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Practices / Considerations

Lighting design as a possibility for the design of training and work spaces: a research proposal

Il lighting design come possibilità per la progettazione degli spazi formativi e lavorativi: una proposta di ricerca

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Abstract

The unstoppable transformation we are experiencing globally, fuelled by technological and social innovations (Mazali et al., 2023), is redrawing the boundaries between the worlds of work and education. Companies, public bodies and associations are faced with increasingly complex challenges in meeting the needs of an increasingly diverse workforce and the demands of a changing market (Cockayne, 2016). In an attempt to promote attention to change already in educational environments, we will therefore present a possible pilot study for the design of inclusive classrooms in the light of the new possibilities offered by technology, with the aim of improving accessibility and learning in the various educational contexts to enable schools and academies to adapt to the complex challenges of the present.

Keywords: lighting design; Embodied Cognitive Design; special pedagogy.

Sintesi

L’inarrestabile trasformazione che stiamo vivendo a livello globale, alimentata dalle innovazioni tecnologiche e sociali (Mazali et al., 2023), sta ridisegnando i confini tra il mondo del lavoro e quello dell’istruzione. Le aziende, gli enti pubblici e le associazioni devono affrontare sfide sempre più complesse per soddisfare le esigenze di una forza lavoro sempre più diversificata e le richieste di un mercato in continua evoluzione (Cockayne, 2016). Nel tentativo di promuovere l’attenzione al cambiamento già negli ambienti educativi, presenteremo quindi un possibile studio pilota per la progettazione di aule inclusive alla luce delle nuove possibilità offerte dalla tecnologia, con l’obiettivo di migliorare l’accessibilità e l’apprendimento nei vari contesti educativi per consentire a scuole e università di adattarsi alle complesse sfide del presente.

Parole chiave: lighting design; Embodied Cognitive Design; pedagogia speciale.

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1. Introduction

The unstoppable transformation we are experiencing globally, fuelled by technological and social innovations (Mazali et al., 2023), is redrawing the boundaries between the worlds of work and education. Companies, public bodies and associations are faced with increasingly complex challenges in meeting the needs of an increasingly diverse workforce and the demands of an evolving market (Cockayne, 2016). The need to adapt to these changes has highlighted the importance of designing work and training environments (Teli et al., 2014) that are inclusive and capable of effectively supporting all individuals including those with disabilities (Giancaterina, 2015; Pasqualotto et al., 2023; Zappaterra, 2012). Advanced technologies, and in particular artificial intelligence (Valente, 2024), are fundamental tools for improving working conditions and guaranteeing lifelong learning, enabling the personalisation of learning and the plurality of training approaches necessary for a wide range of students and workers. One of the possible fields of research and development, with regard to the provision of increasingly inclusive working environments and designed to overcome possible criticalities, concerns, in particular, the study of ambient lighting (Houser & Esposito, 2021). Indeed, the design of light in working and learning environments has a direct impact on people's well-being and performance, influencing their productivity, emotional state and ability to concentrate (Aghemo & Piccioli, 2004). In this paper, we will explore the role of adaptive lighting in educational environments and set out the possibility of future research for professional environments as well, highlighting how light can contribute to creating inclusive spaces that meet the needs of students and workers with special educational needs, from the perspective of the scientific paradigm of Embodied Cognitive Sciences (Gallese et al., 2020; Gomez Paloma, 2020; Paloma & Meltzoff, 2024) with particular reference to Embodied Cognition Design (Van Dijk et al., 2014). In fact, assistive and immersive technologies, in synergy with dual training models, can be used to respond to the growing demand for reskilling and upskilling. In addition to being important for working with Artificial Intelligence (AI) systems, transversal skills can also be developed and improved with AI. By automating certain tasks and processes, AI can free up staff time and resources to focus on more complex and demanding tasks that require transversal skills. By leveraging AI to optimise and streamline certain processes, organisations can enable their employees to develop and improve their transversal skills, leading to higher productivity and innovation (Morandini, 2023). Indeed, automation can reduce the need for certain technical skills, skills upgrading (upskilling) and retraining (reskilling) by also enabling workers to adapt to new roles and challenges, focusing on skills that are complementary to AI, such as critical analysis, emotional intelligence and creativity (Occhiocupo & Pedone, 2023). This process not only increases the employability of workers but can prepare them for a work environment that integrates AI as a supporting tool. To promote attention to change already in educational environments, we will therefore present a possible pilot study for the design of inclusive classrooms in the light of the new possibilities offered by technology, with the aim of improving accessibility and learning in the various educational contexts to enable schools to adapt to the complex challenges of the present.

2. Drivers of transformation in workplaces and training

The changes that are characterising the world of work and education are fuelled by several drivers, including technological evolution (Riva, 2022), new social demands (Andaloro et al., 2022) and adaptation to increasingly dynamic contexts (D'Onza, 2022). Educational institutions, as well as companies, are faced with the need to evolve rapidly to remain competitive and respond effectively to the challenges posed by a global and ever-changing labour market. These drivers, closely linked to technological innovations, call for a radical transformation of the ways in which work and educational environments are designed, in the perspective of Digital Social Learning (Amicucci, 2024). The first fundamental driver is technological innovation. Advanced technologies, such as artificial intelligence, the Internet of Things (IoT) and robotics, are reshaping the ways in which workers interact with tools and work environments (Floridi, 2022). Companies need to integrate these technologies not only to improve their production processes, but also to ensure a working environment that meets the needs of an increasingly diverse workforce. In the field of training, technological innovation has given rise to new tools and teaching models, such as e-learning platforms, immersive technologies and Augmented Reality (AR) (Benigno et al., 2021). These tools enable personalised learning that considers students' different abilities and specific needs, ensuring a welcoming approach. Another key driver is social and demographic changes. Companies and educational institutions need to address the increasing heterogeneity of the workforce and students (Bornatici, 2019). People with disabilities, young people from vulnerable backgrounds and older workers are just some of the groups that require inclusive work and training models (Scialdone et al., 2022). In response to these needs, organisations need to rethink their environments and practices. Social inclusion has become a key element in designing spaces that can accommodate all workers and learners without distinction. Working and learning environments must therefore be designed to ensure equal access and opportunity for participation for all, regardless of their physical or cognitive needs. Adaptability (Santoianni et al., 2023) to work environments is another important driver. With the introduction of new organisational models, such as remote working, hybrid working and hourly flexibility, the need to design more dynamic and easily adaptable spaces has emerged. Working and training environments must respond to a variety of needs, ensuring comfort, productivity and well-being. The introduction of *disruptive* technologies in workplaces and training has a profound impact, both positive and negative (Mattiello & Taticchi, 2024). Disruptive technologies (Carbone et al., 2024) such as artificial intelligence, automation and virtual reality (VR), are changing the way we learn and work, offering new opportunities but also new risks (Maspoli, 2022). These types of technologies offer tremendous opportunities, including improving efficiency, personalising learning and creating more inclusive work environments. Artificial intelligence, for example, can analyse student or worker performance data and provide personalised suggestions on how to improve productivity or learning (Mancini & Sebastiani, 2024). Immersive technologies, such as augmented reality, offer an immersive learning experience that allows students to explore complex concepts in an interactive way. In the work context, AI can automate repetitive tasks and allow workers to focus on more creative and strategic activities (Butera & De Michelis, 2024). This can lead to improved working conditions, reducing stress and increasing job satisfaction. On the other hand, risks related to security, livelihoods and people's rights cannot be overlooked, such as the biometric categorisation of sensitive characteristics, the untargeted collection of facial images from the internet, the recognition of emotions in the workplace and in educational institutions, forms of manipulation of human behaviour to circumvent free will or the exploitation of human vulnerabilities (Razzante, 2024).

3. Embodied Cognition Design

The characteristics of the physical environment turn out to be decisive in the processes of adaptation, acclimatisation and relating in the world. In recent times, Di Paolo e Thompson (2024) note that the nervous system, the body and environments, both physical and cultural, are closely interconnected on multiple levels. In this sense, human developmental processes continually restructure themselves according to genetic, cellular, social and cultural factors. The interplay of body, mind and environment determines a co-evolutionary process (Schulte & Whyte, 2020) that cannot be simplified into convenient heuristics, but needs to be studied according to a simplistic approach (Sibilio, 2023). For more than a decade, a constructive dialogue has been opened between Pedagogy and Architecture (Gomez Paloma & Vanacore, 2020): in this sense, it is recognised that learning environments, as an extension of the human mind (Clark, 2003, 2004, 2005, 2006), can play a fundamental role in the genesis of cognitive processes. Cognition is embodied: bodily characteristics, our perceptual and motor systems, and the dynamic integration of bodily systems with environmental systems determine our experience in the world and should also be taken as a nodal point for the design of spaces in which complex human activities such as learning, education, and training are declined. In Lefebvre's reading (2015), space is composed of three dimensions: experienced, perceived and conceived. The environment becomes properly meaningful if cognition and intellect can be integrated into it. Even with regard to the design of educational spaces, with a view to promoting dialogue between bodily experience, architecture and engineering, there are many possible approaches, such as the initiation of school building projects inspired by Embodied Cognition Design (see, for example, Italian law 107/2015 with a view to the redevelopment or design from scratch of school spaces).The construction of buildings that enable the creation of environments that meet modern learning needs where human and technical dimensions can be integrated (Black et al., 2012), makes it possible to move in a direction in which education and architecture influence the learning experience harmoniously and by design. For Gallese and Gattara (2015), space can provoke immediate emotional reactions and, therefore, architecture can and must be experienced through sensoriality, promoting the construction of a space that can respond contextually to the individual's corporeity by stimulating it (Munari, 2018). The remodulation of reality passes through complex phenomena in which perceptive, objective and subjective data are integrated, determining processes of understanding and reading of one's experience in the world: in this sense, the very design of buildings can reflect this dynamic complexity, allowing the adherence to a new perspective, narrative and integrated, from which processes of learning, inclusion and quality relationships can arise (Tancredi et al., 2021; Van Bommel & Van Den Beld, 2004). If the body becomes, in such a perspective, an epistemic device that enables reflection on and in the world, the architectural design of spaces plays a crucial role. According to Mallgrave (2013), emotions are fundamental to our experience of the world and, at the centre of architectural design, the construct of human *well-being* must be placed. Reflecting on how modern companies recognise the importance of shared workspaces to stimulate creativity, as can be seen in the blossoming of Hubs and Co-Working in architectural design, the theme of the body must always be present, a guiding theme for architecture capable of projecting it towards a balance between real, spatial and virtual corporeality (Kuhtz, 2022).

4. The importance of light in the design of training environments

The environment takes on the role of a third educator (Malaguzzi, 2010) and is fundamental for improving the quality of learning. Thought of as a pedagogical device, spatiality and lighting can prove to be determining aspects in the development of a design that is not only didactic but experiential and profoundly human. According to Amicone, Petruccelli and Bonaiuto (2017), identifying the factors that can inhibit or improve learning processes is an essential factor for research in the field of human space design, as the perception of well-being appears to be closely linked to the nuances of sounds, colours, lighting, organisation of spaces, use of particular furnishings, and implementation of natural elements in architectural spaces. Every element or material present in the environment experienced by the person influences their behaviour and actions (Chierichetti et al., 2023). Numerous neuroscientific research have demonstrated the significant influence of light on human brain processes, with particular reference to the modulation of circadian rhythms and the regulation of hormones such as melatonin and cortisol, which are essential for well-being and the ability to concentrate (Rea, 2015). In school settings, well-designed lighting can improve attention, behaviour and emotional regulation of students, especially those with Attention Deficit Hyperactivity Disorder (ADHD) (Bonaiuto, 2019; Cohen & Aisenberg, 2018). The positive effects of light are also manifested at the cognitive level; exposure to specific levels of blue light can stimulate neuronal activity, promoting concentration and memorisation (Figueiro & Rea, 2010). Cipollone et al. (2024), for example, emphasise that recent studies have demonstrated that blue light at 460 nm enhances alertness, concentration, and processing speed while reducing errors and aiding cognitive load management. This wavelength has proven particularly effective in educational settings, especially during assessments, by improving focus and response accuracy. Furthermore, it can be beneficial for students with attention difficulties or learning disorders, helping them process information more quickly without sacrificing accuracy. Integrating this light into educational environments could enhance cognitive performance and optimize the overall learning process. A properly designed learning environment that considers the neuronal influence of light can therefore improve both school and work performance by promoting the general well-being of all individuals (Tähkämö et al., 2019). According to Wilson (1984) human beings tend to seek connections with nature: natural elements in the learning environment can promote relaxation, creativity and attention. Thanks to the organisational properties of the visual cortex (Albright, 2015), visual stimuli that are recursive, soft and organised in an orderly fashion allow us to prepare and focus on learning tasks. In this sense, natural daylight would be more beneficial than electric light as it naturally provides better colour rendering (Boyce et al., 2003a). Skilfully using the design of learning spaces considering the alternation of empty-full (Cheon & Su, 2018), reflecting on the importance of lighting and the choice of colours that can stimulate concentration and relaxation, can be decisive aspects for the future design of architectural spaces dedicated to work and human education. To create inclusive environments that harness the potential of light, it is essential to develop a system that takes several factors into account. Firstly, it is essential to carry out a needs analysis, assessing needs related to special educational needs, neurodevelopmental disorders and sensory sensitivities. Classrooms must be designed with flexible lighting, adjustable in both intensity and tone, so that they can be easily adapted to different teaching activities (Barkmann et al., 2012). Another crucial aspect is optimising the use of natural light, seeking to maximise the input of sunlight and minimising the use of artificial lighting. Finally, the adoption of advanced technologies, such as intelligent systems, makes it possible to customise lighting conditions according to the educational context, creating dynamic environments that promote students' learning and well-being.

4.1. Designing for diversity and inclusion: Lighting design as a strategy for inclusion

Designing inclusive environments means recognising the individual's special educational needs and offering solutions that allow everyone to access the same opportunities. In this context, assistive technologies and *lighting design* are key tools to ensure that working and learning environments are truly inclusive. Adjustable lighting, which can adapt to the different physical and emotional needs of users, is essential to create an environment that promotes concentration and well-being. Scientific studies have shown that lighting influenced by circadian rhythm can improve productivity and reduce the risk of stress and fatigue (Cajochen et al., 2014). In a classroom or work environment, the ability to adjust lighting according to the activity or time of day can make a big difference, particularly for people with visual impairments or other conditions that affect emotional and behavioural self-regulation, requiring more accurate control of environmental conditions. Lighting design is a field that goes beyond the simple choice of light source. It is about designing lighting in a way that responds to the psychological and physiological needs of users. The salient features of inclusive lighting design (Creati et al., 2021) include:

- adjustable light: use adjustable lighting that allows students to adjust the intensity of light according to their specific needs (Boyce et al., 2003b). Studies have shown that adjusting light in response to psychological or physical cues, such as level of fatigue or restlessness, can improve concentration (Barrett et al., 2015; Benedetti, 2020);
- circadian light: light that mimics the natural day-night cycle, called circadian light, can stabilise biological rhythms by improving mood and attention (Figueiro et al. 2017). This type of light, which varies in intensity and temperature depending on the time of day, can reduce mental fatigue and increase attention (Rea et al., 2012);
- variable colour temperature light: lighting that varies between warmer and cooler tones can be a way to regulate the atmosphere in the classroom, influencing productivity and mood (Veitch & Newsham, 2000). Cool light (white, similar to daylight) tends to stimulate attention and concentration, while warm light has a more relaxing effect and can be helpful in reducing restlessness. In this case, assistive technologies that allow the regulation of light also play an important role. For example, we can think of using sensors that automatically adjust the intensity of light according to the individual's position or activity. For example, if a student with ADHD moves frequently or struggles to stay focused, the system could lower the light intensity to avoid sensory overload;
- light and augmented reality: AR is another tool that can be integrated with lighting design to create immersive environments that stimulate concentration (Billinghurst & Duenser, 2012). For example, coloured lights and virtual environments can be designed to focus a student's attention on a specific task;
- light and visual feedback: another interesting approach is the use of visual feedback in combination with lighting. The light could change colour or intensity in response to the student's progress, stimulating motivation and awareness.

The adoption of lighting design solutions specifically designed to improve concentration and reduce distraction not only supports the well-being of students but also promotes a more welcoming and productive environment for all. When combined with advanced technologies, customisable lighting could become an integral part of the educational process, promoting inclusion and accessibility in an innovative way.

5. Pilot study for the implementation of lighting design

For an empirical assertion of the inclusive power of lighting design, it is useful to think about the realisation of a project that could envisage a pilot study in schools of different order and grade of the Italian reality (kindergarten, primary and secondary school, university) to implement and test a lighting design model based on the principles of Universal Design for Learning (UDL) and its implementation in school practice (Lowrey et al., 2017) This phase is essential for understanding how lighting can affect students' learning, well-being and behaviour in heterogeneous educational contexts (Vedovelli, 2022). The design of the pilot study consists of a phase of school sampling, a phase of methodological application for data collection, a phase of data analysis and extension of possible guidelines for sustainable design, phases that will be described in the following paragraphs.

5.1. Sampling and design of experimental classrooms

The schools involved will be selected because of criteria of representativeness and diversification of educational contexts, for the design of an evidence-based improvement (Marzano & Calvani, 2020). The research sample can be made up of at least 100 participants (referred to the students) from different school grades. In the same reference grades, in the same institutions, it will be possible to identify any control groups. The sampling and research work can also be envisaged on a national scale with representativeness intended for geographical areas, considering local and territorial complexities. Once the research sample has been determined and a convention agreement has been ratified, it will be possible to begin the phase of designing and setting up experimental classrooms equipped with adjustable lighting systems, capable of adapting to the various teaching activities and the specific needs of students according to generative logics (Stroup et al., 2020) also in light of the new technologies available (Dimitriadou & Lanitis, 2023). These spaces will be designed to respect the principles of UDL (Ghedin & Mazzocut, 2017), guaranteeing flexibility, accessibility and support for diversified learning modes. The variables dependent on the different class sizes will be carefully considered during the research planning phase, with supervision and on-site inspections being arranged.

5.2. Data collection methodologies

To assess the effectiveness of lighting design, quantitative and qualitative assessment tools will be used. In particular:

- cognitive tests: measurements relating to initial cognitive abilities, with instruments such as the WISC-IV scale (Wechsler, 2012); and for d2-R focused attention (Brickenkamp et al., 2013);
- field observations with respect to students' behaviours with respect to lighting conditions with the design of special grids for systematic observation (Zecca, 2022);
- interviews (Cardano & Gariglio, 2022) and focus groups (Crisianita & Mandasari, 2022) with the involvement of students and teachers for the collection of perceptions and feedback with respect to the lighting design of learning environments.

5.3. Data analysis and guideline development

In the third phase of the project, the collected data will be subjected to a detailed analysis to identify correlations between lighting conditions and the various aspects observed, such as cognitive performance, student behaviour and qualitative feedback. Tools used include:

- statistical analysis software: quantitative data (e.g. cognitive test results, behavioural variations) will be processed using software such as SPSS or R to perform descriptive and inferential statistical analyses (Field, 2024). Parameters such as averages, standard deviations and relationships between variables will be analysed using regression analysis and ANOVA tests (Connelly, 2021; Tabachnick & Fidell, 2013);
- qualitative analysis tools: interviews and focus groups will be analysed using software such as NVivo or MAXQDA to perform thematic coding and identify recurring patterns in participants' perceptions and feedback (Bazeley, 2021);
- data triangulation techniques: direct observations, statistical data and qualitative findings will be combined to validate conclusions, ensuring a holistic and reliable view of the phenomenon studied (Patton, 2002);
- predictive models: predictive models integrating collected data with existing knowledge in the literature will be used to develop practical guidelines in order to simulate different application scenarios in school contexts (Hair et al., 2019);
- data visualisation tools: results will be presented via graphs, concept maps and interactive dashboards created with tools such as Power BI or Tableau, in order to make conclusions accessible to non-experts (Few, 2012). Furthermore, the resulting guidelines will be designed to be scalable and flexible, with specific suggestions for lighting design to support well-being and learning in different school environments and adapting to the specifics of individual contexts.

6. Conclusions

To validate the role of lighting design in promoting inclusive learning environments, the implementation of a pilot project is an essential step. Such a project could not only provide tangible scientific evidence on the impact of school lighting but could also open up new perspectives for a more inclusive, personalised and state-of-the-art education. Through this experimentation, it is hoped to make a significant contribution towards a greater awareness of the pedagogical potential of Lighting Design (Mott et al., 2012), recognising the profound impact that light has on the cognitive and emotional processes of individuals. The design of school environments, therefore, is not limited to the simple lighting of spaces, but involves the creation of learning environments optimised to meet the specific neurological needs of students. By adopting an inclusive and customised approach, supported by intelligent management of lighting conditions (Zabihi et al., 2012), it is possible to design classrooms that not only reduce barriers to learning, but actively promote the psychophysical well-being and cognitive development of all students, particularly those with special educational needs. Secondly, in an era of rapid change, an inclusive lighting approach not only improves learning, but prepares students, future workers, to interact with emerging technologies. Adaptive systems can also be applied in business contexts, fostering productivity, well-being and inclusion that can be explored in a broader research design aimed at reskilling and upskilling, key resources to meet the future challenges of a diverse workforce. During the research implementation process we may face various obstacles: from finding funds to finance the activities to the extreme fragmentation and differentiation of the places where education takes place. Through conscious planning, with a co-educational, targeted and extended approach, we will try to build virtuous processes. School environments offer the possibility of networking with universities, and it would be desirable to define formal memoranda of understanding in this sense.

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