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Affordances of the Spatial Design of School Buildings for Student Interactions and Student Self-Directed Learning Activities

AHMED TAREK ZAKY FOUAD[1], KERSTIN SAILER[2]

[1] SPE – UNIVERSITY OF THE WEST OF ENGLAND (UWE),
[2] BARTLETT SCHOOL OF ARCHITECTURE – UCL

ABSTRACT

The importance of school buildings is rooted in the vitality of education for societal development. Literature perceives learning as a social process, enriched by student interactions and self-directed activities, and the school design should afford those learning practices. The term *afford* refers to spatial affordances which are defined, in this paper, as the set of possibilities for activities offered by the spatial design to students. Therefore, research on school buildings requires a broad investigation of the spatial design, to uncover the design potentiality and explore the actuality of school operation, in terms of the occurring student interactions and self-directed activities (as representations of social learning). This investigation outlines the research scope, while more attention is drawn towards informal learning spaces outside classrooms, including corridors, open-plan studios and social spaces.

This paper focuses on the affordances of the spatial design of secondary school buildings. It presents the outcome of quantitative spatial analysis (using Space Syntax tools) on eleven UK schools, designed by three architecture firms, supported by qualitative interviews with the architects of those schools. This data set explores the school design potentiality for possible learning practices. The paper, thereafter, presents quantitative recording of student interactions and self-directed activities in two of the eleven schools, supported by qualitative interviews with the school managements and teachers; and student questionnaires. This data set explains the actuality of student interactions and self-directed activities, relative to operational managerial schemes and student preferences.

Findings discuss the influence of functionalities allocation and configurational accessibility on student interactions, activity types and distribution. This is portrayed through the example of school corridors which afford interactive learning if being highly accessible and connected to

open learning spaces. Nevertheless, operational managerial schemes and student preferences still influence the occurring activities. The research outcome explains the school actual operations, and how they correspond to (or divert from) the original design potentiality. This outcome contributes to the existing knowledge on the student social life in schools, and how the spatial design and school rules impact activity types across informal spaces. This possibly links to future work on interactive design processes that include architects, teachers and school managements to reduce the gap between school design intentions and operation.

KEYWORDS

School Design, Informal Learning Spaces, Affordances, Self-directed Learning Activities

1 INTRODUCTION

According to the UK governmental report on schools (2020), a total of 3.4 million secondary school students were accommodated across 3456 state-funded school buildings in England in 2020. The schooling system and its learning outcome are believed to contribute to the societal development (Dewey 1916/2004), and the physical environment of learning, i.e. the school building, plays a role in this contribution, being the incubator of daily learning activities (Daniel et al. 2019). It is calculated that one secondary school student spends an average of 912 hours per year at school (OECD 2014). This quantified long duration raises questions about the relationship between the student and their school building; and renders the importance of studying schools as the built environment that possibly impacts the learning process.

Although this paper focuses on studying the spatial dimension of schooling, it is important to acknowledge how the schooling system is composed of diverse parameters; these might require a separate study just to present them, their multi-layering and entanglement. There are three main over-arching parameters of the schooling system. Firstly, there is the learning process. It is structured through the curriculum, i.e. what is being studied, and controlled by the teacher. Learning is disseminated through learning activities, such as lectures, discussions, homework, self-guided reading, group and individual projects, etc. These are guided by the learning philosophy, described as the human perception of how knowledge is gained. Secondly, there are the students as the recipients of knowledge, and they are impacted by their daily experiences inside and outside the school, their parental or guardian guidance, their social and economic background and other external factors which all reflect on the student behaviour, performance, needs and preferences.

The third overarching parameter (which is highlighted in this paper) is the school building, being the physical environment where learning occurs. The school building begins as a design project with a design process that follows a brief, a set of regulations, a specified site, client requirements, budget limitations and environmental and social considerations. The design is

influenced by the architects' perceptions of learning spaces and how the learning process occurs. This is alongside the expected (yet questionable to how significant it is) input from the school management and teachers. These factors shape the design output, expressed as a set of drawings with embedded spatial attributes of functionalities, configurations, forms, areas, etc. The design process and its output drawings yield (upon construction) a tangible premise, i.e. the school building, with a set of spaces, like classrooms, halls, studios, dining spaces, a library and play areas, connected by a circulation network. Those spaces themselves are characterised by tangible attributes, such as furniture, equipment, partitions and materials; or other intangible attributes, such as illumination, air quality, acoustics and spatial functions and relations of accessibility or visibility.

This paper explores the school building parameter through specific spatial attributes which are the spatial functions and configuration. Firstly, the allocation of functions decides which spaces attract certain student activities, for example, the school library is argued to be an attractor for intellectual activities. Secondly, the spatial configuration, as described from a space syntax perspective, explains the relations between spaces according to the degree of accessibility or visibility which influences the student patterns of movements, co-presence and encounters, by increasing (or restricting) their chances of mixing in space, hence, shaping their social life and subsequent activities (Hillier 1996). The aforementioned attributes (functions and configuration) are perceived as spatial input that influences the school design potentiality, defined as the spatial potential to impact the types and distribution of student learning activities. Since this perception of design potentiality connects to a specific social parameter of the student activities in the school, therefore, it is argued that space impacts activities, linking back to the entanglement of the over-arching parameters: the learning process, the students and the school building.

The social-spatial relationship between learning activities and learning spaces is expressed in the generic research question which inquires how the spatial design *affords* the student learning activities. The term *afford* refers to spatial affordances which are the opportunities for learning activities relative to the design potentiality. In that essence, in order to highlight (and then understand) the impact of the spatial design, the research minimises interference from other parameters, such as teachers who could highly control student activity types and distribution in space (mostly during class-time). Instead, the study focuses on the student self-directed learning activities which are initiated by students themselves mostly during their breaks, when students are granted more freedom; and mostly within informal learning spaces outside the boundaries of the formal classroom. Accordingly, the research question is refined to investigate the potentiality of the school spatial configuration and function allocation to afford the actuality of occurring student self-directed activities, especially within informal learning spaces.

2 LITERATURE REVIEW

The previous section explained the focus of this paper which is to explore the impact of the functionalities and configurations (as spatial attributes that shape the design potentiality) on the affordances of the school building for student self-directed activities (occurring actuality), especially within informal learning spaces. This renders the importance of defining and exploring literature on those main parameters: the spatial configuration, the learning activities and the concept of affordances.

2.1 The School Buildings as a Social Structure

Buildings, including schools as one typology, are perceived as active contributors to the social life of the inhabiting society (Hillier 1996), following as earlier perception that introduced the society's social practices as means of shaping the environment (Lefebvre 1992); and the human behaviour and activities to be impacted by their environment (Kelly 1955). The interrelation between the society and its spatial form was articulated in Hiller and Hanson's (1984) argument that buildings are capable of shaping the user movements, interactions and activities in space, in respect to the spatial configuration that shapes the occupants' encounters, thus, bringing them together or taking them apart, relative to configurational integration or segregation (Hillier 1996). In this context, the school building and its spatial configuration are perceived as main contributors that influence the student interactions and activities in space. Nevertheless, it is argued that the building programme (i.e. the set of social rules – strong or weak) impacts the occupant activities and behaviours (Penn 1991). The school building is expected to follow a strong programme guided through social rules imposed on space. Even if the research focused on self-directed activities initiated by the student themselves (to minimise control over activities), it still acknowledged the input from the management regulations and teacher supervision on activities.

2.2 Learning as a Social Process: Interactions and Self-directed Activities

By acknowledging the relationship between buildings and the social life of their inhabitants, school buildings are recognised as social entities, such that learning is the main social activity happening inside the school (Brown 2004). The perception of learning as a social process is founded on a constructivist philosophy that expands the human understanding of knowledge gain beyond the conventional methods of content delivery into the student mind, for instance, lecturing (Bruner 1990; Cooper 1993). Constructivism, as a learning philosophy, recognises the student as the builder of their own knowledge (Cooper 1993) through experiences, thoughts and perceptions from their daily social life which encompasses a set of diverse learning activities (Jonassen 1991). This brings in the idea of social constructivism, where learning, as a social process, is enriched through social activities and interactions initiated by members of a learning society (Vygotsky 1978), represented by the students in this context of the secondary school. These ideas (on social learning) are the main reason behind the research decision of including

student interactions as one form of learning activities inside the school, driven by the students themselves.

Alongside interactions, the recognition of learning as a social process (driven by the students) renders self-directed activities as important learning tools, because they grant autonomy to the students to decide on their activity type, resources, pace and goals; to self-motivate themselves; and to regulate the process with possible self-assessment at the end (Gibbons 2002). Examples of self-directed learning activities, which are expected to happen inside schools, include independent self-guided reading, reflective writing, solving problems and learning discussions (Hiemstra 1994), all possibly performed collaboratively or individually (except for discussions which require a group). The aforementioned variations of self-directed activities are mostly considered as intellectual activities. Nevertheless, a wider understanding of self-directed activities comprises additional practices that benefit the student mental wellbeing, such as relaxations and performances (Hughes et al. 2019); or practices that benefit the student physical wellbeing, such as sports (Ucci et al. 2015). Acknowledging this spectrum, diverse student self-directed activities (alongside interactions) are recognised and included in this study, as long as they are not initiated nor fully controlled by teachers. In fact, the autonomy granted to the students (to decide their activities) is an important condition, to ensure that the research captures the influence of the design potentiality on the student activity preferences as the primarily contributor, with less (and secondary) input from teachers.

The occurrence of self-directed activities alongside interactions is related to certain spaces that attract students outside the classroom environment or other formal spaces, hence, referring to informal learning space (Knapp 2007). Informal learning spaces are perceived as areas inside the school building which do not have a single discipline (Harrop and Turpin 2013), such as presentation spaces and lounges (Lackney 2015; Pasalar 2003), libraries (Oblinger 2006), dining areas (Hughes et al. 2019), playgrounds (Knapp 2007) and corridors (Sailer 2015; 2018). As mentioned at the beginning of this paper, this study focuses mainly on the school informal learning spaces, because it is argued that their design holds the potentiality to influence the type and distribution of activities, especially as the study has already declared a selective investigation of only self-directed activities and interactions which are not driven by teachers.

2.3 Spatial Affordances for Activities

Whilst it is argued that activities are impacted by the spatial design, it is also argued, in another way, that the design (and its potentiality) affords the occurrence of those activities (Daniel et al. 2019). The term *afford* was introduced by James Gibson who argued that organisms perform actions within the environment that affords those actions; a chair affords the act of sitting (Gibson 1979). In the context of the school building, students are organisms that perform learning activities (studied in this research as interactions and self-directed activities) which are in return afforded by the school building (with focus on informal learning spaces). Following the

same train of through, spatial affordances represent a set of possibilities for learning activities that are offered by the learning environment; and are capable of influencing the student preferences as the user in space (Rietveld and Kiverstein 2014). The complexity of the spatial affordances is derived from the inter-relation of the environment, its possibilities and the activities taking place which are relative to the users (the students and their preferences in this context) and the society's normative practices (the school regulations and teacher input) (Chemero 2003; Rietveld and Kiverstein 2014).

In summary, through exploring the main parameters of this study, this literature review has supported the main argument: that the spatial design of the school informal spaces potentially affords the occurring student interactions and self-directed activities. The school building, through its spatial configuration, contributes to the learning process that is recognised as a social process, expanding beyond typical content delivery methods, to be enriched through student social interactions. Social learning cultivates through the constructivist perception of knowledge gain in the student mind through experiences, thoughts and perceptions. The recognition of constructivism highlights self-directed learning activities as crucial means that support the student knowledge gain inside the school, such as intellectual self-directed activities of independent reading, reflective writing and solving problems; but also expand to encompass other self-directed activities that improve the student mental and physical wellbeing (e.g. relaxations, performances and sports). These self-directed activities are expected to concentrate within informal learning spaces outside the classroom boundary (e.g. corridors, dining spaces, libraries, playgrounds, social spaces, etc.), especially during break-times when students have the highest degree of freedom. In that essence, the design of informal spaces is supposed to afford the student self-directed activities and interaction patterns, such that the spatial affordances are the possibilities, or the learning opportunities, offered by the learning environment to the students.

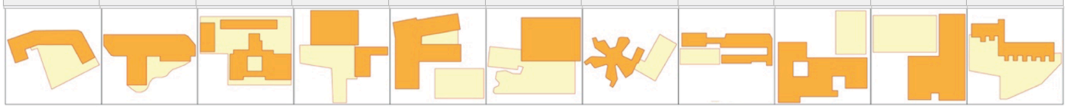
3 METHODS AND DATA SETS

This research explores the relationship between the design of informal learning spaces inside secondary school buildings and their impact on student learning activities, thus, to eventually understand the spatial affordances as opportunities for student interactions and self-directed activities that are realised in the school building. To explore this relationship between space and activities, the study utilised mixed quantitative and qualitative data through two main phases which explore (1) the potentiality of the spatial design and (2) the building actuality of occurring activities.

The first phase studied the design potentiality through focusing on the spatial functions and configurations as two spatial attributes that are argued, in this paper, to influence the potentiality, i.e. the possibilities or opportunities for learning activities initiated by the students themselves.

For that, the research studied the spatial design of eleven secondary school buildings, as the main case studies (A1, A2, A3, A4, B1, B2, B3, C1, C2, C3 and C4; table 1), selected from the projects of three different architecture firms (A, B and C). The three firms were carefully chosen to have high expertise in the design of school and learning spaces, while the cases studies were selected to maximise the diversity of building typologies for school buildings.

Table 1: Layouts of the Eleven Case Studies (Lighter Yellow is the Outdoor Area)

	A1	A2	A3	A4	B1	B2	B3	C1	C2	C3	C4
Area	12218	11724	21298	8314	12352	20156	48961	35912	20087	11316	7686
Layout											

To study the school design potentiality, the main data set is the quantitative spatial analysis using space syntax methods, to evaluate the configurational accessibility of the floorplans (figure 1). The main measure used for that is Visual Mean Depth which measures the average number of turns to reach every space in the school from all other spaces. In that essence, a low value (more red on the graph) indicates that a space is shallow or highly accessible, whereas a higher value of Visual Mean Depth (more blue) indicates that a space is deep in the system, i.e. highly segregated. Values of Visual Mean Depth are comparable between different spaces of the same school or different school buildings, which helps throughout the comparisons between the eleven schools. There is another quantitative data set, prepared on GIS software for every school building of the eleven, which includes the spatial function of each space (figure 2), its geometric area and its categorisation as a formal teaching space, an informal learning space, an office, a service space or a circulation space (which is perceived as an informal learning space but kept in separate category to understand the properties of circulation). Both data sets, i.e. the configurational accessibility analysis and the spatial functions with areas and categories, are combined on GIS software to deduce the configurational properties of every individual space, every spatial function of multiple spaces (e.g. classrooms, corridors, halls, dining spaces, etc.) or every spatial category (e.g. informal learning space, formal teaching spaces, circulation, offices or services). Finally, the quantitative data sets are complemented with qualitative semi-structured interviews with one lead architect (involved in the school projects) from each of the three firms. These interviews explain the main design decisions taken for the projects and the architects' approach to configure learning spaces.

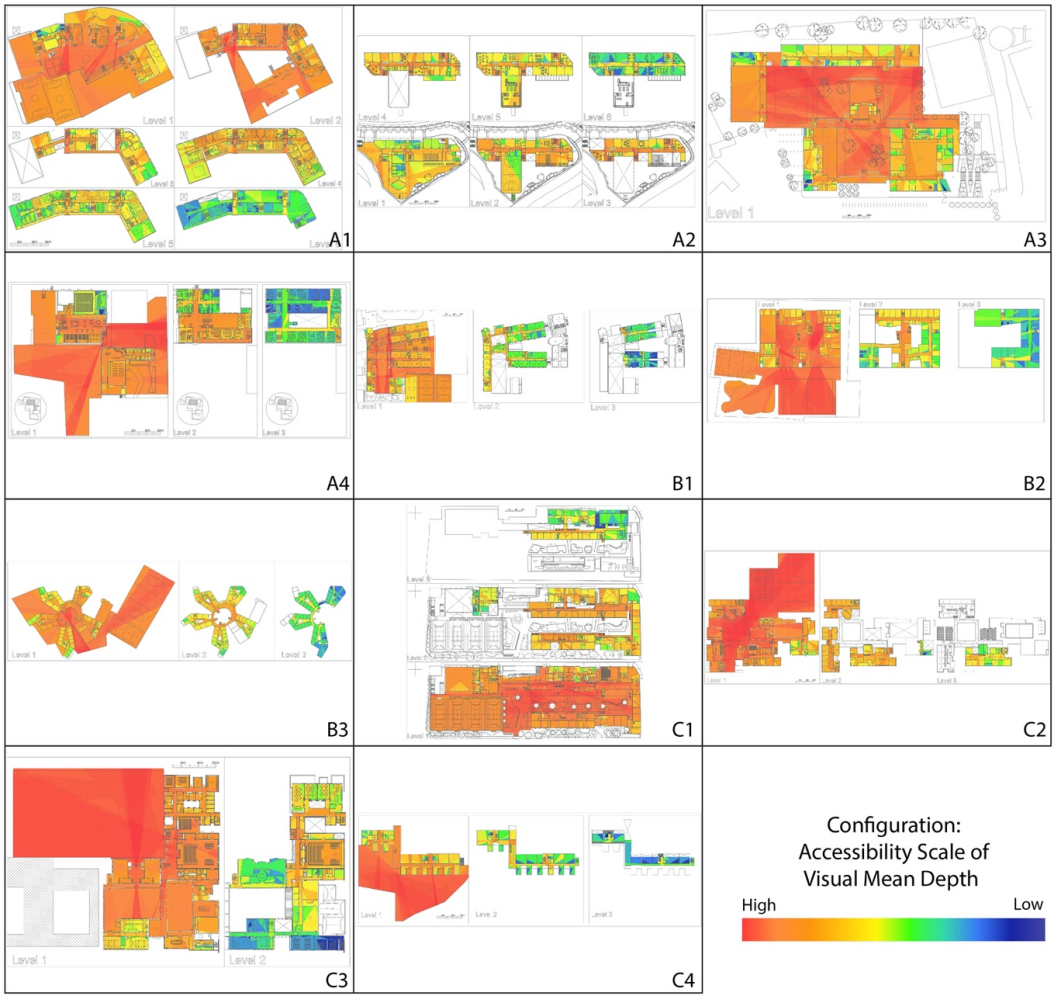


Figure 1: Visual Mean Depth (Accessibility) of the Eleven Schools

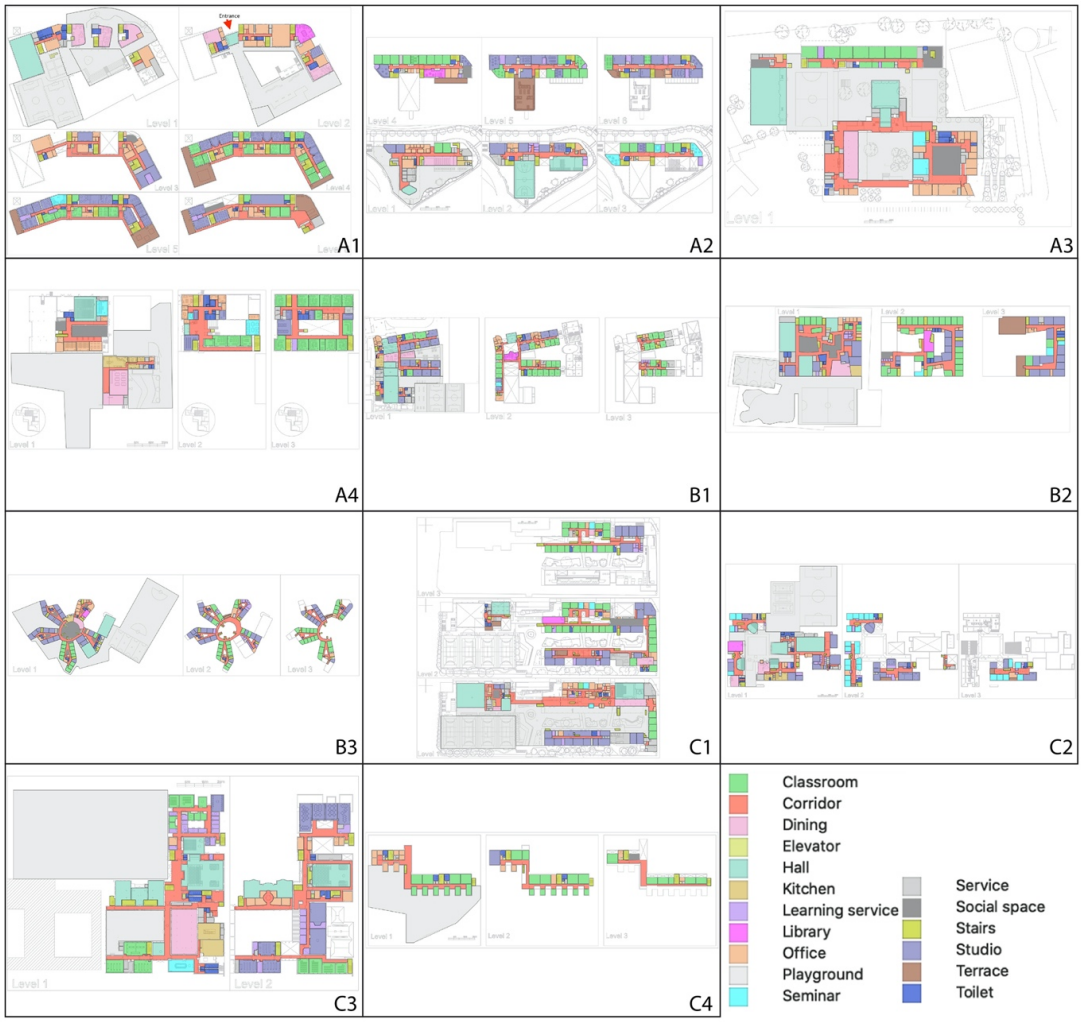


Figure 2: Spatial Functions of the Eleven Schools

The second research phase studied the school building actuality of occurring activities through focusing on activities initiated by the students with less control from their teachers. These include the patterns of student interactions (which are perceived from literature as social learning), student self-directed intellectual activities (e.g. independent reading, individual or collaborative studying and revising) or further self-directed activities that, according to literature, are important for the student mental wellbeing (e.g. dancing, praying, relaxations). To collect these data sets, two schools (A1 and B1) were selected from the eleven schools (already studied for their potentiality – functions and configurations). They have different building typologies and different types of learning space to diversify the output of data collection. For the same two schools, the quantitative data of student activities are complemented with qualitative semi-structured interviews with two teachers and two members of the school management, to understand the school regulations, teacher supervision and the daily schedule. Finally, the research also prepared and distributed an online student questionnaire to collect information about their activity preference and ratings to different school spaces.

To collect the main quantitative data set of student activities in space, this study conducted fieldwork observations, utilising a method defined as snapshots. One snapshot records the location of students within a certain observed area, in addition to their activity type (e.g. studying, reading, eating, talking, etc.), their grouping (e.g. individual, in a pair, group of three, four, etc.) and their locomotion (sitting, standing or moving). Multiple snapshots are conducted in different spaces of the school with emphasis on informal learning spaces, perceived from literature as spaces outside the closed classroom, like school libraries, dining spaces, playgrounds, terraces, corridors and social spaces. Snapshots are repeated at different times of the day with focus on the break times (e.g. morning break and lunch break) which are argued, in this paper, to host a higher variation of self-directed activities, providing more student freedom and less teacher control. All of the collected snapshots are digitised, compiled and geo-referenced onto the floorplans using GIS software, while maintaining the data attributes (activity type, grouping and locomotion). One extra attribute is added from the spatial analysis data set (through a GIS spatial join) which is the accessibility (visual mean depth value) for each recorded student in space. The final step is to create activity categories based on general themes of similar activities (table 2), for example, grouping the activities of talking, arguing, shouting at each other into one category: interactions. These categories facilitate understanding the activity diversity (through simplification) and help in the process of plotting correlations with spatial attributes (shown in the findings). This process also groups activities that were not self-directed by students but driven by their teachers, to be excluded from the study. The output of collecting the student activities is displayed in figure 3.

Table 2: Categorisation of Activities into Main Themes

Main Activity Categories	**Variations of self-directed activities**
Interactions	Shout - Talk – Argue
Intellectual	Draw - Explore - Laptop - Origami - Read - Revision - Rubik's cube - Study - Colour – Computer - Get Book – Homework – Paint – Portfolio -
Sports	Ball - Football - Basketball - getting and throwing ball – Gym – Ping pong
Eating	Eat - Drink – Snack
Performance	Dance - Play Music - Rehearse Play - Sing – clap
Chill	Relax - Sleep – Stretch
Games	Cards - Carry each other - Chess - Coins - Game challenges – play elastic bands
Spiritual	Pray
Store/Retrieve	Locker – Put Bag
Solitude	Sit - Walk alone (without doing any other activity)

Waiting	Wait - Queue to class - Get food - Get laptop - Queue get food -
Watch	Watch
Clean Challenges	Chase - Jump - Roll in grass - Run
Physical challenges	Bag Fight - Fight - Push - Tie Fight
Misbehaviour	Climb Post - Flip on Sofa - Jump Fence - Mobile – Scream with water - Sneak Scooter - Spray Water - scream
Others	Comb hair - Party - Take Pictures - Wrap up - Write on hands
Teacher Driven Activities **(recorded but not included in the study)**	Detention - Attend class or tutorials run by teachers - Print - Search - Sent out of class

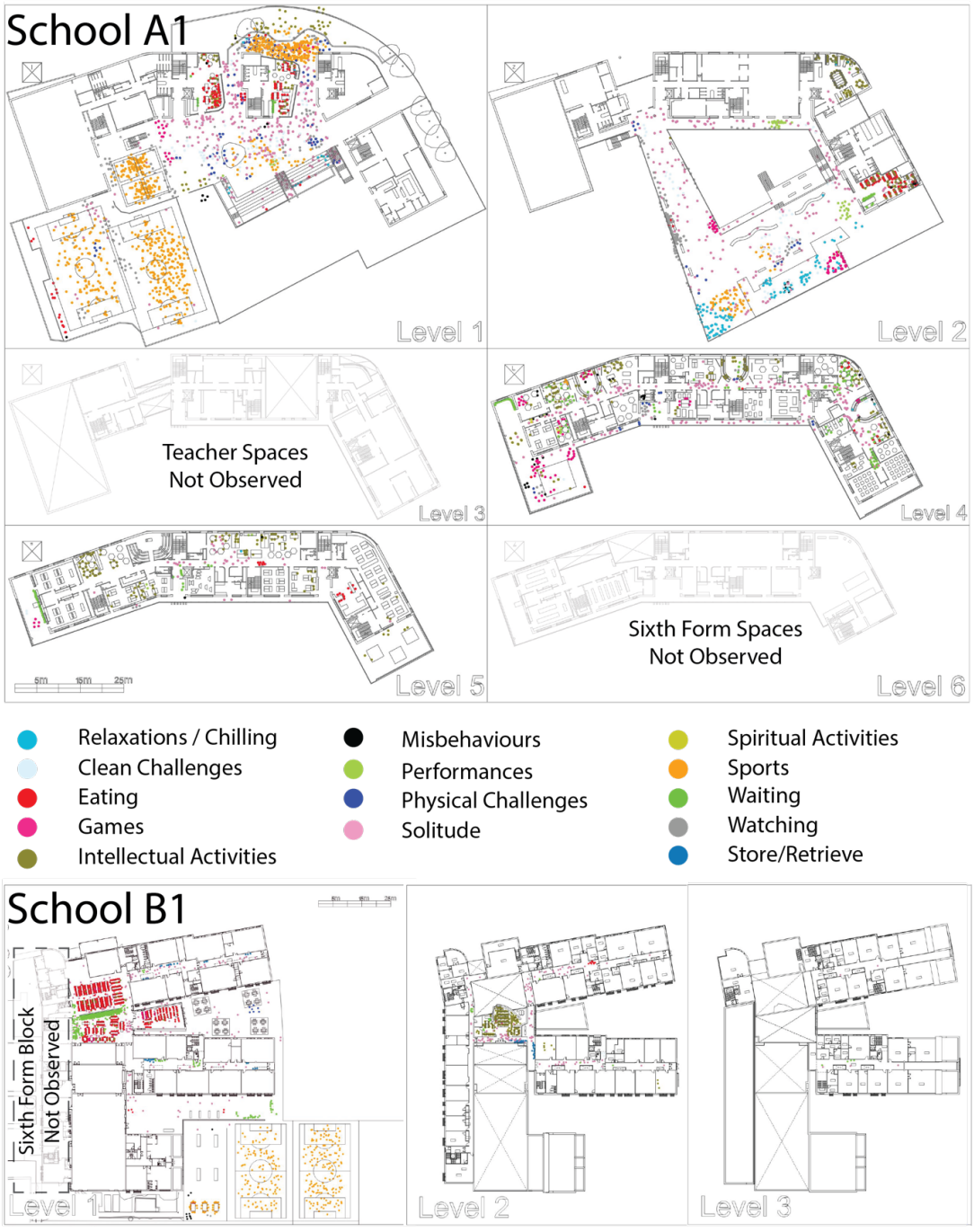


Figure 3: Student Self-directed Activities on the Floor Plans (A1 vs B1)

In summary, the research studies the school design potentiality and building actuality of student learning activities. This is achieved through quantitative analysis of the spatial configuration and functions of eleven school buildings, designed by three architecture firms; and quantitative data of the student interaction patterns and self-directed activities, recorded from two of the eleven schools. These data sets are complemented with qualitative semi-structured interviews with the architects to understand the design process; or with the teachers and school management members to understand the school regulations, schedules and supervision. Finally, an online questionnaire collects the student activity preferences and ratings to different spaces. Table 3 summarises the research phases and the corresponding methods of data collection.

Table 3: Research phases and Data collection methods

Research Phase	Case Studies	Attribute investigated	Method of Investigation	Data Type
Design Potentiality	3 architecture firms	Design intentions and ideas	Semi-structured interviews with one lead architect	Qualitative
	11 secondary school buildings (from the 3 architecture firms)	Spatial functions and configurations	Space Syntax analysis of Visual mean depth; GIS function analysis	Quantitative
Building Actuality	2 school buildings (design by 2 of the 3 different architecture firms)	Student self-directed activities and interactions	Snapshots during fieldwork observations	Quantitative
		School regulations, schedules and supervision	Semi-structured interviews with Management members and teachers	Qualitative
		Student activity preferences and ratings of spaces	Student Questionnaire	Quantitative

4 FINDINGS

4.1 The Potentiality of School Design

Through studying eleven school buildings, the research infers that the spatial functions and configurations have significant properties, as spatial attributes that influence the potentiality for student interactions and self-directed activities. Firstly, the study of the floorplans and their geometric areas reveal a pattern in the area allocation of functionalities. In all eleven schools, there is a significant strong variance in the area of different types of spatial functions (P-value<0.0001), as displayed from the R^2 values of the ANOVA test in table 4. This possibly indicates that the area allocation for spatial functions is not randomised but follows a design logic which is somehow expected to happen during the design process. Yet, the more interesting finding is that informal learning spaces, like the playground, main hall, one corridor, the dining space and the library, are always the largest on the scale of each separate space – not considering the aggregate area where classrooms (formal spaces) will get into this rank. This is the first spatial property (i.e. area) that shows the potentiality of informal spaces to bring students together in a single space that (by area) could accommodate their group social interactions or further self-directed learning activities. Those large informal spaces are attractors for students especially during break-times when a large number of students gather in the same location, unlike their division during class-time.

Table 4: Strength of the Coefficient of Variance (R^2) in the Areas of Spatial Functions

School	R^2 (Variance of areas for school functions)
A1	0.88
A2	0.89
A3	0.72
A4	0.97
B1	0.82
B2	0.99
B3	0.68
C1	0.88
C2	0.81
C3	0.61
C4	0.99

Secondly, studying the design reveals another spatial property related to the school functions which is the degree of mixing different functionalities in one zone. The lowest degree is the non-mixing of functions, for example, creating a cluster of repeated classrooms. This happens across multiple blocks in a campus layout (e.g. school A3 and A4), across multiple zones within one level or more (e.g. school C3) or along the spine of a compact building (e.g. school C4). In other design scenarios, the school floorplan exhibits a mix of functions in one cluster, but of the same

formality, like classrooms, studios and seminar rooms (e.g. school B1 - level 1 and school C2 - level 3). In those two design scenarios, i.e. mono-functionality (only classrooms) or mono-formality (classrooms and studios), the design limits the potentiality for students to initiate interactions or self-directed activities, due to the non-existence of informal spaces to accommodate those activities, except for the formal mode of teaching inside classrooms, controlled by the teachers. This potentiality slightly increases for designs that allocate teacher offices proximate to classrooms in the same cluster (e.g. school A1 – level 3). In this case, while there is still mono formality (as offices are formal spaces), there is potentiality for student self-directed activities during breaks, if teachers, who are close-by for supervision or natural surveillance as they walk in corridors, allow students to occupy the classrooms.

Continuing with the degree of mixing functionalities, in contrast to the previous design solutions, other schools exhibit a mix of functionalities and formalities, because informal learning spaces are integrated among formal teaching classrooms or studios. In the simplest example, terraces are allocated at the peripheries of the floorplan as informal break-out spaces that are proximate to classrooms for students to use between class-times (e.g. school A1 – level 4 and 5; school A2 – level 5 and 6). A higher degree of mixing functionalities is portrayed in further design solutions where the repeated cluster has formal teaching classrooms, offices and a central informal courtyard (e.g. school B3); or the compact floor level has classrooms, offices and open-plan studios that integrate into the main corridor (e.g. school A1 – level 4 and 5). The highest degree of mixing functions is the design of independent clusters, each having its own formal classroom (or studio), an informal social piazza, a local dining space and office (e.g. school C1). In the latter two design scenarios, the potentiality for student interactions and self-directed activities is arguably very high, as students meet together and occupy the informal spaces for diverse activities that lasts for short periods between class-times or extends for longer periods during break-times. Table 5 summaries the mixing of functionalities and formalities in the eleven schools.

Table 5: Mixing Functionalities and Formalities in Every School

School	Building Typology	Functionalities	Formalities
A1	Compact urban block	Mix on upper levels	Non-mixing of formalities Separated by levels
A2	Compact urban block	Mix on all levels	Mix on lower levels
A3	Campus environment	Non-mixing Clustered in different blocks	Non-mixing Clustered in different blocks
A4	Multi-grade campus	Non-mixing	Non-mixing Separated by levels

		Clustered in different blocks and across levels	
B1	centralised resources with classroom wings	Limited mixing within wings	Non-mixing (highly insulated by departments)
B2	Compact urban block	Mixing on all levels	Mixing on level 1 and 2
B3	centralised resources with classroom clusters	Mixed within the cluster	Mixed within the cluster. Hierarchy of formalities within cluster
C1	Compact urban block	Mixing within the wings	Mixing within the wings
C2	Campus environment	Mixed within each block	Mix on level 1 with Hierarchy of formalities. Non-mixing on upper levels
C3	Compact urban block	Non-mixing Clustered along spine	Non-mixing Clustered along spine
C4	Elongated single spine	Non-mixing Clustered along spine	Non-mixing Clustered along spine

Alongside studying spatial functions, the spatial configuration is another main spatial attribute that contributes to the potentiality for student interactions and self-directed activities. Configurational high accessibility (measured through low values of visual mean depth) yields higher student movements, thus, increasing the possibilities for student encounters with each other (or with teachers) and the consequent interactions that could further grow into collaborative self-directed activities. The study of the eleven schools indicates a significant variance (p-value<0.0001) in the configurational accessibility of different functions, evaluated through an ANOVA test for the visual mean depth vs the spatial function. For example, corridors are usually highly accessible and centralised with multiple access points and connections to most of the other spaces, thus, having high potentiality to bring students together and trigger their interact. Contrarily, formal classrooms or studios are less accessible, being clustered and segregated on upper floor levels; and terraces are more segregated on the floorplan peripheries. Those spaces have low potentiality for student cross-passing or interactions. Finally, informal dining spaces, libraries and social spaces are in the mid-range accessibility, relatively shallower than formal classroom but deeper than corridors. They have the potentiality for self-directed activities, when being open and directly connect to main corridors.

After establishing the relationship between configuration and the spatial potentiality and similar to understanding the floorplan zone through its degree of mixing functionalities, the floorplan

zone is also analysed for the degree of diversifying its configurational accessibility. It is argued, in this paper, that diversified configurational accessibility, i.e. different visual mean depth values for different spaces in one zone, yields higher potentiality for student activities to diversify in one zone, providing that the design secured mixed functionalities and formalities (discussed before). For example, a shallow informal social piazza (e.g. in school C1), a courtyard (school C2) or an open-plan studio (school A1) would potentially accommodate the vibrant student collaborative self-directed activities, entangled with their interactions that propagate from the circulation corridor. In the same zone, quieter focused self-directed activities might potentially take place in the more segregated and closed classrooms or studios; and all activities are supervised by the close by teacher offices. In an opposite scenario, the design of mono-functional blocks of classrooms of monotonous segregation (school A3 or B1) would yield no potentiality for self-directed activities, while the corridors are expected to have less movements, less encounters and less interactions.

4.2 The Actuality of School Operation

Whilst the previous section has discussed the design potentiality based on eleven secondary school buildings, this section complements the findings with data of the actual operations of two of the eleven schools (selected and discussed in the methodology). Thus, it shows which potentialities are realised into actual student learning practices, relative to the design. In the two schools A1 and B1, where student interactions and self-directed activities were recorded, there is a significant variance (P-value<0.0001) in the types of student self-directed activities across different spatial functions, as indicated through a Chi-squared test (categorical variables of activities vs functions; table 6). This indicates that certain spatial functions are attractors for specific student self-directed activities (e.g. intellectual activities in the library) more than other activities, hence, supporting the original hypothesis that functional allocations shape the potentiality for self-directed activities. Nevertheless, the same data set suggests another interesting finding; that a single functional space is not accommodating one type of student activities but incubates a higher diversity. For instance, student interactions disperse in different informal spaces, like the corridors, libraries, dining spaces and play areas. Even the self-directed intellectual activities are not limited to the boundary of the library but spread into the dining spaces of both schools and the corridors, open-plan studios and terraces of school A1.

Table 6: Percentage of Occurrence of Self-directed Activity in Each Spatial Functions (A1 vs B1)

Column%	Classroom		Corridor		Dining		Gym		Hall		Library		Playground		Stairs		Studio		Terrace	
	A1	B1	A1	B1	A1	B1	A1	B1	A1	B1	A1	B1	A1	B1	A1	B1	A1	B1	A1	B1
Chill	0	NA	0	NA	0.2	NA	19	NA	0	NA	1.4	NA	1	NA	0	NA	0.5	NA	0	NA
Clean Challenge	0	0	0.3	0.6	0	0	0	0	0	0	0	0	2.1	0	0	0	1.1	0	2.4	0
Eating	0	0	1	0.9	40	35	0	0	0	69	0	0	0.4	0.7	0	0	0	0	1.2	0
Games	22	0	0	0	1.7	2.8	0	0	0	1.6	0	0	1.4	0.7	0	0	1.8	0	22	0
Intellectual	33	43	0.4	0.2	32	3.4	0	0	0	6.9	68	86	0.6	0	0	0	38	0	14	0
Misbehaviour	1.8	0	0.8	0	1.6	0	0	0	0	0	0.9	0	0.1	0.6	0	0	1.9	0	6	0
Performance	5.4	0	0.1	0	0.3	0.7	0	0	0	0	0	0	0.8	0	0	0	0.5	0	0	0
Physical Challenge	0	0	1.4	0	0	0.2	0.3	0	0	0	0	0	1.3	0.6	0	0	0.3	0	1.2	0
Solitude	0.9	0	17	13	1.4	2.5	2.7	0	0	2.5	0	2.2	6.1	3.9	7.1	0	5.9	0	5.4	0
Spiritual	4.5	NA	0.3	NA	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Sports	0	0	0	0	0	0	16	0	0	0	0	0	12	32	0	0	0.6	0	0	0
Store/retrieve	NA	0	NA	7.8	NA	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA	0
Interactions	21	57	68	75	16	20	62	0	0	20	29	7.1	71	59	93	100	41	0	23	0
Waiting	12	0	7.9	3	6.9	35	0	0	0	0.9	0.9	0.8	0	2.3	0	0	7.3	0	23	0
Watch	0	0	2.9	0	0	0.4	0	0	0	0	0	3	3.7	0.2	0	0	0.8	0	2.4	0

The potentiality for student interactions and self-directed activities is not only influenced by the spatial functions, but it is argued to be also impacted by the spatial configuration. This was shown previously as one function is not associated to one activity, hinting to other spatial attributes that possibly contribute. However, the argument is fundamentally supported through an ANOVA test of plotting the student activities against the corresponding accessibility (Visual Mean Depth) of the space where they occurred. This data set indicates a significant variance (P-value<0.0001) in configurational accessibility of each activity type in both schools A1 and B1 (figure 4). In other words, certain configurational accessibility properties correspond to certain types of student self-directed activities during the school actual operation. Therefore, the spatial configuration influences the types (and diversity) of self-directed activities, as already argued in the original hypothesis. The impact of the spatial configuration continues to show for the dispersal of student interactions. When students are granted freedom of movement, for example in school A1 during lunch breaks, the student co-presence and encounters are shaped through the accessibility properties. Therefore, there is a pattern of denser encounters within the shallow highly accessible spaces (low values of Visual Mean Depth – where movements were already expected to be higher), and the frequency of interactions fades away towards the deeper segregated spaces (high Visual Mean Depth – where movements are limited). This scenario changes in school B1 whose management control where students stay during lunch breaks, and consequently the student distributions take place within spaces of random accessibility (figure 5), relative to the spaces where teachers allowed students.

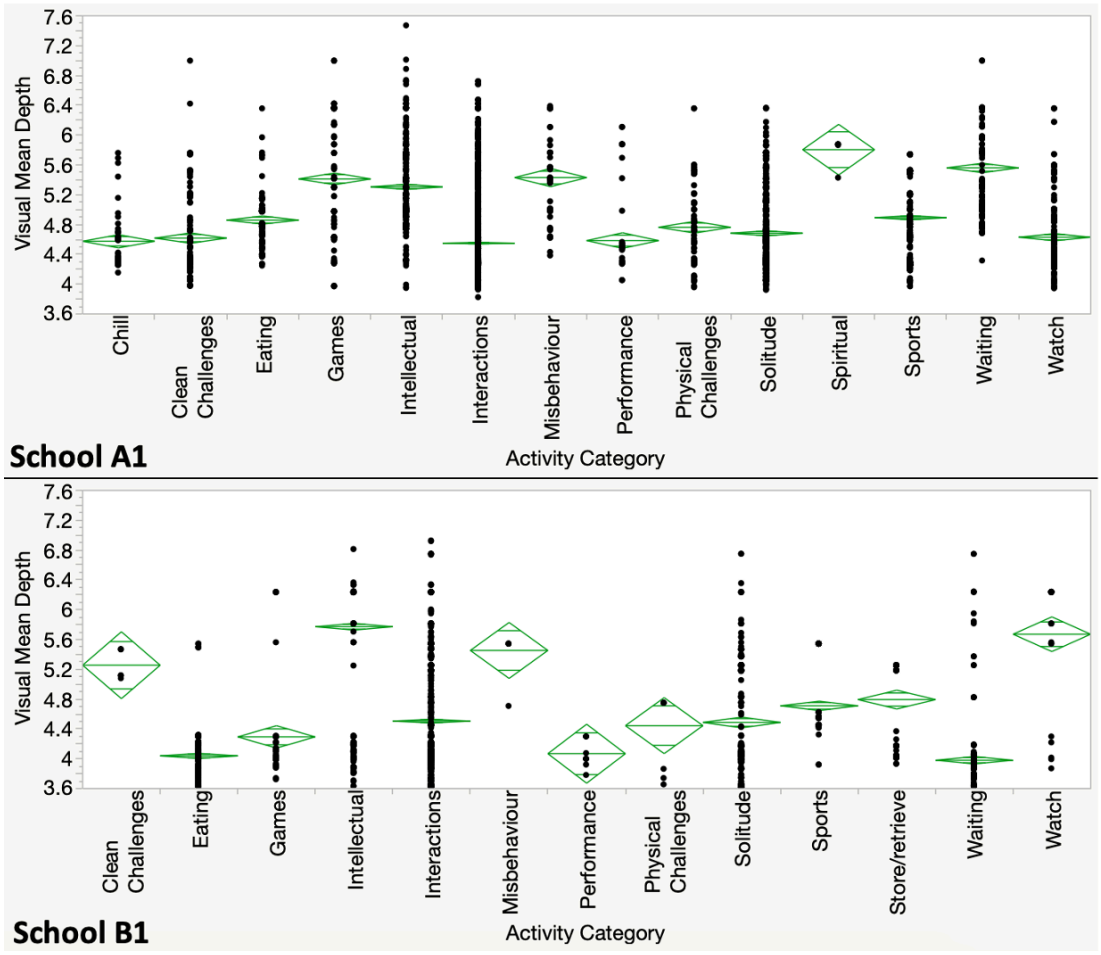


Figure 4: Visual Mean Depth Correlated Against the Student Activity Categorisation (A1 vs B1)

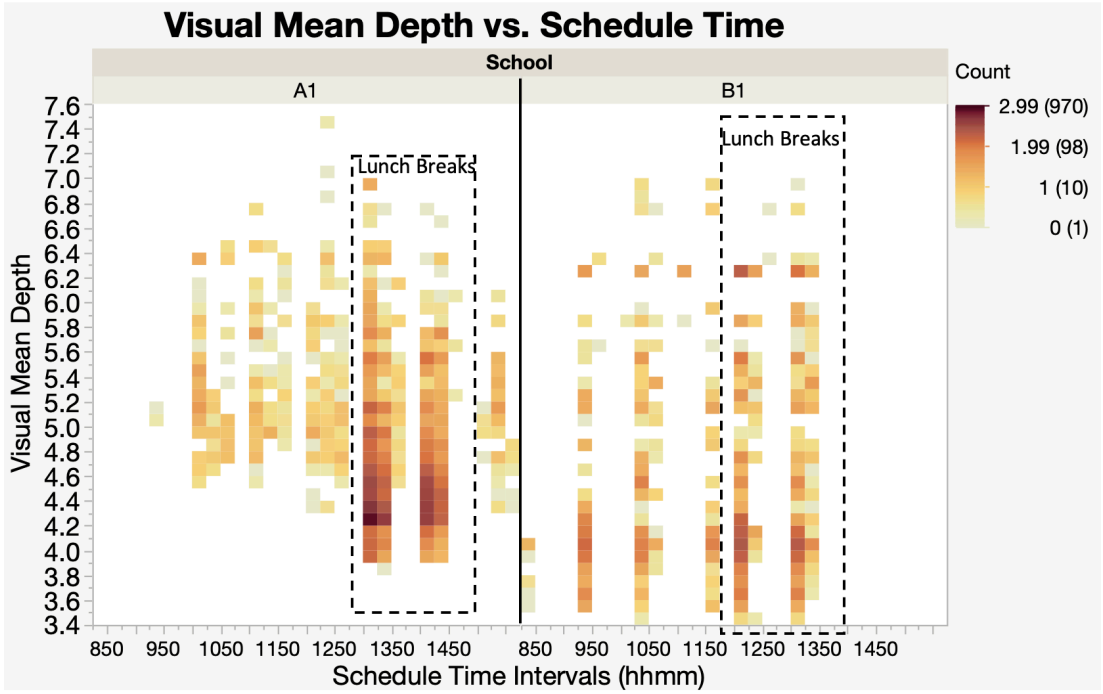


Figure 5: The Degree of Accessibility and Frequency of Interactions Framed for Lunch Breaks

4.3 The Potentiality vs Actuality of Corridors and Open-plan Studios

It has been demonstrated in the previous two sections how the design potentiality relates to the actual student interactions and self-directed activities, from a generic point of view for the whole building, being applied to different informal learning spaces, like dining spaces, libraries, corridors, social spaces and play areas, which are argued to incubate more student self-directed activities than formal teaching spaces. Although the full research expanded to those diverse informal spaces, this paper focuses on how the actuality of student interactions and self-directed activities corresponds to the design potentiality in specific informal spaces. The chosen spaces are the internal corridors and their surrounding spaces: open-plan studios in school A1 – level 4 or the social break-out space in school B1 – level 2 (figure 6). The study of those specific informal spaces brings in the furniture types and layout as another spatial attribute that impacts the design potentiality. It also brings in the role of teacher supervision and management regulations which are relative to each individual space and therefore impact the realisation of potentiality into actuality, as briefly demonstrated through the randomised student distribution in spaces of different configurations in school B1, following where teachers allowed students to be, unlike A1's student free distribution that followed a configuration logic (from shallow to deeper spaces) rather than regulations.

Figure 6: Studied Informal Learning Spaces in A1 vs B1

Starting with School A1, the actuality for student interactions and self-directed activities originates from the design potentiality and is supported by the school's free-movement environment and lenient rules. During break-times, A1 management does not restrict students to the playground, the dining spaces nor the library. Instead, they allow students to move along the main vertical cores (which are configurationally shallow, hence, attracting movements) into the upper-floor internal corridors and the surrounding open-plan studios. This operational model yields diverse student interactions, self-directed intellectual studying and further self-directed activities that are important for the student mental wellbeing, such as dancing, praying and individual relaxations. A few misbehaviours were recorded, like using mobile phones, spraying water, fighting or playing with a ball. The occurring activities also indicate that a free environment allows student preferences to surface and manifest in space, as expressed in the student questionnaire which stated that open-plan studios were favoured by students for

intellectual activities (17%), social interactions (16%), individual relations (16%), quiet conversations (9%) and to eat (7%).

Figure 7: Interactions and Self-directed Activities in A1 Corridors and Open-plan Studios

While the student interactions disperse and the self-directed activities diversify, their location (figure 7) is relative to the spatial configuration that facilitates for students to either meet and mix with others or isolate and focus individually, thus, referring to the previous discussion of how diversified configurational accessibility (within one zone) maximises the design potentiality. For instance, vibrant interactions (as the most frequent activity – 37%) are densified in the accessible locations in front of staircase, where encounters with other passers-by are frequent, thus increasing the size of the social group. Intellectual activities (as the second most frequent activity – 23%) occur as collaborative group-work sessions in the shallow open-plan studios, where students re-arrange the movable furniture (tables and chairs) to form their study group. This intellectual studying is entangled with socialisation within the group, with other groups or with passers-by in the corridors. Moreover, fewer groups studied in the corridor itself. The segregated closed classrooms are student destinations (with teacher consent) for focused studying or revising that require high degrees of concentration; or to play chess (11% of total activities), pray (3%) or dance (2%). All activities are supervised by some teachers whose offices are among and visually connect to the open-plan studios; or by natural surveillance as other teachers walk along the corridors (or occupy the open studios with students). This is apart from the student misbehaviours which hide from supervision in highly segregated spaces, like the toilet corridor or hidden corners behind the furniture of the open-plan studios.

In contrast to school A1, the operation of school B1 is very different. This results from the lower design potentiality to attract student interactions or self-directed activities; but it also corresponds to managerial constrains on student movements and distribution in space. In terms of the design potentiality, it is minimised because the internal isolated wings (north or south) have cellular closed classrooms, segregated from the narrow corridor. The movements, co-presence and interactions (already expected to be low by spatial potentiality) are further minimised during break-times, as the management closes down the gateways leading into the internal wings and only allows students to access the dining space, the library and the playground. Nevertheless, the

wings' empty corridors became desirable for some students who want privacy and do not prefer other loud and busy informal space, like the playground, the library and the dining space. These students take advantage of the un-attentive supervision (at the corridor gateways) to sneak in and interact discretely around their lockers which provide an alibi for their presence in the corridor, thus, to avoid a corridor loitering penalty. The popularity of the corridors for student interactions, despite the loitering penalty, corresponds to the student preferences as expressed in questionnaires. Corridors were the preferred location for group interactions (5%) and even higher percentage for quiet conversations with a friend (35%).

Contrary to the low design potentiality of B1's isolated wing corridors and closed classrooms, the shallower social break-out space (no 5 - framed in brown on figure 6) has relatively higher potentiality for interactions and self-directed activities, as it opens onto the busy corridor artery between both north and south wings and the library; and it is furnished as a social seating. Nevertheless, its lack of student activities illustrates the major role played by B1's school management and teacher supervision to inhibit activities, hence, overriding the existing design potentiality. There are strict penalties, displayed as multiple signages hung along the corridor walls (figure 8), to warn and restrict students from occupying this space during breaks. The emptiness of this social break-out space could relate to the lack of an alibi for the students' presence (unlike their alibi of using the lockers in the wing corridor); and due to the supervision provided by the librarian who sees the break-out space from their desk across the low-partitioned library (unlike the unregular supervision over closed wing corridors accesses).

Figure 8: Warning Signage and Penalties for Loitering in B1 Social Break-out Space and Corridors

In summary, the design of informal learning spaces has the potentiality to trigger student interactions and self-directed activities, as studied for eleven secondary schools. This is relative to the spatial functionalities that are attractor to certain types of self-directed activities, demonstrated through a significant variance in activities within spatial functions. Then, mixing different functions and formalities yield higher potentiality for diversified activities, while the size of informal spaces, i.e. being large, accommodates the large grouping of students for interactions and collaborative self-directed activities during break-times. Moreover, the design potentiality is fundamentally influenced by the spatial configuration which shapes the

accessibility of spaces and the expected patterns of movements, co-presence and interactions. The variation in accessibility properties within the same zone (of different spaces) increases the potentiality for diversified activities, either vibrant collaborative activities in the busier highly accessible spaces or quieter and focused activities in more segregated spaces; also relative to the furniture types and layout in each space. The impact of the spatial configuration is demonstrated through the significant variance in the configurational accessibility properties of different types of activities. The potentiality of the design and how it is realised into actual recorded activities is illustrated through the examples of corridors, open-plan studios and social break-out spaces in two different schools (A1 and B1). Those informal spaces exhibit a potentiality to trigger student interactions and self-directed activities which are initiated according to student preferences with minimal teacher control, within a free-movement environment and lenient management rules, as seen in A1's open-plan studios. Nevertheless, the school management and teacher supervision are capable of shaping the student activities, with less efforts when the design potentiality is already low – not triggering student mixing (e.g. B1's segregated wing corridors); or shaping the student activities even against the existing high design potentiality (e.g. B1's closed social break-out space) which requires a lot of strict rules and regular supervision.

5 DISCUSSION

5.1 The Affordances of Informal Learning Spaces

The affordances of informal learning spaces resemble the outcome of the realisation of certain learning opportunities of student interactions and self-directed activities from the possibilities offered through the design potentiality which itself is shaped through the spatial functions and configurations. This realisation process (from potential opportunities into actuality) is not only guided those spatial attributes (functionalities and configurations), but it is also deeply embedded in the managerial input (regulations and teacher supervision) which either provide a free environment (i.e. few and more lenient rules – the case of A1) for student preferences to surface and manifest in space; or impose a strict environment (more rules – the case of B1) that limits the dispersal of student interactions and minimises the diversity of self-directed activities. In that essence, it is possible to argue that an informal space affords student interactions and self-directed activities, if the design potentiality offers the learning opportunities which matches the student preferences, and the school management simultaneously allows the realisation from possibilities to actuality. For instance, informal open-plan studios (studied in school A1) afford student interactions, being directly open towards the highly accessible corridor, thus mixing passers-by to occupiers of the open studio. They also afford student self-directed activities, facilitated through their functionality that attracts students to perform collaborative intellectual studying and supported through the existing flexible furniture to accommodate the students' group or individual seating. This example is described in literature as a rich landscape of affordances (Rietveld and Kiverstein 2014) which portray the spatial manifestation of is referred

to (also in literature) as social and collaborative learning (Vygotsky 1978). Contrarily, it is not possible to state that the break-out social space (in school B1) affords student interactions nor self-directed activities even if the design intended to, because the management input has overridden the high design potentiality (through regulations), preventing the realisation of affordances into actuality.

Although the affordances are always constrained by the school management, the primary input from the environment (through the design potentiality of informal spaces) varies in its intensity, hence, impacting the probability of activity occurrence. In some scenarios of school operations, the design highly triggered a certain student behaviour, for example, B1 quiet wing corridors with allocated lockers which triggered some students to gather and interact discretely. In this case, the student preferences, supported by a design that fulfils their needs, have overridden the management regulations, despite the risky situation and the potential loitering penalty. Even in other scenarios, when the managerial input prevented the realisation of affordances, for example, B1 management preventing the use of the social break-out space, it required heavy supervision and strict regulations to alter the student behaviours that, again, were supported through the design potentiality. These examples draw attention to the strong impact of the design on the spatial affordance, a concept which is referred to in literature as affordances that command to be acted upon (Rietveld and Kiverstein 2014).

Throughout the investigation of the design potentiality vs the actuality of student activities when affordances have been realised (or not), there are multiple situations that illustrate how the school building design is not offering what the school management needs for their daily operation. In other words, there is a mismatch between the original design intentions, created by the architecture team during the design process, and the operational schemes, implemented by the school management which has a different vision than that of the building team of architects. Accordingly, it is necessary to maximise the collaboration between the architecture team and the school management and teachers; and to open direct communication channels between both entities, to ensure that the design output adheres to the upcoming modes of operation.

5.2 Student Activities Beyond the Spatial Function

The study has portrayed that student self-directed activities are diversified, and one spatial function incubates multi-layers of activities. This challenges the conventional design perception of allocating functionalities in the school building, especially for informal learning spaces. Instead, there should be a more inclusive understanding of every spatial function; provision for the variation of evolving activities in space; and design considerations to accommodate the student preferences (e.g. student desire to interact and group vs isolate and relax), while respecting the management regulations and the teacher needs. This brings in the role of analysing the spatial configuration of the school building during the design process (before the start of school operation), to evaluate the possibilities of student activities beyond the assigned spatial

functions, relative to accessibility properties (or other spatial measures). For instance, it is crucial to evaluate the expected patterns of interactions in highly accessible shallow spaces; or the expected undesirable patterns of misbehaviours in highly segregated space.

6 CONCLUSION

This study explored the spatial attributes of functionalities and configuration, while evaluating the resulting design potentiality in comparison to the actuality of student interactions and self-directed activities, which yields a complete picture of the realisation of spatial affordances of informal learning spaces, as seen in the example of corridors and surrounding open-plan studios and break-out spaces. When investigating the learning process beyond the formal teaching methods and outside the formal classroom boundary, the affordances for student self-directed activities and interactions are primarily shaped by the design potentiality. Firstly, spatial functionalities are attractors to certain activities. The student activity diversity is further maximised in zones that have mixed functionalities and formalities, as the informal learning spaces are integrated and located in proximity to other formal teaching spaces. Secondly, the spatial configuration shapes the student movements, encounters and interactions, bringing them together in shallow spaces that are vibrant with collaborative self-directed activities or taking them towards the segregated spaces which potentially affords quieter self-directed activities, if situated with a zone of diversified accessibility properties.

Considering the spatial potentiality and its realisation into actual student activities, the school building, as a learning institution, is recognised as a complex organisation whose learning output is highly impacted by spatial attributes. Nevertheless, the realisation of affordances is co-dependent on the school management operational schemes that impose regulations on spaces and the teacher supervision; both factors permitting or prohibiting the dispersal of student interactions and the diversification of self-directed activities. This is alongside the preferences of the students who select what activities to pursue. Between the spatial design and managerial operations, the school organisation, from its initialisation as a design idea towards its final completion as an operating building, should be handled by the architect(s), the school management and the teachers to insure the coherence of all the stakeholders' vision of how learning is expected to take place in the boundaries of the school building.

There are certain research limitations in consideration to the multi-dimensional types of spatial and social data in this study, therefore, requiring improvement in the future research plans. For instance, the number of architects (three), from which the case studies were selected, and the number of case studies (two), which involved fieldwork observations to collect the student activity types, are small and could be maximised in future plans to widen the perspective of how architects perceive learning space design and how students use school buildings. Moreover, this paper has only discussed the operation of informal learning spaces through the example of

corridors, open studios and social break-out spaces which could be expanded (as included in the full research data set) to discuss other informal spaces, like libraries, dining spaces and playgrounds in future papers. Finally, the study on the building design and operation has been conducted for a specific period of time without considering the continuous changes that happen across years onto the design and the operation by the management. Accordingly, a longitudinal research approach that expands the data sets across different academic years (for the same student population) would be desirable.

In the end, the research contribution is summarised as explorations of school design attributes of functions, configuration and operational schemes which all impact the affordances for student interactions and self-directed activities, especially within informal learning spaces. The data sets and the findings could be used to educate architects about the implications of their design and how it is actually used by students and teachers (compared to their original intentions). The findings could be also communicated to school managements, either of the studied cases or other institutions, to better understand their building potentiality and its challenges; and how to improve the daily school operations.

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