all aimed at dissolving the overdetermination of the traditional classroom.

Given the functional complexity of readjusting furniture arrangement, moveable walls, etc., there is only so much one can do. As some interviewees pointed out, many teachers fall back to the traditional educational model.

Still, we would suggest acknowledging the classroom as a given reality and engaging in creative dialogues with it rather than farcing new typologies as mandatory replacements. We see creating space as a constant discourse. So why not allow students to paint the room walls? Why not let the users arrange the classroom themselves or turn it into an improvised maker space? Why not use the classroom as a place to practice spatial agency? Why not hack it? The reflection and creativity this requires from teachers and students is already a good step towards the implementation of SENSE..

4. Stakeholders' views

The research team at HB engaged with a group of Stakeholders[1] by reaching out to schools and other educational institutions/professionals that showed interest in adapting a STEAM approach or already had resemblances to one within their existing curriculum or activities. We invited each stakeholder to semi-structured interviews to understand their idea of STEAM and discussed the SENSE.STEAM methodology with them. The collated views expressed in the following chapters are from these interviews.

4.1. Spatial Configurations

Most interviewees agreed that the traditional classroom had serious limitations for STEAM education. It was acknowledged that more suitable spatial configurations were being developed, emphasising flexibility and open-plan. However, most classes are still run in traditional classroom settings. To make classrooms more STEAM-ready, students and educators would have to creatively adjust their space by using furniture that can be arranged. As one interviewee pointed out, this would involve wasting a good part of the lesson and can result in increased noise levels. The disconnect between 'space and use', results in teachers resorting to easier and more 'tried and tested' teaching methods that allow them to maintain order amongst students. With a struggle to collaborate across subjects, it also becomes harder to connect content across curricula and choose a method of delivery that allows for both transdisciplinary connections and an in-depth understanding of concepts to be developed.

The closed-off, obscure nature of classrooms as a "black box" was criticised, too. An interviewed stakeholder (Interview P-Appendix), 2023) told the research team that having a large workshop space with glass windows surrounding two sides of the room allowed for a high engagement and more expressive creative outlet amongst students due to the exhibitory nature of the classroom. While this space also has the capability

[1] The selectinon of stakeholders have been limited to London and Ireland due to the reach of HawkinsBrown's school outreach programme connections. It was limited to these two places as these were the schools that are participating in the STEAM Labs led by Hawkins\Brown.

to distract students, the activities run here need to be engaging enough to promote a sense of chaotic order that still produces interesting results.

> *My classroom is three stories high. It's a central circular room in the middle of the school, and it's got a glass roof. There are two levels of windows that go on a circular corridor that can peer into the room. And, you know, it's a real pain in the neck to teach because students love to press themselves against the glass and look in. But then also the wonderful thing about teaching there is that when something is interesting going on, students see it from the outside. The room is always visible.*
>
> (Interview P-Appendix, 2023)

But the reality is that teachers do not always have a choice:

> *"Most teachers just make the best use of the space that is given to them."*
> (Interview N-Appendix), 2023)

As brought into consideration by some stakeholders (Interview L, P and O-Appendix 2023), workshops appear to be the more future-facing learning environments in schools. Many schools have only a limited number of workshop spaces and would need to change drastically to become maker-based workshop learning environments.

A big, bright workshop with seamless indoor and outdoor spaces will make for more flexible and integrated learning environments while also aligning with the needs of current STEAM curricula that incorporate many hands-on activities. As highlighted by several stakeholders (Interview S, K and O-Appendix, 2023), large open spaces and the seamless transition between indoor and outdoor areas will allow for a sense of freedom amongst students to enhance their creative and critical thinking abilities.

> *"Flexible and multifunctional spaces are essential to run a successful STEAM space. Larger spaces make it easier for students to think freely and look at their tasks from different angles. This is the main purpose of our dream space laboratory."*
>
> Interview S (Appendix), 2023

The interviewees saw outdoor space as an essential extension to maker spaces. Firstly, it enabled larger or "dirty" projects, which would be impossible to carry out indoors. Secondly, the liberating and stimulating effect of the open environment would give students "a different, fresh" perspective and lead to potentially less conventional learning outcomes.

The size and open-plan arrangement of larger maker spaces were seen as sometimes challenging, where it is easy to lose a student's attention. If the room is too big, students get distracted trying to take in their surroundings, and if it is too small, it is more likely to disrupt classes (Interview P-Appendix, 2023). Behaviour management can also be challenging, although one teacher pointed out that working "self-directed with an aim in a group" can lead to better focus and less disruptive behaviour. (Interview P-Appendix, 2023). The 'Goldilocks Principle" extends onto space whereby students can lose focus when an area is under or overstimulating or too small or big.

In this context, one Interviewee (Interview O-Appendix, 2023) raised an interesting point: To keep students engaged students should constantly change the spatial environment.

> *"By not allowing them to get too used to one space, they are kept on their toes. It doesn't matter if these new spaces are within school premises or within 'culturally charged' external locations. The main intent is to keep their senses sharpened to induce a well-rounded form of learning."*
>
> Interview O (Appendix), 2023

Next to the maker spaces, another typology, the extended, open-plan circulation area between and in front of classrooms, has become a space to specifically support STEAM education. (Interview Q-Appendix), 2023) The research team visited the UCL academy in London, which runs a specific STEAM curriculum, i.e. project-based, interdisciplinary assignments complement the national curriculum. Open-plan "super studios" in front of traditional classrooms provide flexible space for various teaching and learning modes to support this educational approach.

> *"These super studios are designed to be collaborative spaces in the central corridors of their school. With the capacity to accommodate up to 90 students within each studio. This is where students come to do group work of focus work"*
>
> Interview Q (Appendix), 2023

Learning and teaching facilities are enabled through flexible specialist furniture. Miniature amphitheatres, for example, can be taken apart to create smaller group and individual study configurations. The sofas are also made of thick fabric that helps create a sound barrier of sorts and helps diffuse any disturbance that may be carried across the corridor.

> *"These setups are easily accessible, and students are found to be spending nearly 60% of their teaching and independent time here."*
>
> Interview Q (Appendix), 2023


Figure 11 & 12 Central Corridor Space used for collaborative learning; Close-up of the Super Studio, (src: Penoyre and Prasad)

While the spatial set-up fulfils the functional needs of the STEAM curriculum, the interviewee admitted that the operation of these spaces can be challenging – not because it is difficult to control noise or light – but due to the lack of educational practice of some of the students and teachers. Especially after the COVID years, many students and teachers find it difficult to change back into a project-based collaborative learning and teaching mode.

Overall, the discussion with the stakeholders gave the impression that the advent of STEAM pedagogy, which was generally described as collaborative project-based work across subjects, usually involving a physical output, materialised first in the art studios or newly introduced larger Maker Spaces. In some schools, it seems to be creeping into enlarged, multifunctional circulation areas but has yet to reach the classroom, where traditional spatial conditions prevail. Typical spatial conditions for STEAM spaces in this sense – and all interviewees confirmed this – are larger multifunctional open-plan areas. Interestingly, drama performance spaces that can be part of STEAM education played no role in our conversations. Whilst this aspect was highlighted by research consortium members (Interviews E K and G-Appendix 2023), it did not play much of a role in stakeholder interviews.

Transferring these layout typologies to more traditional class settings might also help increase engagement in those subjects whilst encouraging transdisciplinary knowledge exchange, but this seems to happen rarely, although the potential was acknowledged: Making adjustments to current classroom configurations can help create fluid spatial experiences that allow for students' true behavioural patterns to emerge. Students will feel more comfortable in their learning environments, which enables teachers to make necessary educational changes. However, dynamic furniture layout changes often require additional operational time resources that teachers in curriculum-driven school environments do not necessarily have. (Interviews M and G-Appendix, 2023).

“Teachers can teach a STEAM lesson every week. But just 1 hour. They could do whatever they had on hand, but they needed more time. It takes a while before the space is prepared. Instead, they would have needed 3 hours in a block or more flexible space, or so.”

Interview G, Adelina Dragomir, 2023

Most teachers in the stakeholder group (Interview K, M, and Q-Appendix), 2023), admitted that until the current curriculum changes, STEAM will stay an add-on to the traditional classroom. Another aspect that was raised in one interview was that STEAM spaces need to support social interactions, which are more important in self-directed project-based work. Good STEAM spaces should ideally allow unexpected social exchanges and shared activities to occur while maintaining the objective conditions needed to perform. This social activation is crucial to the ideation process and overall learning outcomes. This can also have an impact on the way formal versus informal classroom activities (e.g. public presentations) are valued across the school (Interview L-Appendix, 2023).

4.2. Operation

Adjusting and adapting the spatial environment to promote individual spatial comfort will allow all the students to remain supported through their learning journey.

Teaching students in group settings where they can see how everyone interacts with the material will help open them up to different perspectives and learning methods. STEAM spaces need to support social interactions, which are more important in self-directed project-based work. Ideal STEAM spaces should enable unexpected social exchanges and shared activities to occur while maintaining the objective conditions needed to perform. This social activation is crucial to the ideation process and overall learning outcomes. This can also have an impact on the way formal versus informal classroom activities (e.g. public presentations) are valued across the school (Interview L (Appendix), 2023).

Some stakeholders (Interview K and M (Appendix), 2023) also stressed how some students put more pressure on themselves by being perfectionists.

“Girls are less willing to fail in a way that they're perfectionists. They want to, you know, be good at things straight away rather than maybe failing, then learn from their mistakes.”

Interview K (Appendix), 2023

Working in groups and having more informal presentation boards or differentiated spaces with visual privacy for the students who need it can help eliminate any unnecessary stress they may put on themselves. It is equally important for teachers to focus on the process of learning rather than the final examination outcomes to relieve this pressure (Interview K (Appendix), 2023)

There was a consensus among the stakeholders that STEM subjects were inherently creative and need to be reconstructed to revive that creative spirit - and attract a wider student demographic.

> *"STEM process is a creative process, but it's not often recognized as that. But with the inclusion of the A in steam for arts, it will obviously appeal to more students."*
>
> Interview M (Appendix), 2023

> *"Traditionally, maybe people who are creative might not enjoy the sort of maths and science side of things, but allowing them to see them within arts, you know, maths and science can be used to benefit and make art even more exciting. So seeing that sort of crossover of where art meets science is helpful."*
>
> Interview K (Appendix), 2023

While this requires some organisational reforms where teachers need to be just as involved as the students, spatial interventions can also help guide any actions that users may engage in. Focusing on what functional tools may be needed and what environmental changes need to be made based on the intended spatial experience can help create an ideal space for STEAM activities.

The interviewed stakeholders were aware that adjusting a typical classroom configuration to an informal maker space can change the way users behave and think within a space. When users have access to their ideal learning environment and any resources they may need, they become more receptive to alternative teaching methodologies and methods. Spaces have the power to broaden education practitioners' perspectives on creativity and creative thinking. Thus helping enhance how subjective views can be woven into the delivery of objective content. By tweaking school design to unconsciously encourage participatory activities, students can be encouraged to remain involved in social learning activities while focusing on their exams. This can only be achieved when teachers interact with their students enough to notice gaps in their learning while also being involved in design processes to facilitate these passive interactions. For this reason, constant feedback must be an organic part of schools' spatial practice– something common in many cultural institutions – but not necessarily in schools. (Interview O (Appendix), 2023)

With older students becoming more focused on examinations, they have less time to participate in extracurricular activities that take a transdisciplinary approach. Most interviewees identified the rigidity of curricula, together with "high stakes" exams as the key factor why classroom teaching still dominates the spatial practice of most schools:

> *Key barriers to more open-minded science education are [...] high stakes exams providing restrictions. The other constraints are resources and skills and, of course the right equipment.*
>
> Interview M (Appendix), 2023

> *"It is a struggle in secondary schools anyway to collaborate across different sort of science, technology, engineering. I've really struggled in the past with getting teachers on board because everyone has to try and teach their curriculum content. So it's the restraints of the curriculum and focus on passing exams which is the problem at the moment."*
>
> Interview K (Appendix), 2023

One way one of the interviewees (Interview K-Appendix, 2023) could deal with inner school resistance to STEAM pedagogies and lack of educational inspiration was to tap into external networks that any educator or changemaker can contribute and have access to. Several such organisations (Scientix, Science on Stage, and Camden STEAM Hub were named) already exist in England (but also internationally), proving invaluable inspirational resources. It helped relieve pressure on producing enriching material, shifting the focus to enhancing students' learning experience. The core idea of pooling resources is also inherently within the style of STEAM, as it helps redirect focus to the learning process rather than achieving set outcomes.

A last quite mundane, nevertheless important point highlighted is good teaching resource management, where spatial arrangement overlaps with organisational management. Accessible and well-structured school resources are an intended "byproduct" of a good spatial design. A space cannot be classified as a "well-designed and functioning space" if it doesn't integrate the needed resources. Accessible storage, digital connectivity, well-stocked physical and virtual libraries and digital tools are organised by good resource management. However, providing and improving on these resources becomes harder if the overall spatial setting isn't appropriate to the learning model.

> " *We traditionally work in laboratories which, as an architect, you are aware is not very flexible [...] which doesn't lend easily to spaces that can be transformed to what we would describe as much looser maker space."*
>
> Interview M (Appendix), 2023

What – in other contexts - might be described as an incompatibility between hard and software, between the organisation of space and pedagogy, often manifested in little details such as a tap at the wrong place, is, in fact, a not too insignificant roadblock on the way to a more efficient integration of STEAM in current educational practice.

4.3. EDI and Reaching out

The various aspects of EDI did not play a central role in the conversations with the stakeholders. All interviewees agreed that one of STEAMs great potentials is attracting a student demographic to STEM subjects that might otherwise not be pursuing them at school, with an overarching emphasis on positive effects for female students. Two of the schools we engaged with had integrated STEM/STEAM deeper into their curriculum (Interviews Q & S (Appendix), 2023). Both reported a significant increase in interest in sciences by female students.

The Google Global Science Fair was won by the three girls who had previously won the European Young Scientist. And when they won the Google Global Science Fair, there was $10,000 given to the school. [...] By now, the girls are performing better and are overrepresented in the STEAM courses.

Interview S (Appendix), 2023

However, the interviewees did not describe spatial configurations that worked particularly well for a specific student group characterised by gender, ethnicity or socio-economic background. Success was attributed to the wider STEAM strategy, which indirectly confirms the inclusive potential of STEAM spaces in their schools, which were mostly multifunctional open-plan areas.

Another theme we discussed with the stakeholders was the potential of STEAM curricula to be taught outside of school in various locations. While some schools had successfully participated in extra-curricular STEAM activities in non-school locations, this has not been systematically tried or considered. However, it was understood that it is important for students to experience learning in different environments to immerse themselves within environments that people from different walks of life occupy. This will allow them to be engulfed within different perspectives that can spark a sense of creativity that might otherwise be absent in a more traditional school setting. Adapting to change will enable students to become more observant and give rise to the ability to make connections that might have otherwise been impossible. There was appetite amongst the stakeholder to expose their students to new environments; however, a strict curriculum, exams and logistical issues make this harder to plan around. The STEAM curriculum emphasises how such culturally charged field trips can benefit students. It would, therefore, be desirable to convince school management to be more susceptible to making the necessary changes to integrate this learning methodology within their curricula.

“There's a potential that hasn't been unlocked within cultural institutions to extend their offer, which can then be bridged into schools because apparently quite a lot of math teachers want cultural visits for their classes. But they can't find any because there isn't the confidence to do it.”

Interview O (Appendix), 2023

The potential of STEAM education to systematically integrate the space outside of the schools into curricula, making active use of the diversity of urban environments, thus converting every space into a learning space, has yet to be developed.

5. The Research Consortium's views

5.1. Space matters

The Research consortium generally agreed that the physical environment has an impact on educational outcomes. The role of space while assessing the success of a STEAM practice is seen as crucial as the physical environment can greatly influence the designed activity's results.

While some interviewees pointed out that there are situations where space plays a negligible role (Interview F- Appendix, 2023) (and this might even be a desirable outcome), it was generally acknowledged that the physical environment is the underlying determinant that skews the process.

> *"Space plays a huge role in education. Especially today as- Separation in subject teaching is a 20th century model, taught within 19th century classrooms, while trying to set 21st century educational skills"*
>
> Interview C, Anne Krebs and Ines Moreno, 2023

For example, when students are taught in a classroom, they spend most of their time in and then enter a new environment, they receive and analyse any presented knowledge in different ways. If this new environment is distracting, they may not absorb as much. Similarly, suppose students are in a space that relates to the learning contents in unexpected ways. In that case, they may be able to form connections they may never have established within their usual classroom. It was acknowledged that students do not always need new environments while learning new content. However, as many interviewees pointed out, it might be helpful if they had the agency and resources to amend their existing environment to suit the changing needs. It was seen as important that classrooms and schools can be spatially reconfigured to engage users at a deeper level with the learning process.

The social role of the physical environment was also highlighted. Space helps create and strengthen bonds between teachers and students, connecting and relating in a way the virtual world has yet to achieve.

> *"School environments make you share experiences with each other that you may not otherwise."*
>
> Interview A, Florian Theilmann, 2023

Space can be a place where all the senses can be simultaneously stimulated, enhancing the user's experience. Suppose the teacher always remains at the head of the classroom at a distance from the children. In that case, they may be perceived differently from when they are able to sit within student groups and engage in more

meaningful conversations (Interview B-Appendix, 2023). Similarly, children may learn better when allowed to interact with their peers and spatially configure themselves to suit the needs of their lessons. When space allows for different interactions to occur within it, the flow of knowledge and the quality of the content can be invigorated.

> *"When the time for a new course comes, usually we all together create the space where that the course is going to take place."*
>
> Interview B, Theodoris Kostoulas, 2023

When users understand the values built into space, they acquire the ability to overcome these conventions. Using the physical environment in different ways will open up a wide range of options on how the same space can impact the same activity differently. A stage, for example, can have a wide array of influences on how students learn mathematics. All interviewees agreed that spatial context matters.

Accessible space also means different things to different groups (Interview E-Appendix, 2023). While it can refer to the well-equipped nature of a space, it can also refer to the physical ability to approach and engage with a physical space.

Throughout the interviews, the consortium members highlighted the importance of understanding what the word 'space' means to all its potential users. Can a sense of adaptability be woven into the physical realm to make it the participative social forum that we know it has the capability to be?

5.2. Towards STEAM

To fully grasp the relevance of STEAM, it was highlighted that it is important to understand how science has constantly been seen as a fix to societal issues, whether rebuilding after the world war or replacing the power previously given to religion. Science was seen and accepted as the 'above all' (Interview J-Appendix, 2023), assuming control over the reframing of society. While STEM is already attempting to get away from the siloisation of traditional science, STEAM aims to become a conscious and responsible way of improving society. By inculcating diverse voices to create a new, inclusive, and adaptable society, it perseveres to remain everchanging and cater to the evolving needs of our diverse society. As pointed out in the interview with the University of Edinburgh (Interview J-Appendix, 2023), STEAM is an attempt to democratise the process of knowledge production. These concepts are easier to grasp during the introductory phase, making education more accessible. This welcoming nature will allow for a wider spread and mix of knowledge systems, addressing and aiding the different ways STEAM can manifest itself. However, this flexibility also provides space for derivative meanings of STEAM, which often might be too simplifying. It is, therefore, important to allow for flexibility while simultaneously creating a strong vision that stays alive at the core of every alternate version of STEAM produced worldwide.

"STEAM was brought in as a construct to improve and enhance STEM, to make STEM better, for example, make science more interesting for girls. In the United States, they have a curriculum called STEAM curriculum, which is explicitly designed for girls, for people of colour and for indigenous groups. I am horrified when I see things like that. It's almost like the remedial practice for those who can't make it. So within a particular political system, like in the United States, this is the shape that STEAM takes. We are not there in Europe yet, so I feel that there is still a possibility perhaps, to introduce a counter narrative or a counter discourse, and this is my work."

Interview J, Laura Colucci-Gray, 2023

As pointed out by multiple members of the consortium, STEAM cannot be simply viewed as STEM with the addition of art but rather as its own entity that softens the edges of each subject and creates both an underlying and overarching link that makes learning transdisciplinary. By emphasising sensory evoking soft skills, it aims to shed light on the fact that STEM subjects are also inherently creative. This gives us the opportunity to reevaluate current practices to create a more enhanced learning experience. The use of STEAM should be promoted within STEM subjects to the extent where there in no such thing as STEAM. Rather, what remains is the 'transdisciplinary approach that considers different possibilities to co-construct knowledge, understand problems, explore possibilities and meet different needs' (Interview J-Appendix, 2023)

"For the Medical Sciences, drawing was something that was quite well established as a practice and as a means of developing their sensitivity for form, shape, volume, texture, close observation and so on. Drawing here is being recognised as an important skill to have for surgeons as it focuses on hand-eye coordination. We need to bring that back in various forms such as making models and through actual practice."

Interview J, Laura Colucci-Gray, 2023

While an emphasis is put on STEAM to be transdisciplinary, it is also important for us to look at STEAM as a collective knowledge production system that is connected to social phenomena. People need to remain at the centre of STEAM- whether it is studying the role in the production of knowledge, their experience while being embodied within the content or the impact that this content has on people. Focusing on the interconnectedness of STEAM and society will produce a better informed and thus better-formed society (Interview H-Appendix, 2023).

"It's not about the discipline itself it's about how together maybe we can better read reality better. Specific contexts matter more than disciplines."

Interview F, Josep Perelló, 2023

"STEAM is all about making connections between disciplines to form a bigger picture."

Interview G, Adelina Dragomir, 2023

By providing students with various opportunities to access information using multiple avenues, exploratory learning should be embedded into the curriculum. This allows students to cater learning to their interests while still achieving basic learning outcomes that can be set by the teachers. This overlap between directed and self-directed learning allows for a seamless integration of transdisciplinarity.

> *"Whenever I'm picturing a multi-sensory environment, I'm picturing an environment that offers possibilities to the students where they have multiple ways to access the information- through more platforms, tools or more channels."*
>
> Interview G, Adelina Dragomir, 2023

While transdisciplinary and sensory-based learning allows students to make connections that were previously harder to come by, it is also important for the STEAM methodology to equip students with an understanding of how to derive value from different avenues of learning. While the soft skills that are integrated into STEM learning allow for a greater and more in-depth understanding of concepts, it is also important to teach the students how to gain the most from different sources. For example, as highlighted by The University of Barcelona (Interview F-Appendix, 2023), a scientist may value a study's contribution if it is from a scientific paper. But they may not give an art exhibition representing the same findings and value. Different perspectives from varying disciplines can help see the same thing from different perspectives, adding to the knowledge bank. Instead of comparing two representations of the same result, one might gain more from understanding what each offers. By seeing the merit that every piece has to offer, multiple perspectives can be accepted and valued. Teaching students to combine the value from multiple sources, could help result in the development of new revolutionary perspectives.

> *"Cannot stray away from disciplines but focus on the lived experiences within these disciplines- how do you look for value- is a science paper more valuable than an art exhibition? Should It be more about the conversations and the process of getting the knowledge rather than the end goal- do not necessarily have to have end goals all the time."*
>
> Interview F, Josep Perelló, 2023

5.3. Subjective Perception

How the individual within their specific context perceives their environment is central to identifying the nature of spatial configurations. This became specifically apparent as most research consortium members hail from different academic and personal backgrounds. Understanding the unique take on spatial value and implication, helps create a spectrum of views in this scoping report. Ranging from being considered extremely important to being viewed as a secondary tool that plays a lesser role by others, this report consists of a large spectrum of views. Each opinion has value and direct relevance to this study as it highlights how people view space and the extent to which they believe it necessary to alter it in their practice.

Interviewees highlighted that space is often difficult to understand – or even overlooked - as it is considered an object that is either too rigid or too fluid in configuration. However, it was felt that when space is viewed as an experiential tool, we start noticing its effects on any activity. While most STEAM educational practices may seem tailored and planned to occur in a defined environment, STEAM, at its core, looks at everyday encounters that spark connections. Knowledge is produced and encapsulated in various forms when these connections are pursued. While no 'ideal space' exists for STEAM teaching, every space can have different spatial implications for STEAM learning methods. All interviewees agreed that reflection on the subjective perception of space can improve educational outcomes.

A living lab simulation can be created by engaging with students and understanding different perspectives. This in itself is a STEAM activity, but when an externally set STEAM practice is tested in a natural environment, it is bound to have interesting outcomes. With people feeling comfortable in their familiar natural environment, their invoked 'sense of place' influences their behaviour and thus any results. By placing people at the centre of the activity, the experiments help uncover the most important aspects to the users, thus allowing researchers to gain results that help best understand their target research group.

> *"For instance, in one citizen science experiment, we made a kind of collective measurement of No2, nitrogen dioxide air quality, and placed small tubes wherever we wanted. They were low-cost, and people could decide the placement. The point here was to not measure where the scientists wanted but to measure where people wanted. By putting people at the centre of the project, the results became more tangible to the citizens' research aim."*
>
> Interview F, Josep Perelló, 2023

Practices like these help reconfigure perspectives and bring focus back onto society and the people who inhabit it. When people-centric, the results produced by a practice remain of concern to the students involved, thereby having a greater impact on the user group. There is a two-way investment that goes into these activities rather than the usual one-sided approach where teachers are more invested in the creation and execution of the practice rather than the students. It is important that a dialogue is initiated between user and space as this determines the configuration and re-configuration of a space while creating a rounded environment that suits the needs of every user and activity that could take place there. The dialogue ensures that space remains in constant motion, whereby it can adapt to cater to the needs of every changing user group. An element of flexibility is then unconsciously woven into the fabric of the space, allowing it to remain everchanging and dynamic. Here, adaptability and flexibility do not always have to mean an open plan configuration but rather the idea of goal-oriented spaces that encourage the flow of transdisciplinary knowledge.

> *"I like it when the space is open for conversation. When I come into a space, I enter a personal relationship."*

Interview E, Lydia Schulze Heuling, 2023

While some spaces may have a conventional social dynamic built into them due to it being 'traditionally' used in one-way, alternative activities could take place in them to modify or extend – one might say "hack" - the space's affordances- for example, a theatre or a dance studio could be used for completely contrastive activities such as a science or a printmaking class. Seeing how users behave within each space can be considered an 'enactment', which may help form common behavioural patterns within said spaces (Interview J-Appendix, 2023). For example, a classroom can unconsciously dictate how students behave outside or within school hours. Different furniture arrangements can greatly impact the subjective feeling of "being in control". Conducting these classes in alternative spaces may unlock a hidden potential within the content or its users and increase engagement.

Interviewees felt that a hardwired relationship between space and body needed to be broken but not re-moulded by one another set of spatial pressures. Instead, it must be given the opportunity to become flexible and adaptable to be used in a variety of ways. Spaces can be coded, de-coded and re-coded to understand and reflect culturally rehearsed relationships between social behaviour and spatial configuration.

> *"Anything can be a drama space. Even a playground can be viewed as a stage when you see its users acting a certain way within that realm. It is not how you would act in, for example, a classroom or a hospital."*
>
> Interview J, Laura Colucci-Gray, 2023

Allowing children to experience learning in a broad range of environments will allow them to develop soft skills that can be carried through life, which might contrast with the children's socialisation. By engaging students with alternative ways of doing the same things in a range of spaces the understanding of the world could be broadened. The spatial context can play a role in this.

> *"Understand that there are conventions and values built into certain spaces- example a theatre. The activity's impact changes as its spatial practice changes."*
>
> Interview J, Laura Colucci-Gray, 2023

The impact on perception in and of outdoor space was also raised, especially in the interview with CREDA. For example, running a class on photosynthesis in a garden might result in a higher content absorption rate amongst students due to their immersion in practical demonstrations. Feeling the leaves and seeing the sun's impact on plants will help students understand the theory in greater detail. However, a plant can then be taken indoors and deprived of these available natural elements to study the impact of the lack of sunlight on the same photosynthetic process. Indoor and outdoor spaces are part of the individual experience and need to be connected in the perception of the students. By finding an ideal balance, whether that be through time spent inside and outside, or bringing the two together using intermediatory spaces, students start seeing the practical application of the theory they are being taught.

Forming these connections within their natural environment will solidify the transdisciplinary methodology that STEAM aims to inculcate. Existing methodologies like 'Forest education' have helped schools provide their students with insightful connections that can be made between the natural world and indoor classroom environments. Teaching students the skill to balance and form connections between content and practice can aid them in the long run and make them more career-ready. Since children are fast learners, giving them the opportunities to adapt in various learning environments will make them more resilient, tolerant, and knowledgeable. The process of adjustment will also teach educators a lot about their students' behaviour and capabilities.

> *"We need learning spaces and school spaces where the inside and the outside spaces talk to each other, breathe together and empower people to get out and to get in also."*
>
> Interview H, Daniela Conti, 2023

While the benefits of learning outside of school environments was acknowledged, other interviewees emphasized the importance of "being in a defined space" to create an immersive atmosphere between students and teacher.

> *The course times and the contact times with the students are precious, and I have to use them carefully. [...] I believe in that sort of learning laboratory where you create all these things in a space where you interact quite intensively.*
>
> Interview A, Florian Theilmann, 2023

5.4. Objective Conditions

As discussed with the consortium and stakeholders, creating a feedback loop to evolve education spaces using subjective perspectives is important. However, these personal perspectives can only be woven into physical space if objective conditions permit. The two remain symbiotic and must be given equal importance to balance design and use.

On a very basic level, all interviewees agreed that the traditional classroom, with its formal education, is not ideal for an extended understanding of STEAM. A STEAM space is the spatial anthesis to formal teaching:

> *That's why kids are very interested and attracted to informal education because we change everything found in a formal school, such as physical and hierarchical organization. And the space is different. Everyone is allowed to talk. Everyone respects each other, and our space enables them to be both teachers and learners.*
>
> Interview D, Anna Samwel, 2023

In the interview with HVL, the word choreography came up to describe the physical condition of space:

> *I was working with people in laboratory spaces. My background is in dance and choreography. So there are choreographies in laboratories, we just don't know which kind of choreography they are and how they work.*
>
> Interview E, Lydia Schulze Heuling, 2023

Following this, all spaces might be described as performance spaces, i.e. have a choreography that is more or less hidden - inscribed. Lydia illustrated this with a science lab classroom as an example. While carrying out a task within a lab, the users automatically gravitate towards the same spatial configuration. People sit on highchairs around elongated workspace tables with fixed equipment that usually faces a learning display at the front of the classroom. While these configurations may slightly change, the choreographies within these spaces remain the same. Understanding these patterns and designing to accommodate them while inducing new possibilities all lie within environmental control.

While understanding the importance of set choreographies within space, it is also equally important to know how to break a predictable effect from time to time to create new learning opportunities for students. Understanding how to manipulate environmental features within a space to induce new activity, can help redirect attention to parts of the building that are often ignored in more conservative school settings. For example, turning a part of the school into an installation, or changing the affordances of a space to fit a new activity into a more traditional space (Interview A-Appendix, 2023).

> *"We turned our corridor into an installation of the solar system, we have used the atrium to hang pendulums from, and even run acoustics and optics experiments in dark rooms to study sound waves and shadows."*
>
> Interview A, Florian Theilmann, 2023

These activities helped students engage in more maker-based activities to understand theories otherwise perceived differently in a more conservative and theory-based lesson plan model. Spaces can be limitlessly moulded to fit the needs of certain activities. Florian pointed out that students just have to get creative. This process of creativity lies within STEAM and is essential to the process of explorative learning.

While indoor learning and teaching is generally the preferred educational mode due to the ease in the logistical planning of content, both consortium and stakeholder members see the benefit of outdoor learning. The interview with CREDA helped identify how both indoor and outdoor learning methodologies are equally important. While students feel a sense of ownership and control over the absorption of knowledge in their classroom, pulling them out of their comfort zone provides them with new perspectives, ideas and aspirations (Interview H-Appendix, 2023). Outdoor learning is a very effective spatial setting for this kind of "direct" impact. CREDA also highlighted the liberating effect of outdoor teaching.

The change in objective setting enhances the subjective experience of the lesson here. Finding the right balance of outdoor and indoor environments required for the content whilst also paying attention to the impact that this can have on the user's personal and social development is crucial to the learning process.

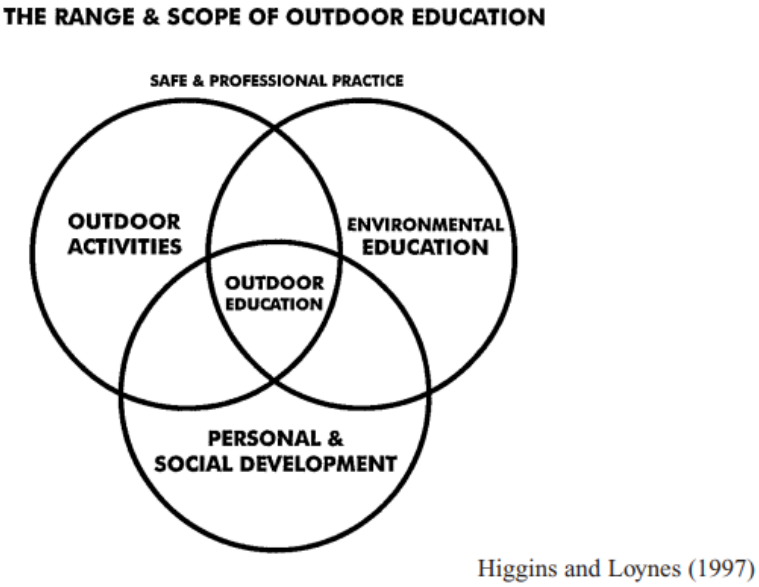

Figure 10 -The ideal conditions for Outdoor learning (src.; CREDA, 2020)

As highlighted by PH Weingarten, Santa Sabina Dominican School and Kinsale Community School, some subjects rely more on some set materials than others.
For example, a science class might prefer to be taught within lab settings as identified earlier; the same lessons can also be conducted elsewhere, say in a theatre. As pointed out by GEYC, while the lesson's content will not change, the mode of delivery that the teacher adapts to and the content absorption rate that students imbibe information within will be drastically different.

> *"A class on acoustics can be taught very differently in a lab and a music studio, allowing students to grasp onto different elements from the same lesson."*
>
> Interview G, Adelina Dragomir, GEYC

All interviewees agreed that the discursively contextualised space is key to find the right educational space. Although there was a general sympathy for flexible open space settings, a flexible and reactive approach was considered more important. While there is ample research on space, they perform under different frameworks and variables, thereby not having enough overlapping factors that allow for a structured review or understanding of an "ideal" space.

> *"And in educational research, not much focus has been given to space, although we often hear things like spaces, the third educator, we don't know much about the impact."*
>
> Interview E, Lydia Heuling-Schulze, 2023

This is why feedback is extremely important for space to be regenerative and continually evolve with the needs of its users. The physical environment needs to be more calculated to create a space where users can interact with the real-world challenges they learn about. Talking to people as mentioned by both Conti (Interview H (Appendix), 2023) and Perelló (Interview F (Appendix), 2023), enhances and broadens the perspectives of the students. It is unnecessary to agree with "every opinion out there", but it is important to hear and understand them and build a more concrete knowledge base. This expanse in subjective view cannot be achieved without refocusing the physical environment necessary to achieve these learning outcomes.

"The idea is to make learning visible and tangible"
Interview H, Daniela Conti, 2023

This moving balance between subjective and objective reality is always in constant motion. But, it is the task of educators and designers to make sure that physical space can operate at all the varying levels of subjective reality.

> *"Teachers are aware that classrooms are not a pleasant place. But how do they escape classrooms? That's the real question."*
> Interview H, Daniela Conti, 2023

In all interviews, the traditional classroom was always the white elephant in the room, playing some kind of role in every discussion amongst the research consortium. Consequently, the research needs to evaluate what the world would look like with or without classrooms. We then need to redesign these spaces to become more malleable while also encouraging the mindset of conducting a set lesson in different spaces to achieve different learning outcomes. By making both users and the physical space more flexible, a dialogue between the two ends of the see-saw can be initiated, encouraging them to maintain equilibrium.

5.5. Inclusive Spaces

This equilibrium will help bring us a step closer to achieving inclusion as it will make us more mindful of the relationship that must exist between subjective perceptions and objective conditions. Humans are resilient and tend to adapt and adjust to their surroundings quite effectively. Given that it is impossible to design a space that caters to every need of every activity that may occur within it, the users begin adapting to their environment or, even better, adapt their environment to their needs. This symbiotic nature of space and its relationship with its users is particularly relevant because it also offers the opportunity to make the physical environment more inclusive to all its user groups. It is important to view inclusion on a multitude of levels to correctly address the identity politics and underlying societal issues within each section. While no one has autonomous control over a space and thus cannot solve exclusivity problems using this tool, identifying spatial language can play a part in creating inclusivity – indeed acting as a "catalyst for participation", as Sasha Brown

(Interview E-Appendix, 2023) emphasised - while designing the STEAM Labs. At this point, it would be useful for Work Packages 5 and 6 to work together.

Looking at the hierarchy and the function of space helps us understand social integration and participation within a given physical environment.

> *It's exciting for me when educational spaces are directly connected to what's going on in the area and what's going on in the places and the communities because It's like an invitation to participate, right? That you can be part of a space and a community.*
>
> Interview E, Sasha Brown, 2023

As Colucci-Gray (Interview H-Appendix), 2023) believes, there is a direct relationship between space and body. For example, the canteen seems the right place to eat lunch in the school. But this does not limit food only to be consumed in canteens. According to Laura, it is more interesting to see how students interact with each other when they are allowed to eat in different spaces within the school. A meal shared between the same students in the canteen, a classroom and a playground will result in different behaviour, thus referring to breaking the regularity of set choreographies that each space unconsciously embodies. This "breaking of affordances" through adaption can lead to a more conscious use of the physical environment and, consequently, more inclusive and approachable spaces.

> *"It's not about additional furniture or additional equipment necessarily, it about how we behave in space and how we alter it to fit our needs."*
>
> Interview H, Laura Colucci-Gray, 2023

This accessibility and personal adaptability of a space, i.e. the low threshold to its use, is a key element of inclusive spaces. The Odyssea maker space, for example, is a customisable environment with movable furniture pieces. This allows every new cohort to decide how their space will look (Kostoulas, Interview B-Appendix, 2023). While fixed features cannot be altered, chairs and tables can be reconfigured to allow users to create a comfortable environment and connect with their physical space on a personal level, thus enabling social bonds across the cohort. Putting thought into the materiality of the space helps create a welcoming environment that adds to the positive experience of its users. Odyssea chose bright blue and white as their primary colours, using round-edged, light plywood for their furniture. Many of the furniture pieces were also built by the students in the workshop space at the studio. This activity aligned with Odyssea's intent of combining art and technology. Students were allowed to explore their artistic ideas within 3D digital space and bring them to life by using skills learnt in the classes. This established a sense of spatial comfort and ownership within the workshop nestled within an overall formal language.

> *"Bright blue, which we believe is a very welcome colour, and we also have some light pink colours, and it's some of the furniture are all made from wood. We used plywood, which to us is a very warm material. The structure we've used for the differential, which we created here, is more of a wavy form, like it doesn't have*

many corners. We believe it gives a sense of flexibility and a sense of allowing people to give their personal interpretation of its meaning."

Interview B, Theodoris Kostoulas, 2023

Another way to encourage inclusion within spatial settings is by ensuring freedom of choice. This can be the choice of place, for example, a subspace in the form of a niche adjacent to a larger space, that helps mitigate anxiety, the feeling of being exposed. This way, spatial differentiation can help make users feel more comfortable and socially confident. As Theodoris points out:

"Sometimes, people might feel anxious when they think they are being exposed or doing something wrong."

Interview B, Theodoris Kostoulas, 2023

Another aspect of choice is the free and comfortable access to tools and other equipment used within the educational process. Paying heed to things like storage for materials, presentation areas, or collaborative and breakout nooks are all factors in promoting spatial inclusivity.

"If we have 15 students, we have 15 screwdrivers. Within the space, everyone can work solo, but everyone also can work in the same workspace."

Interview B, Theodoris Kostoulas, 2023

Through the arrangement of tools, selection of materials and overall structural design, spatial language has the power to influence how users feel within a space.

"There was a community bike shop that I really liked as they had everything you could need hanging on the walls. Displaying the tools like that opens up possibilities you didn't know existed. Even if you didn't know how it worked, you could point at it and have someone provide guidance."

Interview E, Sasha Brown, 2023

6. Summary

6.1. Are there STEAM spaces?

At the end of this long exploration, the answer is a clear “Yes and No”.

On the yes side, we identified certain spatial STEAM conventions which have been evolving over the last 20 years and are now widely accepted. In this convention, STEAM spaces are mostly multifunctional open-plan workshops for hands-on project-based education. A wide spectrum of established guidance exists on how to design good STEAM maker spaces.

However, the interviews with the research consortium and our wider academic explorations have shown that this might be a reductive approach. There is a clear appetite for a more dynamic understanding of the relationship between space and SENSE.

So, No, we might not know what STEAM means for the physical environment.

Core to this “No” is our understanding that STEAM spaces cannot be designed by following a set recipe. It is a highly contextualised discursive model (Interview J (Appendix), 2023) that is guided by a loose framework. There is ample research on space that shows us how they perform under different frameworks and variables. However, it is an immense task to track overlapping factors that allow for a structured review of the ‘ideal space’. Even if a good attempt is made, it will still only paint a partial picture.

While the objective qualities of space can vary, the subjective qualities can be better determined by the learning outcomes of the STEAM activity and, thus, reflected within the physical space. Through the involvement of constant feedback, the social and physical affordances of a space can be better identified (Gibson, 1979). This results in a better chance at adapting the physical environment to fit the subjective needs of the users and vice versa. As identified by this scoping report, STEAM spaces present themselves in a variety of ways. As long as they aren’t seen as ‘add-on’ spaces, the STEAM methodology can be woven into space in an innumerable number of ways. The creation of STEAM spaces needs to be seen as a negotiation of space, whereby a dialogue is initiated between the physical environment and its users. When one can adapt to ease into the other’s needs, a successful STEAM space is created. There has also been a recurring pattern of STEM spaces imbibing the values of STEAM. This is because STEM is inherently creative and the soft skills that art brings to the table can often be unconsciously woven into STEM subjects. However, this amalgamation needs to become a more a conscious effort, whereby students are placed at the core of learning rather than the subject material.

6.2. Spatial Awareness Kit

The scoping report helped conceive a methodology that can be used to study existing STEAM spaces while also helping be mindful while creating new STEAM spaces. This methodology has been presented in the form of a Spatial Awareness Kit. This document essentially breaks down the analysis of STEAM spaces into four categories- Function, Spatial Configuration, Environmental Control and Appearance. Each category is explained, keeping in the spatial implications of these factors on user experience. Once these factors have been identified and analysed, the kit provides a loose guideline to engage the user in a process of reflection. This is the most important part of the process as it not only helps us understand why space has been designed a particular way but also helps us internalise the benefits and drawbacks that space can play as both an enabler and a tool.

7. Spatial Awareness Kit

7.1. A manifesto: STEAM spaces are not cooking recipes.

“The classroom is the third teacher” – This is one of the famous – and often repeated - lines attributed to Loris Malaguzzi, promoting the Reggio Emilia approach. On the surface, this is a convincing statement. It rightly points out that teaching and learning always happen “somewhere,” and this “somewhere” matters.

So far, so good. We would agree with this. There is no neutral space on this planet, and schools are no exception.

However, the idea of the environment “as a teacher” also conjures a –top-down? - notion that an environment that is arranged in a particular fashion improves education through its specific physicality, like a behaviourist experiment: Space A will cause outcome B.

And we do not agree with this, not in an educational context.

I deeply value the Reggio Emilio approach, and the reader is kindly asked to forgive me for the out-of-context use of Malaguzzi’s quote. However, some (and the emphasis is on “some” and not “all”) of the RE classroom configurations come across as overdetermined: There is a defined corner for painting, one for materials, and one for exploring the alphabet. Yes, child-led, but don’t do the wrong thing in the wrong place!

Underlying is a common understanding of spatial design as producing a kind of behaviourist blueprint with predictable outcomes, like a cake recipe; we don’t know the taste exactly, but we are sure it will be sweet. School education loves predictability.

However, at STEAM.SENSE, we think the physical environment is neither an active teacher nor an experimental configuration to channel predictable outcomes. The environment gives us interactive options and NOT firm directions. Or, if you like another metaphor: space is a dialogue between human beings and physical reality where neither side uses the imperative.

Understanding complexity

When JJ Gibson developed his theory of environmental psychology in the 1960s, he encountered a world where behaviourism and cognitivism were locked in antagonist

positions. One side said that actions are determined through environmental stimuli, and the other side located human agency solely within the human brain.

Gibson's approach occupied the middle ground between the two, between human choice and physical conditioning. In his famous theory of "affordances," he described how beings perceive the world as a place that offers a range of finite action possibilities. How and if these possibilities are taken up depends on many factors, such as the shape of the physical reality and the individual's physical disposition. A stair, for example, invites – depending on the actor's size and intention – to be used to climb, but also as a place to sit, if needed and size permits. It surely is less suitable for sleeping unless the actor is very small – for example, a baby – or, indeed, very intoxicated. Or take chairs: Most people will sit on them; some will use them to replace light bulbs, and a child might transform them into a toy.

For Gibson, perception is an active and dynamic sensual process. Engaging with the physical world alters the environment and vice versa. His concept elegantly combines objective conditions and subjective choice without pre-determining the outcome.

Dissecting complexity

Gibson's concept of human perception, where free will and physical reality entertain each other in an intense tango, is a convincing way to describe the world's complexity.

However, does it help us in real life?

Yes, it does, but it provides us more with a philosophical base than an instruction manual. It helps us to understand the physical environment as a dynamic system between human perception and physical reality.

Using the concept as a practical guide for design, however, causes more headaches. As design practitioners, we need a method that reduces complexity into manageable chunks to understand how certain aspects of the environment afford which opportunities.

With this in mind, we conceptualised four categories – you might want to call them affordance dimensions to describe the physical environment:

Function - Does the space provide the essential functionality? What things need to be in place to support what I want to do? This can be as simple – and essential – as the right storage.

Appearance – What is the look and feel? There is, for example, an understanding that STEAM workshops always have a very functional, humble appeal. What if you painted all the workbenches gold? Because this IS a special place.

Environmental - What are the light conditions? How does the place smell? Acoustics? Some neurodiverse participants need an environment with low visual stress levels. Being able to darken the room opens many opportunities to explore light but also taste in unexpected ways.

Space – This category is often overlooked. However, spatial configurations can play a huge role. A tall space lets us think differently than a space with low ceilings. Is the space large and allows a maximum of visual control? Will it give us a lot of niches where participants with lower confidence levels find a visually sheltered environment to feel less observed?

These categories are NOT a checklist, and – of course! not a cooking recipe. It is a loose guide to trigger reflection, discussion, and experimentation. Engaging with those aspects offers a way to look at the same problem through different lenses, finding sometimes unexpected perspectives and things you might have never thought of. The aim is to identify and rank the most relevant Interventions for a STEAM space, allowing for integration of the specific context. And it is also important to discuss these considerations with the participants before and after the experience, so everyone becomes part of the creation process.
There is no magic formula for STEAM space; however, there are magic conversations.

Reintroducing complexity

An approach to the physical environment that tries to be uber-analytical will quickly identify the many overlaps and ambiguities between the selected categories. Dissecting feels naturally unnatural. This is when we need to step back and bring complexity back.

Look at the space you are in: How does it feel, and how do we relate to it?

This holistic reassessment can take many avenues. For our research, we were interested in whether we created more passive or active spaces. Or, in other words, does it support our undertaking well, giving us exactly the right range of affordances and freedom? Or is it an environment that becomes an active part of our explorations?

Claude Parent, the eccentric French architect, was famous for his exclusive use of oblique planes to help humans sense the world's ambiguity. A steep ramp, with students feeling and exploring the forces of nature, might well be the place to understand the concept of gravity differently.

Spaces can be, of course, both supportive and explorative, passive, and active, with defined and less-defined affordances. It is important to understand the spectrum and use it. A passive space can easily be turned into an active tool.

Hacking complexity

With reflection and analysis comes enlightenment and knowledge. Affordances are not almighty forces and mechanisms because we humans are an active part of them. We can -deliberately and with subversive joy – work with them and transform the space into something completely different. This is when we take the driving seat and actively use the environment. It will be an enlightening and immersive experience that will teach how to live creatively with the complexity and ambiguity our environment naturally embodies – and this is at the heart of SENSE.STEAM.

There might be no cooking recipe, but we still can be good cooks.

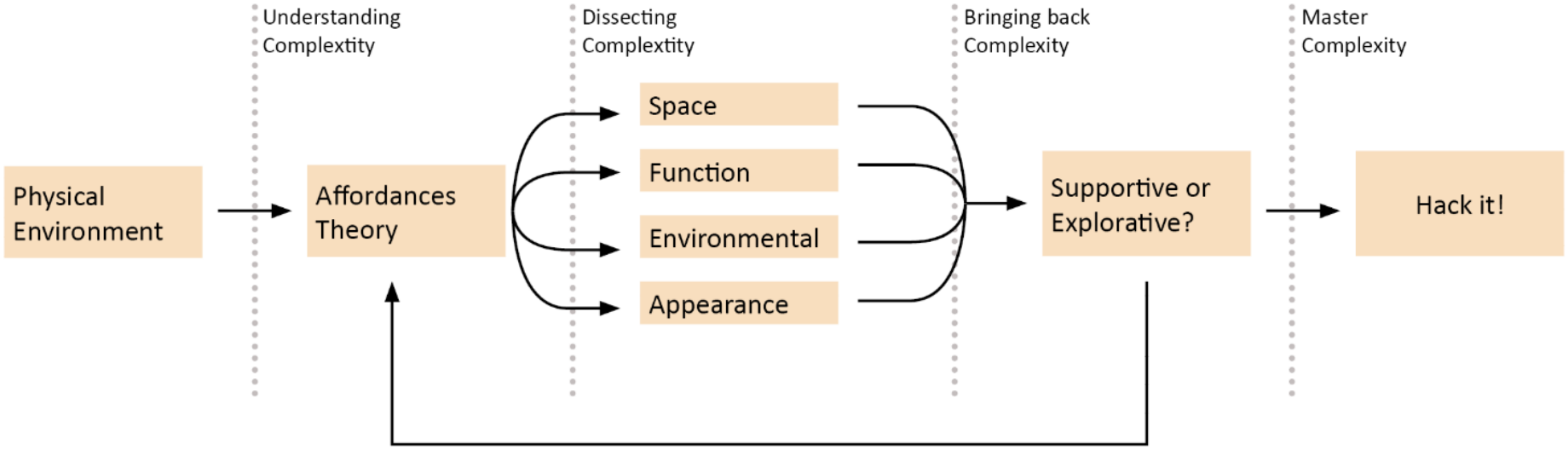

Figure 14 Breaking down and re-building the concept of space (src: H\B)

7.2. A guide to spatial reflection

As described in the manifesto, we suggest that space is best understood and created through a structured reflection on the different aspects of the physical environment. This analytical step is important before joining the elements in a final synthesis to test the overall hypothesis.

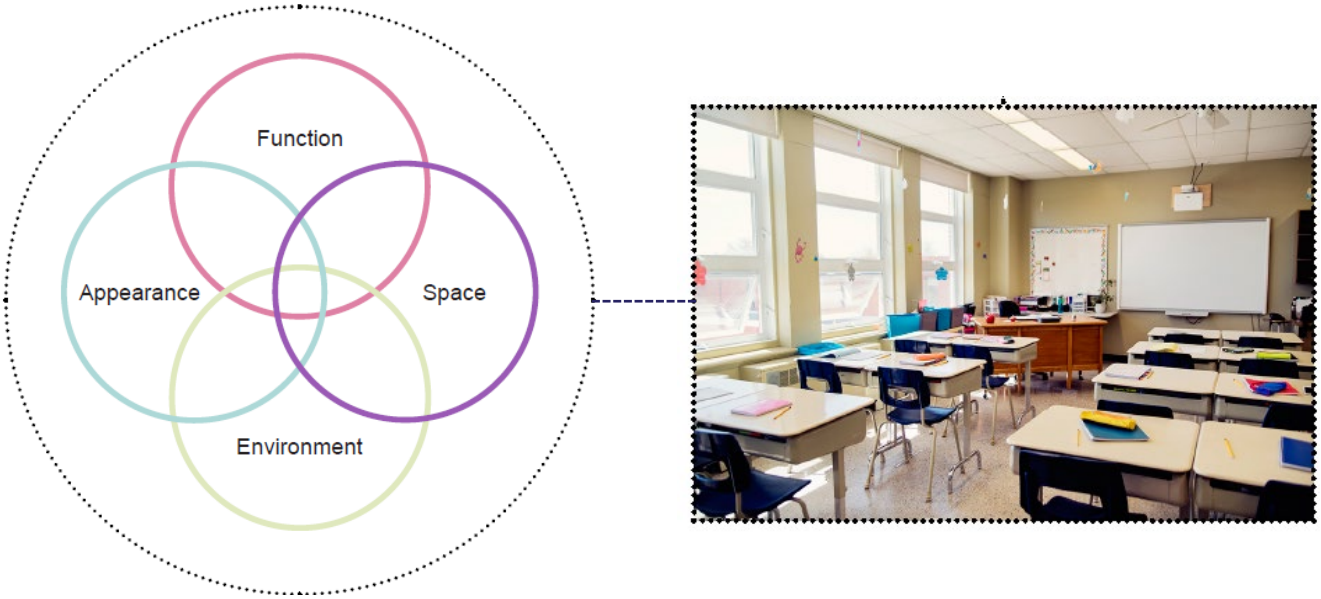

Figure 15 The four lenses used for Spatial Reflection (src.; Hawkins|Brown)

Analysis

Below, is a list of questions that help dissect the activity and understand their spatial implications for each practice. This is not an exhaustive list but merely prompts to structure a discussion/reflection. Users should feel free to add to the list and highlight aspects that they think are relevant while understanding the spatial needs and implications of the chosen STEAM activity.

Looking at each activity using this structure will help improve our understanding of the type of space that is needed for an activity or its user group.

Funded by the European Union

Function	In this section, you should reflect on what kind of equipment is necessary for the activity and its users? • Equipment required to run this activity smoothly (Tables, Chairs, blackboard/whiteboard, digital tools, etc)? • Requirement of specific supplies like- power, gas, specialist goods, etc.? • Does it require storage, access to washrooms, showers, a kitchenette, etc.? • Does this space require disabled access, or does it need multiple entrance/exit points? ....
Spatial Configuration	In this section, you should reflect on the types of spaces in which this activity could be carried out. Think about their internal and external configuration. Space doesn't necessarily mean a room in a building. It can also be an outdoor location or public place—for example a market square, a park, etc. • Would you need one or more spaces? • Is this an indoor, outdoor or mixed-space activity? • What is the height, type, shape, and size of the selected space? • What is its internal spatial configuration (for example, is it a row-based classroom, an open plan arrangement, or follows activity-based learning, or just an empty room)? • Does this need an area for performative activities? How would this manifest spatially? .....
Environmental Control	In this section, you should reflect on the environmental conditions of the space, such as air, light, temperature, noise levels, etc. Will these parameters need to be controlled? • Type of light – Natural or artificial? • Do the windows need blackout curtains? • Does it need natural ventilation or air conditioning? • Would windows need to be glazed and soundproofed to control temperature and noise levels? Would the sense of smell enhance the activity? ....

Appearance	In this section, you should reflect on what the physical environment looks and feels like. • Materials used for furniture. • Will the colour scheme of the space and the furniture impact the activity? • Are there many visual stimuli around? ….

After filling out the table, reflect on the importance of each dimension to understand how to prioritise the set-up of the conceptualised spatial environment.

Name of Activity	**Dimension**	**Reflection on Importance**
	Function-	
	Spatial Practise-	
	Environmental Control-	
	Appearance-	

Final Reflection and Synthesis

After discussing the different aspects of the physical space, we want you to step back and reflect on whether the environment you conceptualised as an **enabling space**, i.e. more a passive space that supported the experience OR if it was used as an **explorative tool.** i.e. it played an active role in the enquiry process. It is important to acknowledge that there is a sliding scale between the two categories, and the activity does not have to fit into a particular box.

Enabling

explorative

Name of Activity	Enabling Elements	Explorative Elements

7.3. Best Practices List collected from the Consortium-

7.3.1. Submission from CREDA-

The first thing we want to share with you is that, based on what the Consortium has highlighted in D3.5 and D3.4, and on what we are learning so far in the SENSE. project, in SENSE. we are questioning whether there are practices or methods that are inherently SENSE.STEAM, or best practices anyway, by considering, let's say their "different pedagogical ingredients".

In the meeting we had with our colleagues in CREDA, we are leaning towards thinking that it is necessary to broaden our perspective and consider variables and contexts and considering that the focus should be more on the quality of the educational relationships at the centre of SENSE.'s educational practice or/and pedagogical setting, rather than intrinsic characteristics of a sequence, tools, method, model, instruments, spaces, places etc. On the other hand, the quality of the educational relationships itself can be enhanced or facilitated by a range of conceptual and material tools.

Our attention will move (try to) on the people involved, the problems and issues they want to address, and the needs of those individuals within a specific context. This is why we are having some difficulty deciding which activities to analyse, and for sure, we are not proposing "best practices" even though perhaps you were expecting some best practices (at least, that's how we interpreted it when reading the email subject and file name you sent us)

So what we did was reflect on function, spatial configuration, environmental control, and appearance in 4 different situations in which our organization operates, thinking to the principal activities we carried out in spring 2023 and tried to summarize some key points that seem important to our view, while also considering the dimensions we have identified in the SENSE. Manifesto, which we interpret as tensions, directions, or pathways to strive towards and as a compass to analyse our work.

The 4 'situations/settings/spaces/places' are the following ones:
Activities run at our centre (indoor space, named Spazio Invento). Keep in mind that in this case, all our half-day programs still include the use of Spazio Invento and outdoor spaces described below in point 2).
Activities run at our centre (outdoors in the park of Monza).
Activities run in schools.
Activities run in public spaces.

In the table below, for each of them we tried to describe both the initial conditions and reflections-

	Spazio Invento Examples of activities: https://www.creda.it/energie-in-gioco/ Photos of the building: https://www.creda.it/fai-qui-il-tuo-evento/ ✓ the equilibrium is more toward an enabling space, even though it displays some explorative feature/possibilities)	**Outdoors (Centre for education of the park of Monza)** Examples of activities: https://www.creda.it/mulini-asciutti-2023-24/ ✓ seen as enabling space *and* explorative space	**Schools** Examples of activities: https://www.creda.it/monza-piu-pulita/ ✓ the equilibrium is more toward an enabling space, even though it could be and should be also an explorative context, but there is the need to overcome the impossibility to use the body in the class at the moment -ie to move, to interact, to sense, etc)	**Public spaces** Examples of activities: www.creda.it/wp-content/uploads/2020/07/Urban-Science_unità_di_apprendimento_completo.pdf www.creda.it/wp-content/uploads/2022/08/Una-didattica-per-il-futuro-del-clima_Change-the-Story.pdf ✓ seen as enabling space and explorative space
FUNCTION: In this section you should reflect on what kind of equipment is necessary for the activity and its users?	Easy-to-move (and stackable) tables that are sturdy and can be used with various materials without getting damaged. Different types of seating are needed that are also easy to store in small spaces. The challenge is to have enough empty spaces	In all activities there are moments where participants share (for example things they did, craft, collect, find, or thoughts and reflections). Sometimes a cozy spot for a group to stand in a circle is enough, but other times seating might be needed and	The school classrooms where we have worked this year are generally set up with a desk or podium (for the teacher) and tables for the students. The feedback from our educators is unanimous: the classrooms should be larger and more	We choose a place/space where participants, after the exploration phase, can talk, exchange ideas, identify things to do or actions. This place/space should be shielded from the road, spacious enough to accommodate us in a circle. Ideally, it would be a square with room for a group to pause and converse, perhaps with some coverings (for rain and sun). There may be people who need to sit.

	for sitting in a circle or working in groups, or individually ---- the equipment must be movable and easily storable. There is access to water, electricity, wifi etc.	sometimes sitting on the ground/grass can be uncomfortable if it's damp or if someone has physical problems. The seats should be lightweight, portable, and simple. Optionally, a place with fixed seating could help. Tables or boards are necessary, again, nothing too fancy. An area with Wi-Fi coverage. A place that provides shade (in case of hot and sun) and shelter in case of rain. A water source, and an electricity point. A place to store materials and equipment. Toilets nearby. Appropriate ways to collect the produces waste (if any).	spacious, with the possibility to easily reconfigure the space when needed, for example, if there is a need for a different arrangement (such as a circle, as we often use in our activities). More space would also be necessary to organize the area with tables or seating according to the requirements of some activities, for example, for group work. There is often issues with power outlets (there are not enough). The multimedia whiteboard is not always accessible to everyone. There is no space to place objects and equipment, or for making, crafting things. In general, the idea is that students (or only their bodies?!) just stay sit all the time they are at school.	Ideally, we would have seating available (as in some Parisien gardens and squares)
Spatial Configuration	It's an open space, and there can be challenges when multiple classes or	The park outdoor areas we have chosen for our activities are	In general, the spatial configuration is the classic one that fulfils	Read above

In this section you should reflect on the types of spaces this activity could be carried out in.	groups work together. Open spaces are versatile, but the coexistence of multiple large groups or those engaged in different activities can be disruptive for the participants themselves and, in some cases, even obstructive.	configured to have an exploration zone (where we work on sensing, exploring, doing, drawing, running, measuring, painting, etc…) and a sharing zone. Ideally, the area should allow for movement and expansion. It must be meaningful and/or have a specific feature we are working on. This leads us to say that some outdoor spaces may be more suitable than others for certain activities. The choice of space is never random. Our educator always conducts a site visit beforehand.	the following function quite well: the teacher speaks, the students listen and take notes, sometimes with the help of a whiteboard (interactive or traditional). The idea is that everyone remains seated. There is a lack of movement; the bodies are present but can do nothing except remain passively seated. Classes generally have minimal surfaces, even smaller than what is mandated by law. This results in virtually no maneuvering space due to bags and backpacks placed on the floor near the desks, the number of students, the number of desks, etc	
Environmental Control In this section you should reflect on the environmental conditions of the space, such as air, light, temperature,	Light: the large windows of Spazio Invento are excellent for natural light and because they make us feel like we're among the trees, but it may be necessary to darken them on certain occasions.	Temperature, noise, light, darkness, cold, heat, humidity, and the presence of odors are all part of being outdoors. These factors cannot be controlled, but we can make choices so that the	Light, temperature, and noise are all factors that are not always well controlled and impact well-being (of both teachers and students). Unlike outdoor spaces, it doesn't make much sense to be indoors if	Refer to what was written in the section dedicated to the outdoors. However, since we are in a public space, which is a 'designed and constructed' space, the presence of drinking fountains, toilettes, shade, and sheltered areas for rain and heat could be helpful in some cases

noise levels etc. Will these parameters need to be controlled?	Certainly, controlling these parameters (temperature, air, light, noise…) can be useful, but in this case it's not always easy to apply in our case because it's a building constructed 200 years ago on which the Superintendency has prohibited certain modernizations. So, it's okay to set up sensors/devices/structure to monitor and work on these parameters in the case of creating a new space. But for existing spaces? How to control these parameters in a building that is already in place, considering the ever-present challenge of having the resources for intervention?	situation is not too overwhelming for the participants (as their willingness to learn would be compromised at that point). Just to make an example: planning an outdoor activity on a cold, rainy day, in a noisy and dark environment, can be too challenging. On the other hand, an outdoor activity in moderate temperatures but with a lot of noise (for example, on a busy street to place a sensor for particulate capture) can be an interesting and enriching obstacle to overcome.	these parameters cannot be mitigated.	

7.3.2. Submission from Odyssea-

1.

2021 marks the 200-year anniversary of the Greek Revolution of 1821. Given the health conditions, in the context of celebrating the 200th anniversary of the Greek Revolution, arose the need for the students of the Peloponnese Region to experience the event from the prism of active learning, using Sport and Technology as educational tools. The purpose of this educational activity is for students to combine Physical Education and the local history of the Greek Revolution, using ICT as an educational tool. The students are led to discover local references of the Greek Revolution, which are located in their hometowns, in order to highlight the historical connection of each place with the Greek War of Independence. They are asked to plan a route, which includes references of the Greek Revolution (statues of heroes, street names, battle locations, etc.) and record it with an application. The activity will be enriched with a happening, that will be related to the Greek Revolution (eg. dance, song, music, poem, storytelling, or crafts of any other art they wish to involve). Then, they are asked to compose a video, which includes the best parts of the route, the parts related to the Revolution of 1821, a screenshot of the walking/running app and the happening. After that, they are asked to watch the videos of the other participants and vote for the ones they like best. As they become familiar with creations of other students, they compose a more complete picture of the Greek Revolution, as it developed in the Peloponnese, they learn about relevant monuments, local heroes, locations and customs. At the same time, they are in touch with different approach methods, athletically and artistically as well as technologically. Finally, they are given the opportunity to use smartphones/ tablets as educational tools. It seems to be a new challenge for Physical Education teachers to integrate ICT into their courses to optimize motivational and behavioral benefits. In addition, a review of the literature shows that the integration of ICT in Physical Education may have a positive impact on the motivation of students and, directly or indirectly, affect performance through motivation (Legrain, Gillet, Gernigon, & Lafreniere, 2015).

https://steamonedu.eu/platform/node/289

Function	• View video • Power point presentation • Word file with instructions • Google forms (registration, voting, rating) • Smartphone or tablet with internet connection • Mobile app • Computer with Internet access. • Registration of individual pupils or school sections in the educational activity

	• Installed mobile application that can record distance in meters and capture the route on a map
Spatial Configuration	Students are guided to discover places - references to the Greek Revolution, which are located in their place of residence, in order to highlight the historical connection of each place with the Greek Revolution. They plan a route, which includes elements/references from the Greek Revolution (statues of heroes, street names, battle sites, etc.) and record it with an app. The educational activity can be carried out remotely (individual participants) or in person (group participants). Each student can work either from home, at a time of his or her own choosing, or in a group at school, within the timetable. The role of the teacher is to guide and support through the instructions provided to the students.
Environmental Control	Environmental conditions within the classroom do not affect the application. However, when students create a video of the route, the weather conditions should be good in order to capture it clearly and without difficulty.
Appearance	The monuments and statues that will be recorded in the videos act like a stimulus for the search for the history behind them.

2.

The Folklore Museum of Amorgos Island wants to do a renovation and at the same time, with those changes, save energy. So, this is the project that this learning scenario is based on. Students will deal with the lighting of this renovation as professionals would have done, for that reason they need to become “experts in a week”. Collaboration for this practice, will start with teachers; a physics teacher, an electrical engineer, an IT teacher and an Art teacher from the school, will work together to organize the project and with different activities to transform students into experts. Students, working in teams, will first learn about semiconductors and diodes, to understand LED, how it works and its advantages. Next step will be about LED lights in electric circuits and how LED lights save energy, as well as luminosity, light intensity and lighting. Continuing, they will deal with some applications to control LED light and lastly, the students will learn about artwork and the lighting it needs. With this comprehensive knowledge, students will begin to design how to illuminate the works of art in the museum and promote sustainability. This educational STEAM practice, aims to develop the necessary knowledge and at the same time, during the procedure, students to acquire the essential skills. This STEAM practice,

was implemented at the Vocational Upper Secondary School of Amorgos from the students of the second grade of the electrical engineering department. The two students who participated first had a meeting with the head of the folklore museum of Chora during a visit there. Then, they attended their classes as it was planned. Finally, students completed their project by presenting a study on the replacement of existing light bulbs in the museum with LED lights and the energy gained from their replacement since the valid COVID-19 pandemic measures. Students, after the completion of this week, were very pleased and satisfied that they managed to deliver their project, working as a team. Because they had a goal, the theory they were taught did not tire them, for it was soon used in practice. With the research they did, they managed to complete the study of changing the lighting in LEDs. All this contributed to the development of student's skills, like research and synthesis of gathered information, critical thinking and decision-making.

https://steamonedu.eu/platform/node/194

Function	**Hardware/Software/Other Resources** *Materials:* Smartphone, Notebook, Internet, Engineering Laboratory, Printer *Online tools:* *Youtube.com*, *Padlet*, *PhET*, polleverywhere, Kahoot, Evernote, Trello, Simulator of Diode Characteristics Online apps: Philips Hue, duoCol Strip, LED BLE, Lux Meter, Lux Light Meter Free, Smart Luxmeter
Spatial Configuration	Students will download some free online apps to measure the light (as Lux Meter, Lux Light Meter Free ,Smart Luxmeter etc). Next step is to visit the folklore museum and do a research about the existing lighting, take light measurements and photos before the renovation. Subsequently, back in school, there is a discussion with some theory of artwork, colors and the importance of proper lighting in artwork, followed by research students will do online to find ideas about their project. It is proposed that students check videos from the Smithsonian American Art Museum concerning lighting. They can use Evernote or Trello to gather and organize

	their information from the research they have done, also in previous lessons. Then, every team needs to decide their complete proposal for the museum manager based on arguments. After that, students must prepare their presentation to communicate their proposal to convince the museum manager that they have the best and most reliable idea that fits the demands of the museum. Ultimately, with the museum's manager joining us in school, every team will present their project, with the participation of all team members and using a study/poster/painting/design they created.
Environmental Control	The types of lights need to be both physical and artificial as students need to measure and understand the existing conditions. Measuring during a sunny day and in complete dark is important, so the windows will need blackout curtains.
Appearance	The activity will take place both in the classroom and the Museum. In the Folklore Museum of Amorgos Island there are numerous exhibits and pieces of artwork on display that would serve as significant visual stimuli, showcasing the cultural and historical heritage of the island. The color scheme of the space and the choice of furniture can have a significant impact on the activity and learning experience. Warm colors like reds, yellows, and oranges can create a vibrant and energetic atmosphere, while cool colors like blues and greens can promote a calm and focused environment.

List of Activities	Spatial Needs and Implications	Reflection on Importance
1.	Function-	High
	Spatial Practise-	High
	Environmental Control-	Low
	Appearance-	High

2.	Function-	High
	Spatial Practise-	High
	Environmental Control-	High
	Appearance-	High

Final Reflection

Activity	Enabling Elements	Explorative Elements
1.		The space in this activity acts like an explorative tool, as students have to identify elements/references from the Greek Revolution (statues of heroes, street names, battle sites, etc.) and record them.
2.	This activity takes place in different places. When it takes place in the classroom the space acts like a passive element	The space in this activity acts like an explorative tool, as students have to measure and understand the existing light of the museum and decide about the artificial.

7.3.3. Submission from University of Barcelona-

List of Activities	Spatial Needs and Implications	Reflection on Importance
1. xAire (Air quality measurement- Citizen science). Performed with Primary school families and their schools. Replicated with architecture students in Barcelona and Venice.	Function-	In all phases of the activity, it uses quite ordinary materials. Phase 1: in a classroom: tables and chairs and paper, sticky dots with printed maps or a digital screen with google maps or open street maps app open. Phase 2: Use of low-cost sensors to collect NO2 concentration levels and a ladder to put the Palmes diffusion tubes in lamp posts or other urban elements with a ladder and string of 2,5m long.
https://doi.org/10.1016/j.mex.2021.101475	Spatial Practise-	A workspace to discuss and plan in a communitarian form: Art centre to meet (auditorium) at large scale and for each school group seated in a circle and with tables to work together. When going out to public space, subgroup choose to place the sensor in different streets and paths.
	Environmental Control-	Fully adaptive to current conditions. Day-light

	Appearance-	Use of maps and a global sense of the neighbourhood
2.CoAct for Mental Health	Function-	Writing personal experiences in a research diary. A computer and good internet to share the experiences in online meeting. Alternatively, we used email, and the communications were shared by the facilitator with those attending to online meeting. This was part of a research process to identify and map social support networks in mental health
Citizen science project where we focus on one strategy which is the writing process of individual experiences on mental health	Spatial Practise-	Private space, and a research diary that helps to structure particular micro stories. We fought against geographical distance and met together as isolated participants
	Environmental Control-	Participants wrote their own micro stories and we meet periodically to share their efforts, their feelings and put together all micro stories. The importance to leave stigma aside and to create a mutual learning environment about mental health. I like the tension

		between privacy and individuality and the sense of collectiveness or shared experiences. To do so we worked online where people shared their experience from their homes (safe space) but at the same time we use online to connect this privacy
	Appearance-	N/A

Final Reflection

Activity	Enabling Elements	Explorative Elements
1.	Plames tubes	NO2 concentration levels in our neighbourhood
2.	Research diary	Social bonds around and their relationship with mental health

7.3.4. Submission from HVL-

Activity 1-

http://www.susanneschmitt.org/#/how-to-not-be/
https://movingnaturalhistorymuseums.com/

Function	The activity is and audiowalk. Hence it takes place in a museum. The space brings everything with it, just as it is. The challenge is rather, to deal with the space , the exhibits, the lights and the other visitors that are there. Something similar was done by the same people with the natural history museum in Berlin.
Spatial Configuration	I wonder if such an audioguide has to be space specific. Or could it also be created as an audio ballet or something like that? But then the space-specific experience would change. In which direction? I don't know.
Environmental Control	The museum is a highly artificial space in which many parameters are controlled to best preserve the exhibits while making them accessible for the public at the same time. Control of temperature, humidity, natural and artificial light. Museums do have a specific smell. Where does it come from? Decisive use of smell could work tougher with the question of how to not be a stuffed animal. Some pooh smell in the vicinity of a stuffed elephant? Would be interesting? Would it open up to create own narratives, beyond what is told us by the curators?
Appearance	Depends, on the one hand the furniture shall store and display the exhibits. At the same time, the furniture is designed in specific ways. E.g. in natural history museums the large glass vitrines are old and have a very authoritative and history-laden appearance. At the same time, we all learned the behavioural code of museums. "Misbehaving" in order to un-stuff the stuffed animal will be challenging. Not every person might be daring to fly around a natural history exhibition like a bird, crawling on the floor like a chameleon, etc.

This activity works the other way round, it take the space as it is and transforms it. Stretches its limits, the cultural codes, transforms it from a place of death where animals dont speak for themselves, into a space of creation.

Activity 2-

https://www.epfl.ch/labs/instantlab/improgineering/

Function	In this section you should reflect on what kind of equipment is necessary for the activity and its users?

	• Equipment required to run this activity smoothly (Tables, Chairs, blackboard/whiteboard, digital tools, etc)? • Requirement of specific supplies like- power, gas, specialist goods, etc.? • Does it require storage, access to washrooms, showers, a kitchenette, etc.? .... One clean space is needed, where everyone feels invited to actively use the floor. The space should not be too cold nor too warm, not windy. Participants might feel the desire to change clothes or to take a shower after intense physical work.
Spatial Configuration	In this section you should reflect on the types of spaces this activity could be carried out in. Think about their internal and external configuration. Space doesn't necessarily mean a room in a building. It can also be an outdoor location or public place. Example- a market square, a park, etc. • Would you need one or more spaces? At least one clean space, see above. Changing and washing facilities might be great. Additional rooms for play and discovey are also great, normal lecture rooms where participants can play with furniture • Is this an indoor, outdoor or mixed space activity? Currently it is only indoor, but I am sure it can also work outdoor. Largest risk: indoors is a save space where students might feel much more open for improvising and exploring their physical and emotional self. • What is the height, type, shape, size of the selected space? It should be large enough, but not too large. It should be at least 2.8 meters high, but could be higher. That would more be a question of acoustics than of needed height. • What is it's internal spatial configuration (for example is it a row-based classroom, an open-plan, follows activity-based learning, or an empty room)? Can be empty of furniture, or not. Furniture can be used for improvisation.

	Light should be there. • Does this space require disabled access or need to have multiple entrance/exit points? No, not necessary. • Does this need an area for performative activities? How would this manifest spatially? Yes, exactly. Manifest in clean floor, eventually possibility for playing music, eventually light technique, acoustics should not be too disturbing when there are multiple small groups or one big group working with speech and sound in a performance improv class. .....
Environmental Control	In this section you should reflect on the environmental conditions of the space, such as air, light, temperature, noise levels etc. Will these parameters need to be controlled? • Type of light – Natural or artificial? Natural – but indoors there will be support by artificial light. On top stage lights might be wanted to made use of. • Do the windows need blackout curtains? Yes, just to have the opportunity to darken the room if needed. • Does it need natural ventilation or air conditioning? Better natural ventilation since air conditioning can be irritating in terms of wind and noise. • Would windows need to be glazed and soundproofed to control temperature and noise levels? Windows – don't know. Participants should at least not feel being on display. So, windows higher in the walls might be of advantage or glazed. Noise levels – the other study rooms next door should not feel disturbed. • Would sense of smell enhance activity? No.
Appearance	In this section you should reflect on what the physical environment looks and feels like. • Materials used for furniture. A warm floor, no extra heating needed, but not pure concrete, eventually with dance carpet • Will the colour scheme of the space and the furniture impact the activity?

	I guess so, but it is not predicitable. • Are there many visual stimuli around? No, only the environment as it is. Working with prompts is part of the activity. They will be brought by the teachers or participants.

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9. Appendix

9.1. List of Interviews

Interview Code	Stakeholder/Consortium	Name and Organisation	Date Interviewed
A	Consortium	Florian Theilmann- PHW	16.05.2023
B	Consortium	Theodoris Kostoulas- Odyssea	19.05.2023
C	Consortium	Ines Moreno & Anne Krebs – Louvre	19.05.2023
D	Consortium	Anna Samwel, Ida and Ana- WECF	25.05.2023
E	Consortium	Lydia, Sasha and Nickolai – HVL	26.05.2023
F	Consortium	Josep Perello- University of Barcelona	30.05.2023
G	Consortium	Adelina Dragomir- GEYC	30.05.2023
H	Consortium	Daniela Conti- CREDA	05.06.2023
I	Consortium	Joseph Sturm- VELVET	08.06.2023
J	Consortium	Laura Colucci-Gray – University of Edinburgh	14.06.2023
K	Stakeholder	English state secondary school for girls with mixed sixth form/ Inner London	27.03.2023
L	Stakeholder	Inner London University	27.03.2023

M	Stakeholder	Irish state secondary school for girls / Dublin	28.03.2023
N	Stakeholder	Architectural practice	11.04.2023
O	Stakeholder	Museum in London	14.04.2023
P	Stakeholder	English mixed state secondary school / Inner London	02.05.2023
Q	Stakeholder	English mixed state secondary school / Inner London	23.05.2023
R	Stakeholder	Royal Institute of British Architects	25.05.2023
S	Stakeholder	Irish mixed state comprehensive school / Cork	21.07.2023

Table 1- Interview Tracker- Consortium and Stakeholder Data

9.2. Case Studies

Play Maker School
Primary School in California

The school's main learning intent is to teach through technology and it does this by catagorising the school into three distinctive zones. The big spaces allow for freedom of movement and activity.

Location: Santa Monica, California

Architect: Gensler

Type: Private

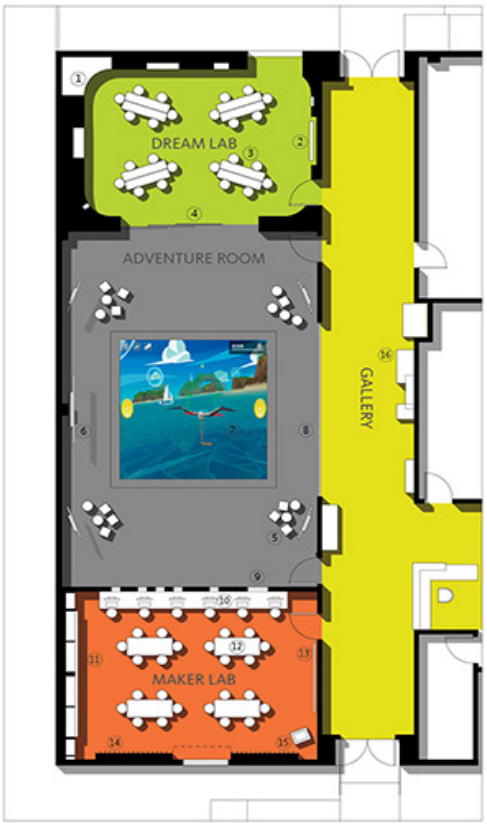
In partnership with GameDesk and New Roads, this school design focuses on play-oriented, hands on immersive experiance. The school is divided into three distinct areas- a dream lab that focuses on the ideation process where students can collaborate; an adventure room where student created games and GameDesk software can be tested and a Maker Lab where students can build and prototype objects. The ideation room has full height whiteboards to allow for unlimited creativity; the maker room has ample storage for the projects created by students and the adventure room is a large space with state of the art technology to get the best immersive learning experiance.

Top right
The Dreamer Lab is a space where every surface is a writable one- ideal for the sharing of ideas

Bottom right
Large desks with digital and traditional tools that can be used for hands on projects. The room also has ample space for storage of materials

Top
Interactive digital hub called the Adventure room.

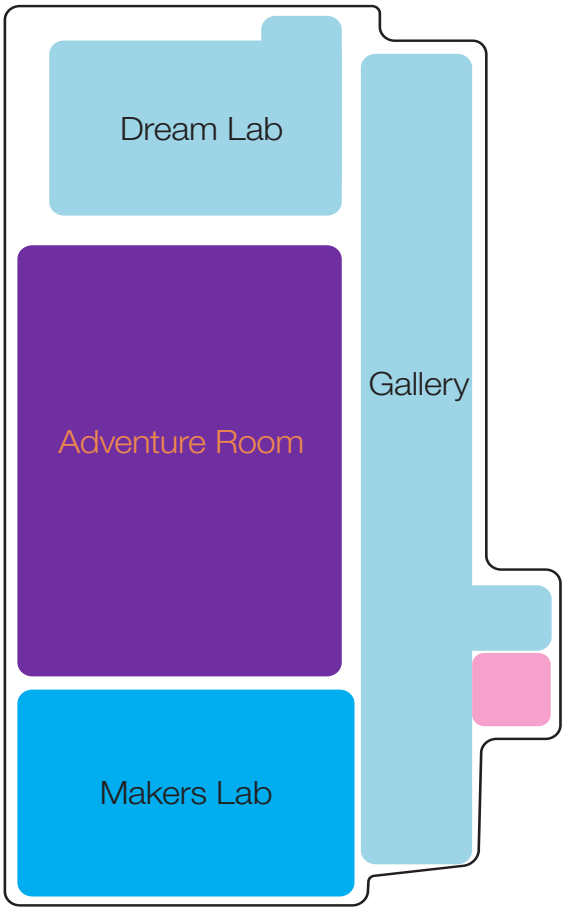
Bottom
Plan view indicating all the facilities in the school



1 Writable Walls With Cubbies
2 Large Monitor
3 Reconfigurable Project Groups
4 Sliding Glass Doors
5 Breakout Groups
6 Projection Screen
7 Augmented Reality Projection Floor
8 Garage Door Connection To Gallery
9 Windows To Adjacent Space
10 CAD Stations
11 Storage+Marker Boards
12 Mobile Shop Tables
13 Short Throw Projector
14 Tool storage
15 MakerBot Prototyper
16 Student Project Display Cases

Play Maker School
Primary School in California

The school's main learning intent is to teach through technology and it does this by catagorising the school into three distinctive zones. The big spaces allow for freedom of movement and activity.



- Auditorium/ Lecture Theatre
- Social Learning/ Flexible / Group
- Traditional Classroom
- Science & Engineering
- Visual Art & Design Technology
- Workshop/
- Staff
- Office/ Meeting

- Indoor Learning
- Outdoor Learning

Play Maker School
Primary School in California

A reflection of the school based on the produced learning zone plan and elements of the Spatial Awareness Kit

The Play Maker School in Santa Monica is designed by Gensler and its central focus is to 'launch a next generation model of teaching and learning that focuses on play-oriented, hands-on and immersive experiences' (Arieff, 2023). By making learning a team sport in this school, students are taught the value of collaboration. The Dream Lab focuses on the process of ideation, with white board walls and plenty of white light to induce maximum efficiency and concentration within the space. The users are given the freedom to jot down their ideas on the wall and brainstorm together. The second space is the Makers Lab- a space where students collaboratively and individually develop the ideas they conceive in the 'Dream Lab'. Finally, the biggest chunk of the school is dedicated to the Adventure Lab- a room that is a dedicated interactive presentation space. Here the students gather to participate in activities that are in collaboration with GameDesk and are given the opportunity to explore their curriculum using state of the art digital tools. The minimal furniture in this space allows for the multiple activities to take place here. This flexibility has helped revive learning by making it more participatory and creative. The school has an even mix of different learning configurations- classroom model, activity based and open plan; with collaboration weaved into every aspect of learning, mirroring a potential real life work experience.

Function-

The Makers Lab is the most functional of spaces when it comes to storage and availability of equipment. This is ideal as this is where students bring to life their ideas. With long tables and high set stools, students have a good amount of space to work in. The space is also well lit given the lack of windows in the studio. However, this helps unleash the student's creativity as they work away in this well managed and stocked enclave. The Dream Lab has a very different ambience with white furniture, whiteboard walls and bright lights to enhance creativity levels amongst the students. Any colour stands out in the space, directing all attention towards it. Finally, the Adventure Lab is a big open space with minimal natural light. This area is perfect for students to play around with the available AR and VR technology. The walls are left empty to project content on and there a sectioned area on the floor where content is projected on too. This allows for students to move around freely around any displayed content, thereby changing the way the space is used according to each specific activity.

Appearance-

The Playmaker space follows a very functional design style that keeps collaboration at the core of its design value. Each room encourages a different form of collaboration, and this is reflected within the appearance of each space. The Dream lab has a very clean feel with whiteboard walls from floor to ceiling. The white furniture blends into the walls when left empty, making the users of the rooms and their ideas the focus in this space. The Makers Lab has longer and bright colored workstations with plenty of storage, presentation space and white boards to continue the ideation and innovation process that is started in the dream lab. Finally, the Adventure Lab is the biggest room amongst the three, with plenty of unrestricted space to test out the prototypes created in the Makers Lab and use the VR and AR equipment on the floor and walls of the lab. This room has minimal natural light in order to facilitate the digital projects that are often presented here. The floor also has a designated raised platform in the center of the room for digital floor projections. But this space can also be creatively turned into a stage for interactive performances and presentations when necessary.

Environmental Control-

The three labs have different lighting conditions to promote a different intention for each space. The Innovation has bright white light to enhance concentration levels that aid the process of ideation. The maker space is well lit but prioritizes natural lighting conditions over an artificial one. The Adventure Lab is dimly lit with no windows to enhance the image quality of any projected digital content.

Space-

The Adventure Lab is also the biggest space with an exposed ceiling. This makes the space look much bigger and promotes a sense of freedom amongst its users. Controlling the light in this room results in the users of this space becoming more aware of their surroundings, thus taking in every detail that is displayed within the room. This hyper attentiveness and focus make their experience in this room more exploratory and liberating. While the Dream Lab and the Maker Lab require just as much of the user's attention, the user is captivated in each space in a different manner. In the dream lab, the space is centered around the user, the Maker Lab is designed to assist the user, whereas the Adventure Lab makes the user a secondary feature. The displayed content is given more attention, and this encourages the user to interact with the content. Each space has been tailored to tap into a different part of the users' senses, making the journey of creation of a prototype from start to finish more inclusionary and interesting.

UCL Academy
Secondary School in London

Location: Swiss Cottage, London

Architect: Penoyre & Prasad

Type: Private

Superstudios created to engage attention through collaborative learning.

There are 5 super studios within the 6 floor UCL Academy building. Each superstudio can accomodate upto 90 students and can be reconfigured using the movable furniture to accomodate a variety of activities. The curriculum is also specifically designed to be interdisciplinary. Creating an intercultural dialouge between subjects inculcates the importqant habit of questioning and drawing connections between various topics. The school tries not to be holed into a single paradigm of learning, thereby resorting to a combination of techniques that ultimately help enhance learning.

Top right
Breakout study spaces for individual and group learning between classes.

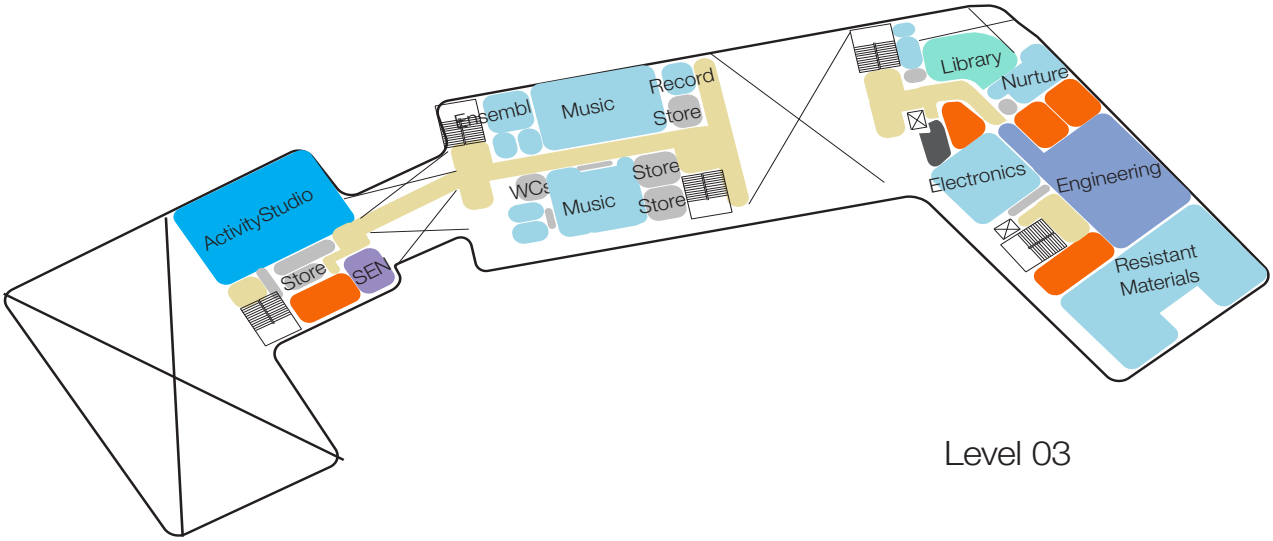
Bottom right
Lecture style classrooms for more individual and focused learning.

Top
Superstudio areas that can be moulded into smaller classrooms by reconfiguring the space.

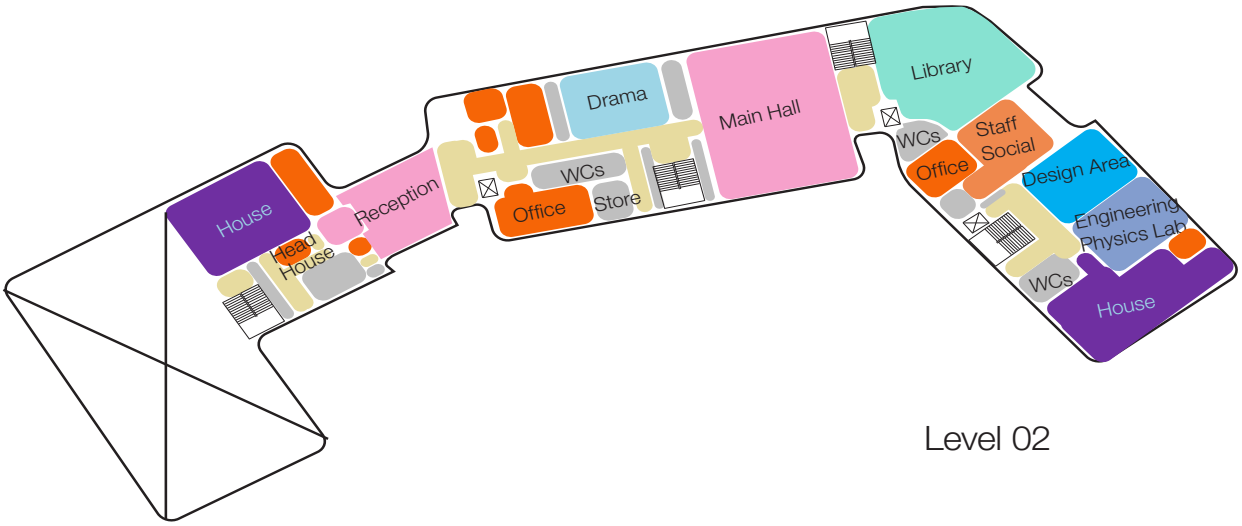
Bottom
The inward facing corridors that run along the external perimeter of the building. They face the open spaces within the school camous.

UCL Academy
Secondary School in London

Superstudios created to engage attention through collaborative learning.



Level 03



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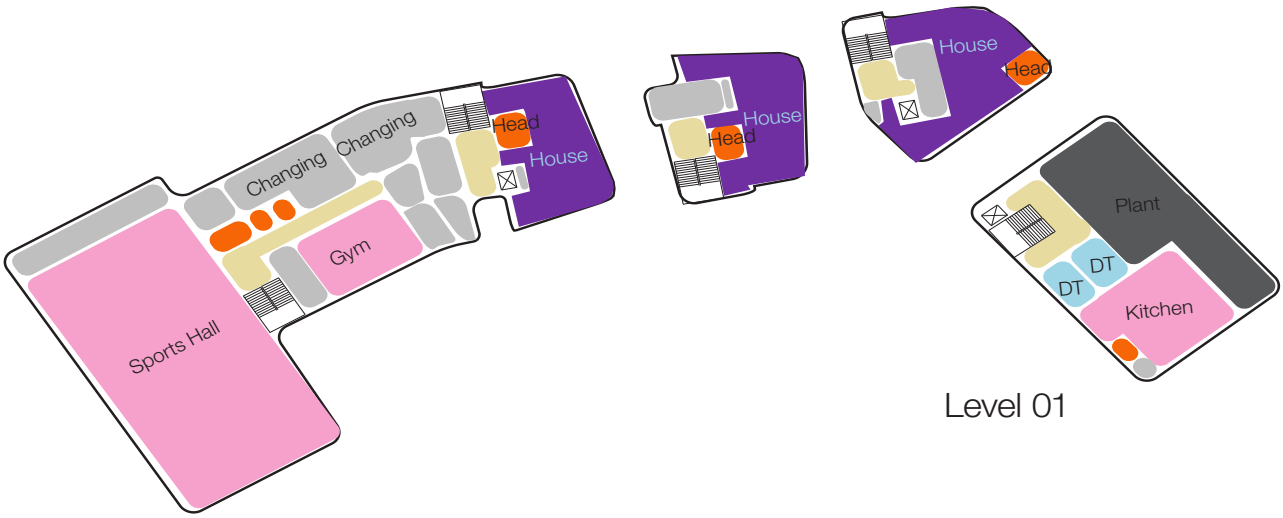

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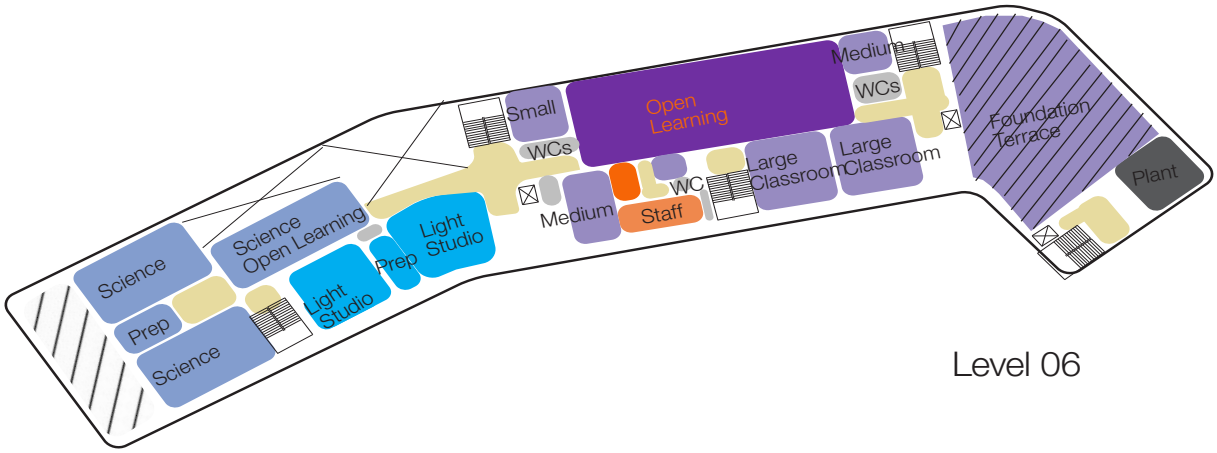
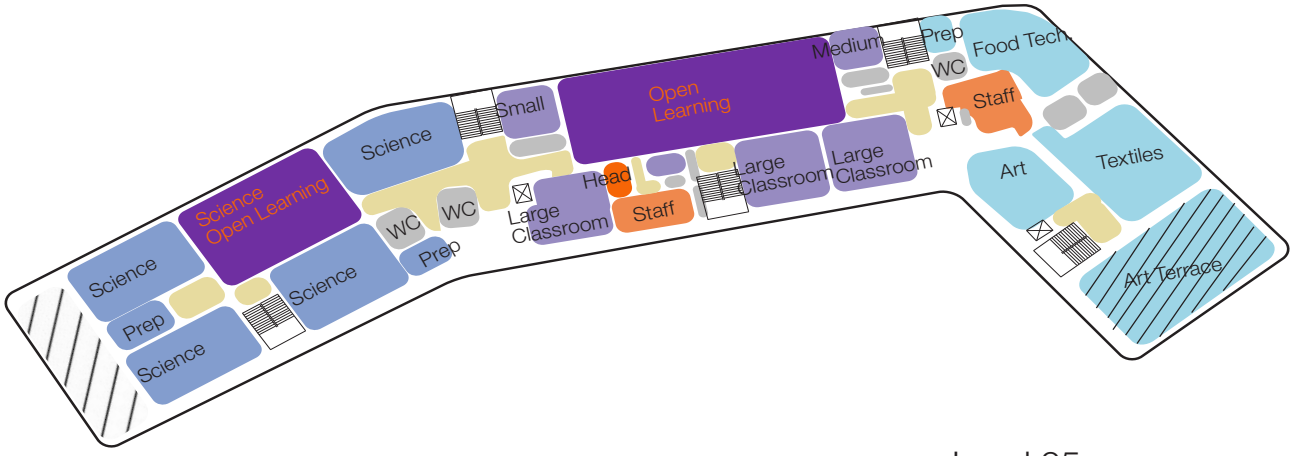
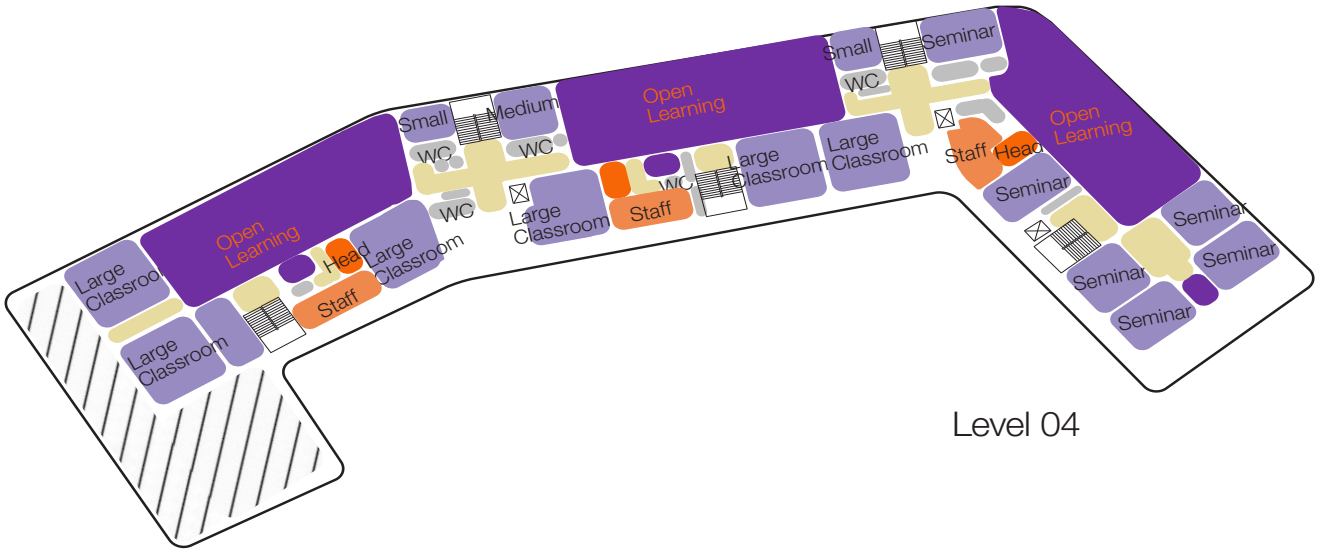


Level 06



Level 05



Level 04

UCL Academy
Secondary School in London

A reflection of the school based on the produced learning zone plan and elements of the Spatial Awareness Kit

The UCL Academy is a secondary school that is sponsored by the University College London. The campus has state of the art facilities that range from science laboratories, demonstration theatres, interactive lecture rooms and design and engineering studios. With a catered focus on science and math, this school focuses on creating a transdisciplinary approach that culminates the arts with the sciences. The school spans across 6 stories whereby each floor is treated as a 'household'. Within each household, there are classrooms for different grade lessons and Superstudio in the central open area. These super studios are essentially group and social learning areas that bring together different disciplines and students from different years. They can be configured in an amphitheatre form or group and individual settings, allowing for various types of learning to be carried out here. The students are given the flexibility to arrange their environment in the way they seem fit to best absorb and participate in the delivered content. With science labs and design studios tucked away in the extreme ends of the building, the middle section is completely dedicated to floating classrooms and breakout spaces. When teachers are given equal space for these two learning environments, students start to equally use both spaces due to necessity. This pushes them to become innovative with the ways their spaces are arranged. This collaborative interaction and participation allow for a seamless dispersion of knowledge across different subjects and class forms, creating unexpected and lively social relationships.

Function-

The layout of the school is such that corridors are in the external perimeter of the building. This leads onto the classrooms and then to the central open space that houses the super studios. While the classrooms have fixed storage units and individual desk spaces, the super studios have movable furniture that can be used for group learning activities. The walls are also lined with presentation boards that helps students stay on top of activities run in the school and their peers outstanding work. These boards are a good way to keep an underlying conversation going without disturbing classes while also acting as a mode of dispersing transdisciplinary knowledge across different year groups.

Appearance-

The school is built using lighter and warm toned materials. Each floor is lined in with windows along both the northern and southern façade, letting in plenty of natural light into both the classrooms and the super studio spaces. The movable seats for the super studios are also lined with fabric to control the dispersion of sound. Different pieces of furniture in each space gives the users a level of flexibility while organising themselves for each class. This independence allows for a higher expression of interest within subjects while also infinitely expanding the interactions that they may normally engage in within school premises.

Environmental Control-

UCL Academy shares its facilities with the Swiss Cottage SEN school. This collaboration that had an influence on the way the spatial environment is arranged. With a minimalistic design approach that appeases the neurodivergent and plenty of natural light, the users have access to a welcoming space with both controlled functional spaces and more free-flowing opportunistic areas. The sound proofed furniture choices also help balance the acoustic levels in bigger studio spaces without inhibiting movement.

Space-

The several double height breakout spaces also provide users with a feeling of openness, leaving a positive impact on their mental health. In a country where the sun sets in the afternoon during the colder months, students appreciate tranquil indoor spaces that leave them feeling comfortable and safe.

RIBA Clore Learning Centre

Workshop centre at RIBA, London

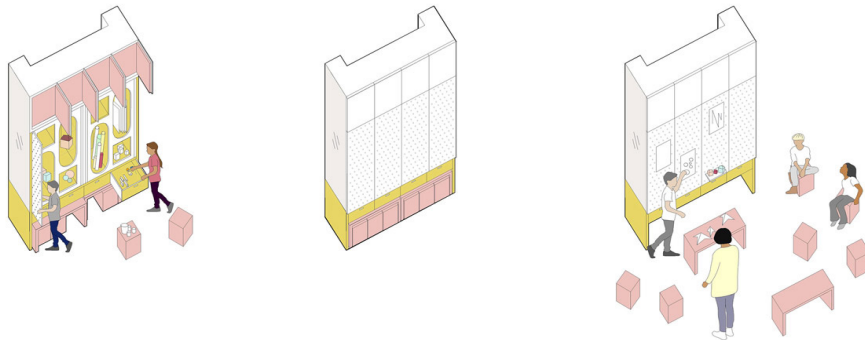
The workshop is an open plan space that can be configured to become an activity based space when needed.

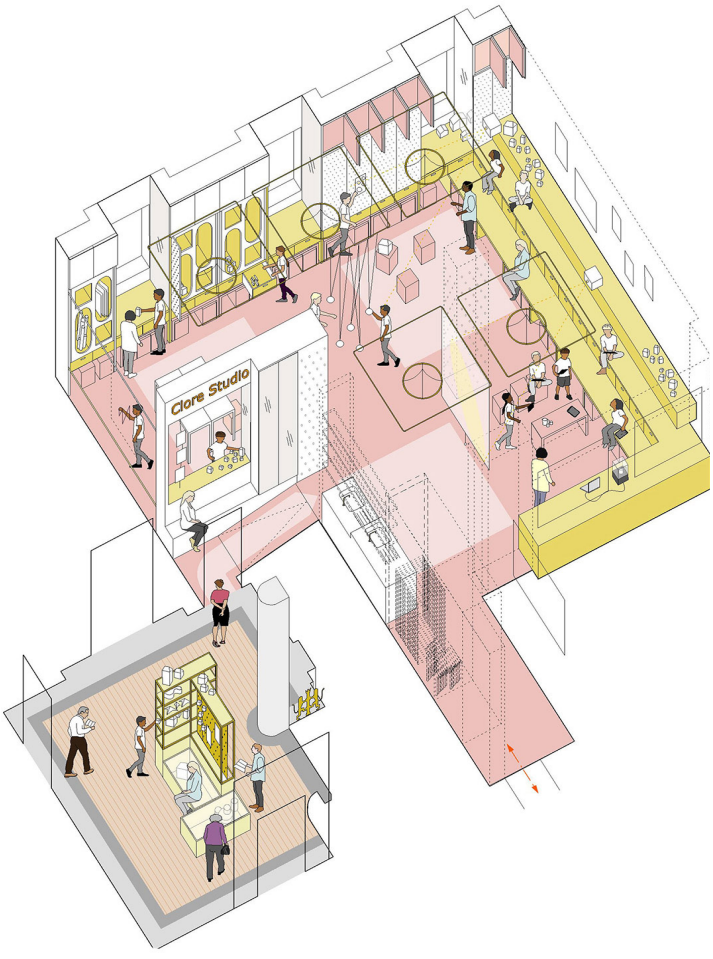
Location: London

Architect: Hayhurst & Co Architects

Type: Private

This learning centre has been designed to be a public engagement space within the RIBA building. It includes a dedicated studio, study room, outdoor roof terrace and an interactive display area. It allows for maker based activities to be conducted in various capacities across agre groups and skill level.





Top right
Configurations of activity space

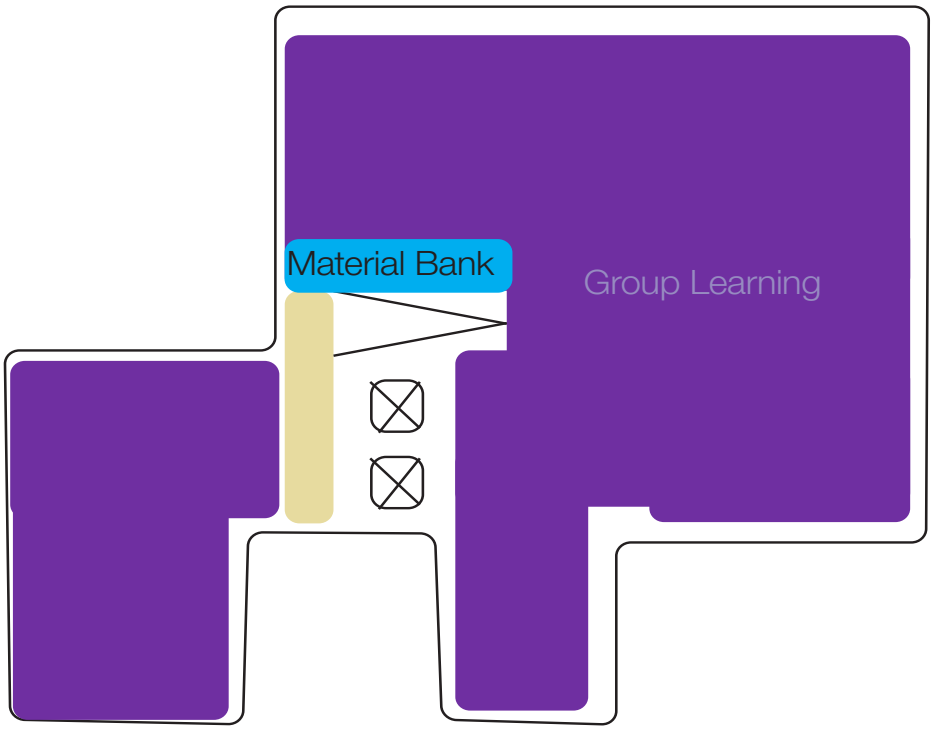
Bottom right
Axonometric plan view of RIBA Clore Learning Centre

Top
Activity space contained within storage during events

Bottom
Using the Activity space for makerbased needs

RIBA Clore Learning Centre
Workshop centre at RIBA, London

The workshop is an open plan space that can be configured to become an activity based space when needed.



- Auditorium/ Lecture Theatre
- Social Learning/ Flexible / Group
- Traditional Classroom
- Science & Engineering
- Visual Art & Design Technology
- Workshop/ Studio
- Staff
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- Indoor Learning
- Outdoor Learning

RIBA Clore Learning Centre

Workshop centre at RIBA, London

A reflection of the school based on the produced learning zone plan and elements of the Spatial Awareness Kit

The CLORE Learning Studio is workshop space for users of varied ages and skill level at the Royal Institute of British Architects (RIBA) building in London. This studio space was designed by Hayhurst & Co Architects. The main use of the workshop space is to be an area for public engagement where it can create opportunities for the public engagement officers at RIBA to participate in activities that allow for a connection to be established with the community. The CLORE space consists of a dedicated malleable studio space, a study room with digital equipment, an outdoor terrace and an interactive display area. This studio positions itself between hosting social events and maker-based activity workshops allowing for a different configuration to be created for each event. With almost 95% of the floor area dedicated to social, flexible and group learning, the studio can shapeshift to cater to ever users' individual needs.

Function-

The Studio is retrofitted with plenty of storage space alongside the three of the four walls. This can be used to store materials and projects that students produce, but it also has the capability of storing the stools and tables that are used during the workshops. This extensive storage not only allows students the access to any materials they may require during a maker-based activity, but also allows for the space to be emptied out and used in other ways of other events. Enabling flexible configurations allows the users to sit on the floor, stand in groups or huddle together in different parts of the room, according to the need that the activity demands. The mix of hand on material and digital tools and software also allow students to explore content and achieve their learning outcomes using an extensive variety of materials, aiding them through the process of exploration, innovation, creation and finally reflection.

Appearance-

While other examples of STEAM workshops often resemble a fabrication lab, the CLORE studio is a space that is meant to mould itself to the activity rather than dictate the behaviour of its users within the space. The space has a very light and airy feel to it with plenty of natural light that bounces of the white laminated storage cupboards and the white perforated ceiling. The warm toned light wood flooring and the and furniture bring a certain warmth to the space, making it feel like a welcoming environment. The seating alongside the windowsill and the lower placed furniture also allows the room to operate for different age groups, making the studio feel like it was designed with every user in mind. The studio also using the building as learning tool as the tiered steps alongside the wall are made from bamboo and the stools and cabinetry fronts are made from recycled yoghurt pots. Not only does this adopt a sustainable method of design but also uses this information to educate its users about topics like sustainability and circular economy.

Environmental Control-

The studio is well lit and has the light materials allow for a zen space to be created. However, the same space can be converted into a colourful and energetic environment when students' work is displayed around the room (example shown in the image). The malleability of the space allows for the studio to be reconfigured in the best way possible to suit groups with neurodiversity and accessibility requirements. The room can be darkened by pulling down the blinds when content needs to be displayed using a projector. With an adaptable environment, learning can be made as interactive as possible through 'observing, testing, making and sharing' (H&Co, 2019). By hacking the space to fit the needs of the activity, the studio environment is made to be as inclusive as possible.

Space-

The open plan configuration with the movable furniture provides the users with an opportunity to play around with the space. The white perforated ceiling allows the space to feel bigger than it is, and the low furniture encourages people to be closer to the floor. This also helps the maker-based activity spill and extend onto the floor from the low table height, automatically giving users more space to work around. Working on the floor also subconsciously makes people open up to the activity they are engaging in, thus openly pursuing the creative energy that is produced through the space and consequently their actions.

Hellerup School
Primary School in Denmark

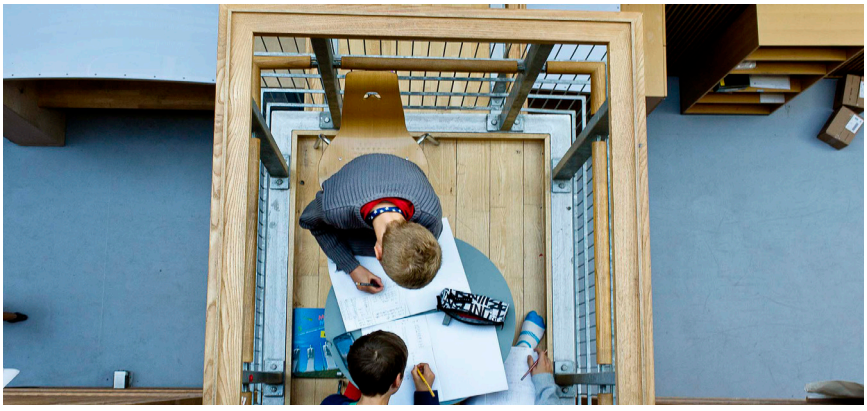
The modelled landscape at Hellerup School is ideal for both learning and playing, creating a fun area to explore and enjoy the process of education.

Location: Hellerup, Denmark

Architect: Arkitema

Type: Private

A modelled landscape has been created with stairs, plateaus, balconies and bridges, where especially the staircase shape is used in many places in the school and forms the common thread between the school's central functions. The staircase area opens onto the different parts of the school, thereby supporting the school's strong internal network. At the stairs a multitude of different activities take place; Traffic, accommodation, teaching, group work, presentations and film screenings for large gatherings, and when the lunch break arrives, many students eat their food here. Movable furniture like screen walls and light furniture are used in the living labratory for various configurations of learning. By inculcating play within subjective learning, participation and retention of matter drastically increases.



Top right
Small nooks in the school being used to work in groups or individually

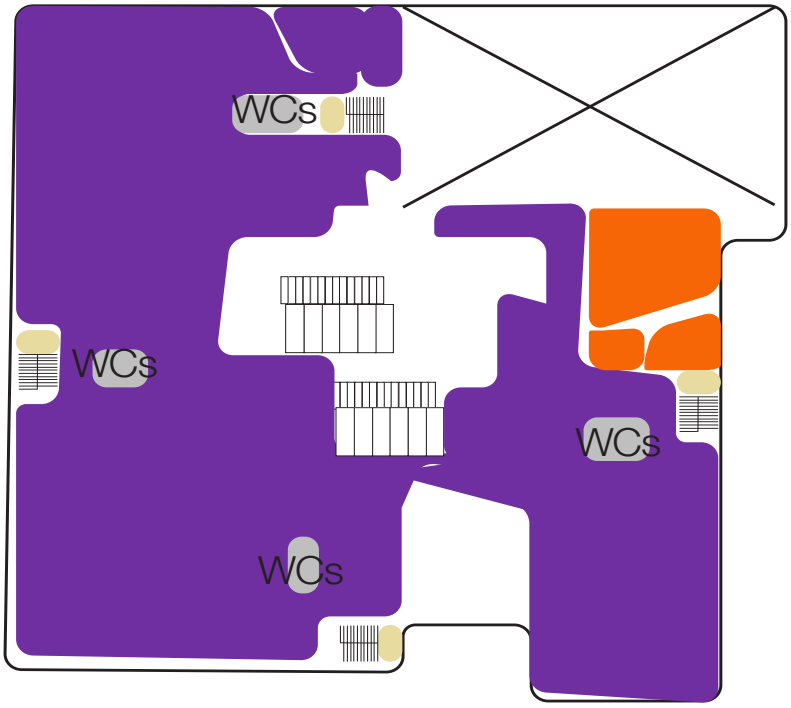
Bottom right
Outdoor gym and playarea in the form of a art installation made out of astro turf

Top
Group activity taking place on the central staircase near the open library in the core of the building

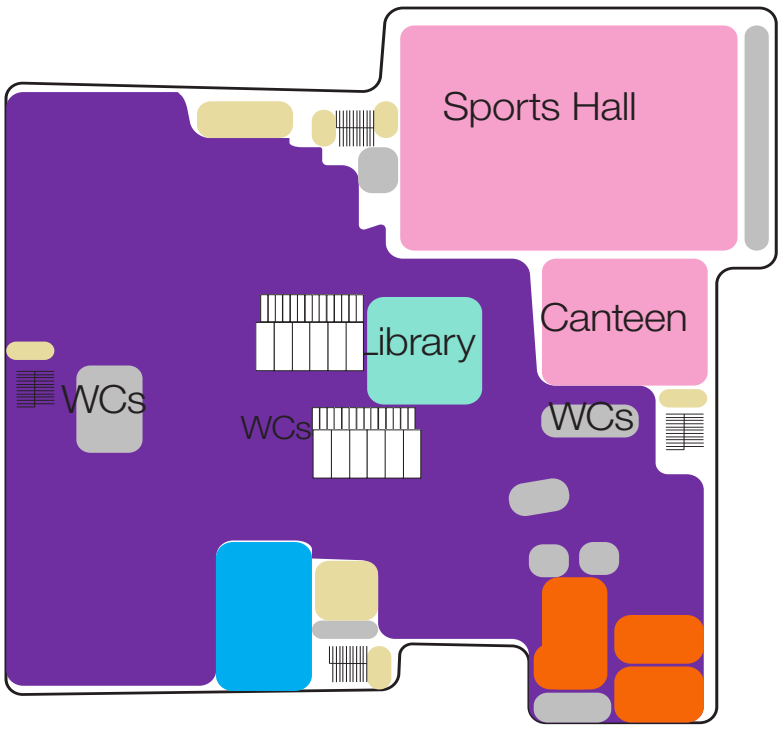
Bottom
Spaces cretaed to encourage activity based learning. Any activity can be conducted in any space as there are no defined classrooms

Hellerup School
Primary School in Denmark

The modelled landscape at Hellerup School is ideal for both learning and playing, creating a fun area to explore and enjoy the process of education.



First Floor



Ground Floor

Auditorium/ Lecture Theatre

Social Learning/ Flexible / Group

Traditional Classroom

Science & Engineering

Visual Art & Design Technology

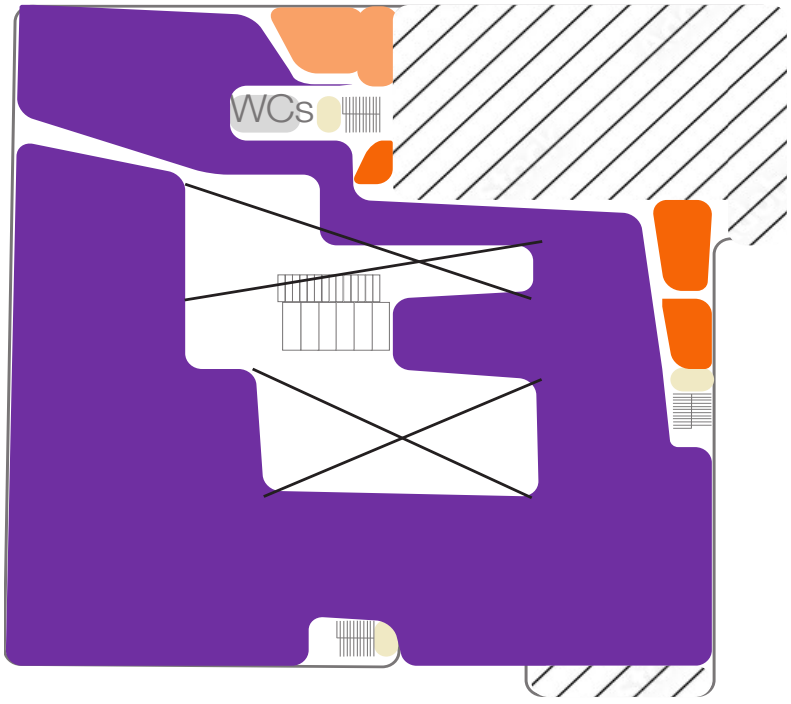
Workshop/ Studio

Staff

Office/ Meeting

Indoor Learning

Outdoor Learning



Second Floor

Hellerup School
Primary School in Denmark

The modelled landscape at Hellerup School is ideal for both learning and playing, creating a fun area to explore and enjoy the process of education.

The Hellerup school is an open plan school in Denmark. This school does not believe in the concept of classrooms and engages learning through a loose activity-based educational structure. Students and teachers amalgamate in varying group sizes and occupy different parts of the school, depending on what the lesson plan dictates. The building has a central focus of building a community spirit within the next generation of students. With over 650 students across kindergarten to ninth grade, the school is full of unexpected interactions between student groups.

Function-

There are no walls that segregate the classrooms, but there are varied options for moveable and stackable furniture that is malleable to different configurations. This allows students and teachers to get creative in the way that space is used. There is also a central staircase that runs through all three floors of the school that provides plenty of space for social learning scenarios. There is also plenty of storage throughout the entire school, hidden behind the wooden slatted doors that merge with the walls. This provides the same level of functionality that is expected from traditional classroom settings.

Appearance-

The most important thing in this space is to not let furniture make the open spaces look cluttered as this can have a negative impact on the students' mental state of mind. Having a clean and organized space will help encourage creativity. While there is an unspoken chaos that is unleased during the process of collaboration, the space must absorb this chaos and turn into a viable environment that still produces good results. The art installations and biophilic elements add onto this feeling of freedom and acceptance that the school wants its users to feel. Bringing in the outside world into the school helps merge the two learning environments, expanding the boundary within which learning can occur.

Environment-

The school has large atrium windows that let in a lot of natural light into the entire school. The light wood wall paneling and flooring also helps reflect the light, illuminating all the nooks and breakout spaces that line the long corridors. The furniture also matches the flooring thereby making the open space look as seamless as possible.

Space-

Unlike other schools as discussed in this case study list, where social learning zones are spatially demarcated in order to engage students in collaborative work, Hellerup finds a way to make social learning the norm. All classes, whether indoor or outdoor, are conducted in a flexible and sociable manner, thereby encouraging a greater exchange of ideas. The staff areas are also kept to the bare minimum for teachers and students to spend as much time together as possible. The co-existence of the two types of users will result in a stronger teacher-student relationship. This would breed a level of understanding between the two, making the learning outcomes achieved in classes more fruitful.

Vittra Telefonplan
Secondary School in Sweden

The didactic learning environment provides the teachers and students here with an array of options to conduct their classes. The flexible space promotes activity- based learning within an open plan space.

Location: Hagersten, Sweden

Architect: Rosan Bosch

Type: Private

In Vittra, they do not believe in regular classes and the school organisation's vision is to create a landscape that focuses on every individual student's development. With a strong focus on innovation and digital teaching, the school is designed as a open plan with varying clusters of movable furniture and installations like the 'iceberg' and 'indoor tree' that offer for interesting areas in which learning can take place. It also has flexible labratory space where hands on projects can be executed.

Top right
Installations liike this allows students to explore the various ways they can use the space, making them more curious individuals in the process

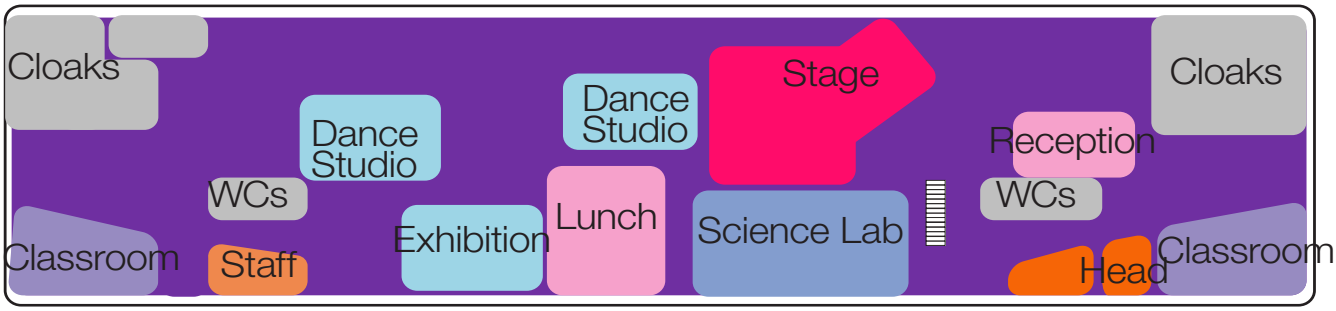
Bottom right
Creating blackboard like this pique both the creative senses amongst students. It can also be used as learning tool during group work

Top
Immovabel furniture like this allows for the activity to be catered around the space instead of the usual way. This makes the process of learning more flexible

Bottom
Tree installation that can be used as a play feature or as a learning tool for a class.

Vittra Telefonplan
Secondary School in Sweden

The didactic learning environment provides the teachers and students here with an array of options to conduct their classes. The flexible space promotes activity- based learning within an open plan space.



Ground Floor

Lower Ground

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Vittra Telefonplan
Secondary School in Sweden

The didactic learning environment provides the teachers and students here with an array of options to conduct their classes. The flexible space promotes activity- based learning within an open plan space.

Vittra Telephonplan is an open plan school that is located in Sweden. This school has been designed to experiment with the ways in which traditional classroom learning and methodologies can be disrupted. Designed by Rosan Bosch, a focus on enabling and motivating every learner catered to spaces that can be used for both collaborative and indvdual learning. Providing this flexibility, allowed for various spatial configurations whereby activity-based learning installations were used in a number of different ways. Creating a space that supports this new age of learning allowed for out-of-the-box ideas to emerge.

Function-

With storage lined alongside the walls and furniture that could operate on various levels, children are given the freedom to explore the space and the created learning landscapes that they are immersed in. By providing traditional tables and chairs but also installations that they can climb and sit on, the students are continually kept active and busy. This helps improve their cognitive and physical abilities whilst also promoting soft skills like patience, tolerance and acceptance.

Appearance-

The furniture operates at different levels allowing for some flexibility in the way different pieces are used by the students. While one may remain seated while using it, another can use it as a desk or lie down on it instead. This creates an informal setting that makes the content that students are dealing with more approachable. Most pieces also have contrastive colours with a shiny lacquer finish that bounces light, illuminating a space. They also have fabric in areas that are meant for seating, standing or lying. This not only makes it more comfortable for its users but acts as a method of soundproofing in an attempt to regulate noise levels in the open plan school. Every surface in the school has been carefully thought to reflect the kind of learning they want to encourage in the school. With solid surfaces, students are given the freedom to write on any surface. They are easy to maintain, and the ideas generated in these spaces stand out against the plain surfaces, shifting all the focus onto the children and their ideas.

Environment-

Teaching takes place in varied environments in this school. Whether it be on a massive iceberg sculpture, a platform area that doubles as a space for play or in a cinema. There are also flexible laboratories that are located around the school that encourages a 'hand on' approach.

Space-

The physical space within the school lends itself to being an educational tool as the lighting, acoustics, furniture and layout of the school have been tailored to fit the needs of the lessons and behaviour of its users. When a space is tailored to the users, it becomes easier to hack the space for activities. With elements like varying ceiling heights, atrium lighting and varying artificial lighting in different spaces, the physical space unconsciously determines the type of activities and behaviour that can be encountered in each area. The symbiotic relationship between user and space unfolds in interesting ways, determining the creative usage of space.