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DESIGN INVESTIGATIONS IN PRACTICE

03.
GAME CHANGERS:
Shaping Learning

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ABSTRACT

New technologies have increasingly moved to the center of 21st century learning inspiring innovative learning concepts and potentially influencing our conception of educational space. This article looks at the connection between game-changing ideas in education and school design. It looks at the benefits and challenges that new technologies bring to the K-12 environment. It describes their connection to inventive pedagogical ideas and their potential effect on the design of physical space.

The research refers to discoveries in neuroscience and cognitive psychology; it introduces theories about the ideal learning environment and takes a look at studies about the influence of the environment on academic performance and behavior. Examples of spaces that respond to inventive educational ideas illustrate the relationship between new learning concepts and physical space.

Data and reports from online and print publications on the subject formed the basis of this research. A number of schools that express the integration of technology and a commitment to new learning styles in their designs were chosen as examples. Site visits allowed to witness the use of inventive learning space first hand and to interview architects, an environmental psychologist, a researcher and educators to gain a better understanding of the learning concepts and the related designs. The fact that many examples are located in Europe does not imply that there are no examples in other parts of the world. The case studies have been chosen based on strength and clarity of design and for their highly experimental quality.

KEYWORDS: K-12, new technologies, games, neuroscience, learning environments

1.0 INTRODUCTION

Traditional educational concepts have been scrutinized in the face of rapidly evolving technology and with the rise of new theories in learning sciences. While traditional education focuses on acquiring basic skills and on content knowledge, many experts believe that success in the 21st century requires the higher order skills as defined by Bloom's taxonomy: the ability to think, solve complex problems, and interact critically through language and media[1].

Alternative learning ideas that build on the availability of technology and on a revised understanding of key skills required for today's global economy have become a central theme among progressive thinkers. Many new learning styles have emerged in recent years as a result. These innovative approaches to teaching and learning question traditional knowledge-based methods in favor of creative, interactive, collaborative, and technology-driven models. Findings in learning sciences often support their validity.

In the context of recent developments in education, it seems surprising that many school buildings are still built the way they were many decades ago. The ConnectED Initiative, introduced by President Obama in June 2013, stated that our schools were designed for a different era. It asserted that the current school system does not sufficiently address the constant learning opportunities of global connectivity, nor does it prepare students for a collaborative and networked economy[2].

This research takes a look at the relationship between innovative learning concepts and the spaces surrounding them. It explores how new technologies in the class-

room and innovative educational concepts can drive the design of K-12 spaces. It looks at the manifestation of progressive pedagogical ideas in school settings and investigates the influence of the environment on students.

2.0 SHAPING LEARNING

2.1 New Technologies

A new form of literacy, embracing information, media, and technology, is often named as one of the most important 21st century skills expected of today's students. Consequently, the need to incorporate innovative digital technologies into the curriculum as a learning tool and as subject matter has been a central topic among educators worldwide. With the youngest generation of students and teachers spending more time online than previous generations, it seems only natural to integrate tablet computers, smart phones, the internet, social media and online learning programs into the curriculum. Increased engagement, interactivity, and personalization of learning are among the top benefits expected of the use of mobile devices in the classroom.

Research on the influence of emerging technologies on learning is in its early stages. Advocates say that digital devices hold the attention of a generation raised on gadgets, teach 21st century skills, and allow students to learn at their own pace. Digital technologies are further expected to support collaboration, improve student achievement, allow for innovative forms of content creation, enable increased access to education and virtual learning communities, and facilitate innovative forms of assessments.

Many teachers believe that students' constant use of digital technology affects their attention spans and their ability to persevere in the face of challenging tasks. Other concerns include theft, network security, internet safety, district liability, and the costs of equipping a school with new technology and of training teachers to use the tools effectively. A 2013 Pew Research survey revealed that the majority of the surveyed teachers believe that technology rarely makes a difference in academic performance and that new technologies could widen the performance gap between students from higher-income families and those from lower-income families with limited access to computers[3].

Figure 1: Percentage of online users by generation.

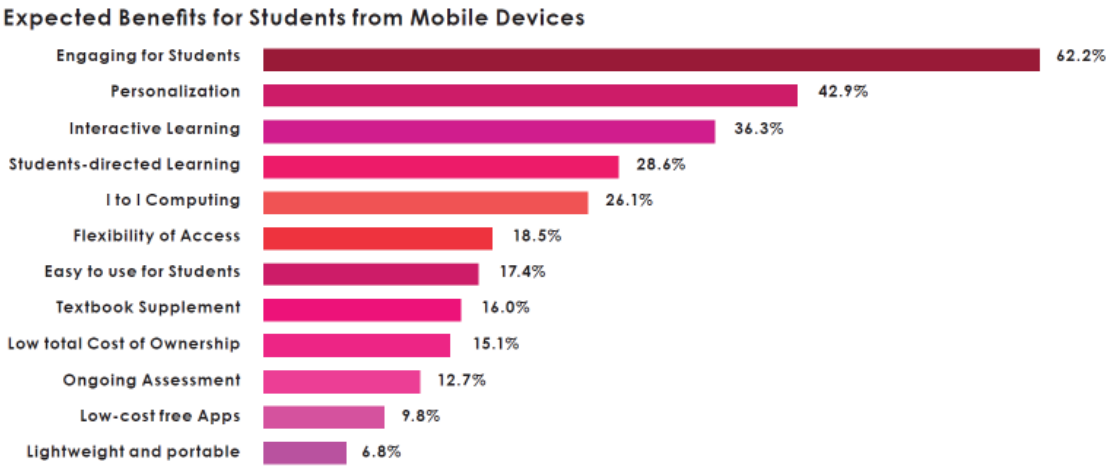

Figure 2: Use of mobile technologies in the classrooms and their benefits (Source: 2013 IESD Mobile Technology for K-12 Survey).

The overall consensus among critics and supporters alike seems to be that the teacher is still the most crucial factor, and that new technologies are just a tool. How they are used is what makes the difference. Many teachers still teach the "old" way with new tools, and as result, do not fully reap the benefits.

Inventive ideas for the use of technologies in the classroom, however, offer possibilities for profound changes in teaching and learning. One method of learning with new technologies that gained attention in the past years is the flipped classroom, where students listen to online lectures at home and use classroom time to do homework. This allows students to learn the new material at their own pace at home and benefit from teacher and peer help to solve problems during classroom time. Some school districts report success with this model. Best known among the providers is the Khan Academy, which offers free online lectures, practice videos and performance summaries.

Critics like to point out that the Khan Academy and similar online learning programs still teach the traditional way relying on lectures and quizzes. TED Prize 2013 winner, Sugata Mitra, promotes an entirely new approach to learning through new technologies based on his beliefs that children are naturally curious and that learning is self-emergent. He suggests "minimally invasive education" where teachers move into the background and watch student-driven learning unfold. He proved his point with the "hole in the wall experiment" in which he installed computers with a high-speed data connection in walls in New-Delhi slums and watched how, within days, children taught themselves to draw on the computer and to browse the net. In his current "school in the cloud" project, children worldwide learn and discover by themselves on a worldwide cloud network.

Salman Khan, founder of the Khan Academy, and Sugata imagine spaces for future learning to be very different from what we see today. Sugata Mitra envisions his "school in the cloud" as a glass pod filled with computers and with one large screen to allow moderators to skype in and play a role in the education of the children. Salman Khan promotes team-teaching and interaction during class time asking "do we have to separate classrooms anymore?"

New technologies and innovative ideas that build on them call for changes in the set-up of learning spaces. With lectures becoming less predominant, classrooms are sometimes complemented or even fully replaced with open learning spaces that foster interactivity and team work. Adaptable and flexible spaces and furniture allow individual and small group learning as well as learning across classes and subjects. Collaborative pods that replace rows of desks reflect the move towards student-directed learning with new technologies. Tablets, laptops, and interactive whiteboards become standard equipment. Learning may not be limited to a specific physical space. Through connectivity and mobility, any space can be a potential place for learning as long as learners and educators effectively connect and collaborate. With the widespread use of new technologies, opportunities to create learning networks that transcend place become available. The immediate environment outside the school can be more easily explored since new mobile devices and apps allow tapping into resources that are available within the community.

Figure 3: Ørestad High School (Photograph by Adam Mørk, courtesy of 3xn architects).

Some progressive schools invest in multifunctional spaces that promote innovative technologies and new ways of learning. One example is Ørestad High School, outside of Copenhagen, Denmark, designed by 3xn architects (Figure 3). This grade level 10-12 school, also known as the "Virtual College," focuses on media, communication, and culture. Almost everything at the school happens online with wireless internet and laptops available for all students. Learning occurs in five stories of predominantly open space. Ørestad High School emphasizes social interaction, interdisciplinary learning and collaboration. The few enclosed team rooms are used mainly for freshmen and at the introduction of subjects.

Acoustics and distractions are a potential issue in this mostly open space. Mille Sylvest, an environmental psychologist whose doctoral studies concern social behavior in buildings, notes that the students at Ørestad High School learn quickly to handle distractions and to adjust their behavior to the environment, occasionally, for example, telling each other to keep their voices down in the open space[4]. Teachers similarly have to adjust their teaching styles to benefit from the open spaces.

The potential noise issues were addressed in multiple ways during the planning phase. A suspended acoustical ceiling made of finely perforated metal provides excellent sound absorption. Walls and floors are acoustically separated. The walls are finished with a multi-layer gypsum system that is particularly effective for medium and low frequency sounds. The rubber flooring compound as well as the carpet in the student islands further help attenuate sound.

Ørestad High School is a fairly radical spatial expression of changes in learning. The open space clearly favors the learning of skills such as the ability to collaborate

and interact effectively through language and media in a technology-driven environment.

In 2009, Denmark became the first country in the world to allow students to use the internet during national exams. Educators wanted to move away from memorizing facts, figures and formulas towards testing a student's effectiveness at finding and analyzing material. The Danish Minister of Education Bertel Haarder explained: "our exams have to reflect daily life in the classroom and daily life in the classroom has to reflect life in society"[5].

2.2 The Power of Play

The integration of new technologies in the classroom as a reflection of society goes beyond merely using digital devices. One interesting direction in learning related to new technologies is play and gaming. Research shows that play, more than any other activity, fuels healthy development of children's brains. Play supposedly improves working memory and self-regulation. It allegedly also helps language development and creative problem-solving skills. Stuart Brown, founder of the National Institute of Play and Associate Professor at the University of California San Diego, calls play "the single most significant factor in determining our success and happiness." His book *Play—How It Shapes the Brain, Opens the Imagination, and Invigorates the Soul* describes how play fosters creativity, flexibility, and learning, how it teaches perseverance and how to cooperate with others[6].

A large amount of time on smartphones and even more on tablets is spent with gaming (Figure 4). Some schools use this popular combination of play and new technologies to enhance learning. Proponents of game-based learning like to point out that games provide freedom to experiment and fail. They teach design thinking and problem solving skills, while fostering creativity and the ability to adapt to diverse situations. They reward perseverance and practice. One interesting aspect about gaming is that players willingly accept that the reward for mastering one level of a game is the harder work required to master the next level. This element of self-motivation appeals to many teachers. However, studies show that gaming has not only positive effects on the developing brain. Negative effects can include addiction or decreased attention spans, and the effects depend on how games are used.

Neuroscientists and behavioral psychologists do not yet truly know the implications of the increased use of technology on the developing brain. When neuroscience looked at the overall effect of our constant use of technologies on the brain, the findings were across the board. Some studies say that it hinders deep and creative thinking. Others, including Dr. Gary Small, neuroscientist and professor at UCLA, believe that children immersed frequently and early in technology are digital natives who are wired to use it elegantly. He believes that technology can train our brains in positive ways. A 2004 study at Beth Israel Medical Center, similarly presented the benefits of new technologies on brain func-

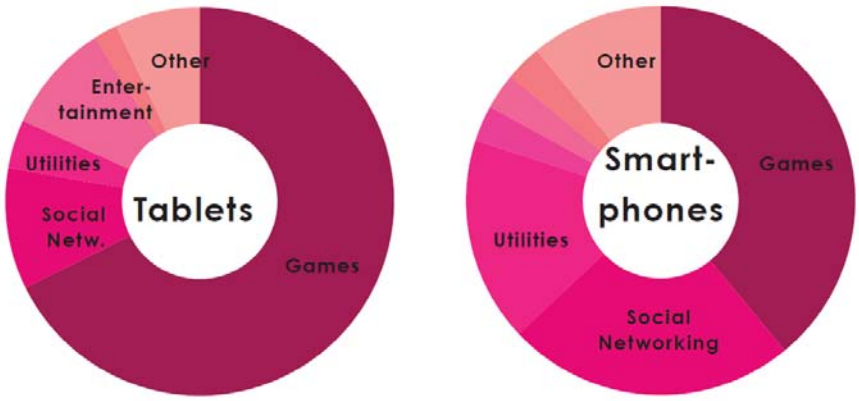

Figure 4: Gaming on tablets and smartphones.

Figure 5: Embodied learning (Photograph by Ken Howie Photography, courtesy SMALLab).

tion, by showing that surgeons who play video games make fewer errors[7].

Quest to Learn (Q2L) Middle Schools in New York and Chicago promote gaming as part of the learning process. The school's support of learning through action manifests itself through their SMALLab space that promotes "Embodied Learning" (Figure 5). Embodied learning brings new technologies, play, and movement together by combining physical interaction with game-based computer technologies. Instead of sitting in front of a screen, students move on interactive surfaces, generating images, graphs, and data through their actions. They can learn chemical titration, for example, by pushing king-size molecules in virtual space or they can study geology by building and shifting digital layers of sediment and fossils on the classroom floor. This model connects the digital and the physical and builds on brain research that shows how merging action with learning results in deeper, longer-lasting memory traces[8].

David Birchfield from SMALLab says that the concept is showing promise when it comes to improving learning results: A 2009 study found that at-risk ninth graders scored consistently and significantly higher in earth sciences on content-area tests when they had also done SMALLab exercises.

Large flexible open interactive spaces are ideal for learning spaces with SMALLab technology. With the mobile technologies generally used in game-based curriculums, learning can happen anywhere. In fact, the shifting boundaries between virtual and physical space and the organization of games around networks may lead designers to question even the need for physical classroom space. Futurelab, a British research organization, states that "rather than continuing to build a system based upon the mega-structures of schools, universities and a national curriculum, we need to move to a system organised through more porous and flexible learning networks that link homes, communities and multiple sites of learning"[9].

Figure 6: Multiple intelligences.

2.3 Learning Sciences

If the setting for learning becomes increasingly interchangeable and less tied to a specific place, what are the characteristics of a space that is conducive to learning?

Research is only at the beginning of mapping the influence of the physical environment on the brain, but safe, social, enriched and stimulating environments show great promise for enhancing learning. Some studies assert that learning in an enriched environment can generate up to 25 percent more brain connections. While research on the effects of the environment on the human brain is still in its infancy, experiments have shown that rats in stimulating environments develop bigger brains. They were smarter and found their way through mazes more quickly[10].

The Academy of Neuroscience for Architecture in San Diego, a collaboration of neuroscientists and architects, claims that there is evidence that certain types of spaces promote the growth of new neurons in humans. Their research looks at how architects could, with the use of color, lighting, and layout, design places that produce improved brain responses. A 2007 study by Joan Meyers-Levey shows how architecture can influence brain process demonstrating that a lower ceiling within a room promotes greater attention to detail by occupants while higher ceilings promoted greater abstract and creative thinking[11].

Discussions in learning sciences about the appropriate learning environment often refer to Howard Gardner and his theory of Multiple Intelligences (Figure 6), which suggests that intelligence is not a static IQ number, but a dynamic collection of talents that is different for each person[12]. Dr. Gardner proposes eight intelligences that all human beings possess in varying amounts, resulting in a unique intelligence profile for each individual. Though disputed among scientists, Gardner's theory has been accepted by many educators who believe that a classroom offering a variety of learning opportunities increases the likelihood of success for students. A number of schools structure their lessons to encourage variety, using music, cooperative learning, art activities, role play, multimedia, field trips, and inner reflection. Thomas Armstrong's book *Multiple Intelligences in the Classroom* describes how classrooms could be made compatible with multiple intelligences[13]. His checklist for classroom space for multiple intelligences suggests, for example, ample space to move around for kinesthetic intelligence, lots of interaction space for interpersonal intelligence and private space for intrapersonal intelligence.

Many visionaries push for a reformed education system based on recognizing students as individuals with diverse talents and based on what they find important to prepare children for the future. Sir Ken Robinson, for example, has harshly criticized the current education system for its lack of creativity. In his humorous and insightful TED Talk "School kills creativity", the most viewed TED Talk ever, he states that creativity is as important in education as literacy. He suggests that personalizing education, rather than standardizing, allows us to build achievement on discovering the individual talents of each child. This calls for creation of learning environments where students want to learn and where they can naturally discover their talents.

Vittra Telefonplan, a K-9 school in Stockholm, Sweden, is built around the concept of respect for different strengths and learning styles. Many of the ideas regarding technology, the learning sciences, and play are reflected in the schools' core philosophies and design. Students at Telefonplan work in groups based on skill levels and learning development. The division into groups is made not by age, but by an assessment of which situation would be best suited for the student's development and level of skill and ambition. Students are free to work independently and grades are not awarded.

The school designed by Rosan Bosch does not have classrooms (Figure 7). The intent is to teach intellectual curiosity, creativity, self-confidence, and communal responsibility by breaking down physical class divisions. Numerous open areas encourage different types of learning. Names such as "The Mountain", "The Village", "Tower of Babel", "Concentration Niches" describe the character of the areas.

Vittra shifted to personal digital learning in 2010. Every student receives a computer for learning. Skills, such as knowing where to find information and how to use it, are as important as students' sharing what motivates and inspires them on web pages, within the community, in the school cinema, and on stage.

The school's uncompromising design incorporates many new ideas in education including an emphasis on creativity and personalized, technology-based learning. The playful interior design and the variety of spaces provide a social and stimulating environment. The school offers an enormous amount of freedom to their students and expresses it in the fluidity of space.

2.4 The Open School Concept

The open school concept as seen at Vittra Telefonplan and Ørestad High School is not new. The idea emerged first in the late 60s, in an era that questioned traditional authority, including the way classrooms and schools were organized and students were taught.

Schools that embraced the open concept had no standardized tests and no detailed curriculum. Instead of in a traditional classrooms setting, children learned often at their own pace with the help of the teacher at "interest centers". Teams of teachers worked collaboratively with one another, using movable dividers to reconfigure the open space for large and small group projects and individual study. Promoters of open education commissioned architects to build schools without walls.

Many open-space schools rebuilt their walls in the culturally and politically conservative 80s. The open classroom experiment was generally considered failed. Noise and distraction were among the main challenges

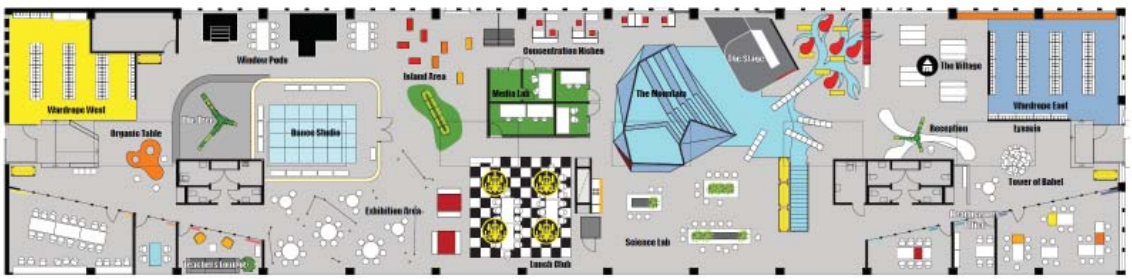

Figure 7: Vittra "Telefonplan" (courtsey of Rosan Bosch Studio).

of open space schools. In many instances classrooms were physically open, but instructors did not adjust their traditional method of teaching. A significant problem was the lack of teacher preparation. Many teachers, who had been trained in a different philosophy of learning, taught as if the walls were still present. This approach did not only complicate teaching, it missed many opportunities that an open learning environment can offer. When the discrete space under the direction of a single teacher is superseded by a more fluid and collaborative plan, however, many new ways of teaching can open up.

As far as distraction is concerned, the arrangement of open space becomes crucial. Many of the failed open schools from the 70s were housed in large undefined spaces. Clever floor plans as designed, for example for Ørestad High School, allow for a more complex layout that provides views and connections, yet semi-privacy in multiple zones. Technology, including building technology, has advanced. Learning becomes less tied to space and new building technologies for screening views and sounds have become more sophisticated and effective.

The open school often did not work as planned in the 60s and 70s. Twenty-first century learning yet calls for team and interdisciplinary teaching, for working in large and small groups. Flexible open spaces can support these ideas architecturally. The revival of the open school idea is no coincidence with the freedom that new technologies offer and the reemergence of student-centered learning.

Though heavily criticized, the open school might have benefits beyond enabling cross-disciplinary learning and team-teaching. Schools nowadays look for innovative solutions to address their budget and space constraints. Open learning space can be easily transformed to larger assembly spaces, reducing the total required area to meet program needs. Flexible arrangement of spaces can facilitate the overlapping of uses and result in building less overall area. Additionally, extending the classroom into the community with support of mobile devices that allow direct access to information could further reduce space requirements by reducing the average number of students in school per day.

The question of how to provide successful spaces for 21st-century learning can become increasingly complex when dealing with existing structures, or historical buildings where limited changes are allowed. School building modernization will be important in the decades to come. With an estimated $542 billion needed to modernize U.S. schools, the majority of school construction will include the renovation and modernization of existing buildings.

Munkegaard School in Copenhagen illustrates a successful modernization by Dorte Mandrup Arkitekter (Figures 8 and 9) that houses inspiring environments for innovative learning in a historical structure striking a deliberate balance between enclosed classrooms and open, collaborative spaces. Originally designed by Arne Jacobsen, Munkegaard School is a protected building that is considered one of the architect's great works. The original 1949 complex is divided into sets of two adjacent classrooms, each with its own courtyard, providing intimate outdoor spaces within a large school. When updates were needed, it was found that the concept did not fit the collaboration-based Danish education philosophy. More open space was needed. Most architectural suggestions were denied due to the school's protected status. To provide open and collaborative learning spaces while leaving the existing structure untouched, a new underground level of wide-open, multi-use spaces was finally approved and built. This space incorporates aspects of learning in a variety of group sizes and introduce a sense of adventure and play into the school environment. Munkegaard School's principal considers the combination of traditional classroom spaces and open learning environments the best of two worlds.

Many school administrators would hesitate before fully committing to nontraditional learning spaces. A long-term commitment to an open learning environment becomes less intimidating if the structural system is planned for both an open learning environment and classrooms. Movable partitions between classrooms, for example, can stay closed for traditional classroom teaching or opened up for team teaching. On a day-to-day level, flexible elements such as movable furniture allow desks and chairs to be rearranged into groups and pods for different learning experiences.

2.5 The Learning Environment and Academic Performance

Often the question is raised if changes or improvements in the physical learning environment can go beyond merely supporting new teaching methods or reflecting changes in society. Could the school environment affect academic performance as well?

Socio-economic status, parents, teachers, the curriculum, and school location are often listed as the key factors to student success. According to the 2007 study, differences in the schools' physical infrastructure, as

Figure 8: Munkegaard School (Photograph by Adam Mørk, courtesy of Dorte Mandrup Arkitekter).

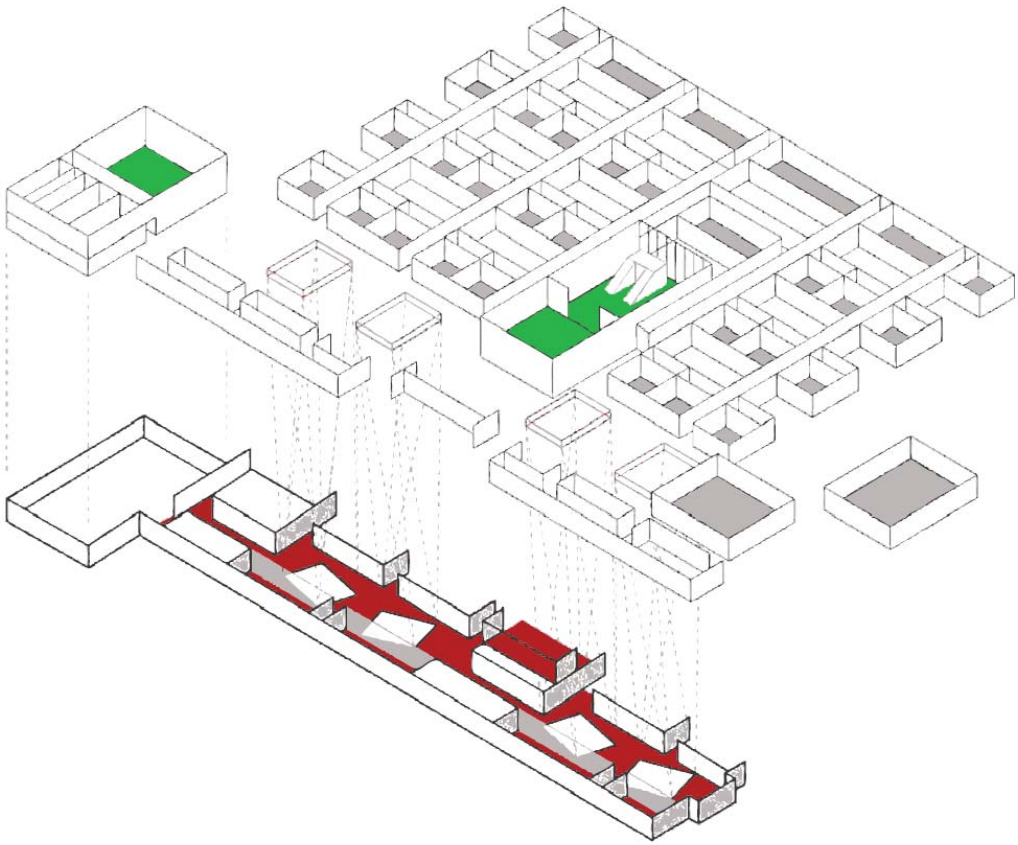

Figure 9: Munkegaard School (courtsey of Dorte Mandrup Arkitekter).

perceived by school principals, have a negligible effect on student performance[14]. On average across OECD countries, the PISA index of quality of the school's physical infrastructure explains only one percent of the variation in mathematics performance. Educational resources, such as computers, software or science laboratory equipment, on the other hand, account for a 2.5 percent performance variation.

A more recent (and ongoing) study, however, by the University of Salford in collaboration with the architecture firm Nightingale Associates, claims that the built environment can considerably affect the academic progression of students[15]. The study looked at 751 U.K. students in 34 classrooms at seven primary schools. Students were assessed for academic performance in math, reading, and writing, while classrooms were rated on six built-environment design variables: color, choice, connection, complexity, flexibility, and light. The proportionate, cumulative effect of these factors on learning progression measured at a 25 percent contribution on average.

The influence of singular factors in the built environment, notably the benefit of daylighting, on people's moods and productivity is well known. However, this is the first time that a holistic assessment has linked the effect of the overall environment directly to academic performance. As the study continues into 2014, it will include 20 additional schools in the U.K.

The direct effect of the built environment on student performance as measured through standardized tests is difficult to assess with so many variables coming into play. This becomes even more complicated when attempting to assess the effect of the built environment on hard-to-measure soft skills, such as creativity, critical thinking, and the ability to collaborate or communicate effectively. Open concept schools frequently focus on these skills. At the time of this writing, studies that investigate the effects of enclosed classrooms on students' performance are not available.

New technologies in themselves similarly have shown little or no direct measurable effect on academic performance. Andreas Schleicher, a veteran education analyst for the Organization for Economic Cooperation and Development (OECD) and Special Advisor on Education Policy, noted that "in most of the highest-performing systems, technology is remarkably absent from classrooms"[16]. He stated that "it does seem that those systems place their efforts primarily on pedagogical practice rather than digital gadgets."

3.0 CONCLUSION

The dominance of the traditional classroom remains an odd constant in planning educational facilities, considering the evolution of learning. The classroom offers many aspects that are beneficial to the learning process: it promotes focused learning in a group, it provides space for teachers to communicate closely with their students, and it creates a sense of home and belonging within the larger school system. The availability of information independent of time and place through new technologies, however, expands possibilities for places of learning. This freedom and flexibility of where learning could take place, inside and outside of school, makes the classroom within a traditional school building only one of many options.

Unconventional concepts for organizing educational space arise particularly with the lecture as the main means of transmitting knowledge moving into the background. Fluid and open spatial arrangements have the potential to foster cross-disciplinary and team-oriented learning models. The open school concept and learning networks, for example, emphasize self-directed learning and collaboration across physical and digital space while benefitting from the students' ability to access information and stay connected beyond the classroom and even beyond the school boundaries through new technologies.

The increased use of technology in itself will most likely not change learning outcomes. If anything, it is a reminder to refocus our attention on making the physical environment most effective for all kinds of learning, with and without digital tools, and on making a school more than a place for acquiring knowledge. Research indicates that safe, social and stimulating environments are best for learning. While spaces that encourage cross-disciplinary communication and interaction as well as impromptu gatherings address the need for social interaction and stimulation, opportunities for introspection and focused work need to be equally addressed in support of personalized and student-centered learning. Students and teachers are diverse and the environment in which each individual might thrive best can be very different. Offering a variety of spaces is crucial to make both students and teachers feel that they are in an environment where they have opportunities to excel.

Neuroscience gains an increasingly better understanding of the influence of space on the brain. Claims that certain types of spaces can foster growth of neurons still need to be proven, but there is evidence that links certain spatial qualities to specific brain processes. An

understanding of what environments are conducive to what type of learning needs to form the basis of each design decision.

Although the relationship between learning spaces and academic performance is complex, the environment can certainly incite and support specific behavior. It can make it easier to act in certain ways, and harder to act in others. A learning environment that communicates playfulness might be more effective in teaching exploration, risk-taking and creativity.

The school building is ultimately the body language of a school. What it communicates to students might be subtle, yet powerful. It can make a difference in students' learning if it demonstrates the respect for students and joy for learning.

Designing with various situations in mind becomes even more important as we are planning for future with many unforeseeable innovations to come. Flexibility is, and remains, a key topic in school design not only with regards to rapidly evolving technologies, but also considering the long-term use of school buildings. With a large number of schools closing in some areas while overcrowded schools are an issue in other areas, future adaptability moves back into the spotlight. Abandoned traditional school buildings are difficult to repurpose while more flexible and open spaces can be re-imagined for multiple future uses.

Ultimately, the ideal learning space will be very different for every school depending on the school's pedagogical vision and its context. New technologies and discoveries in learning science open up new possibilities and allow for a fresh perspective on educational space. Re-evaluating space at the inception of each project and fully understanding what learning can offer nowadays is crucial. The possibilities for learning spaces will soon reflect the diversity and spirit of innovation that currently invigorates the educational sector and society as a whole. Finding new and inventive ways to provide spaces that serve students, teachers and the community as a whole best understanding what drives learning today will be the basis for creating successful spaces for the future.

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