

Architecture: Integration of Art and Engineering

Oleg Kapliński 

Faculty of Architecture, Poznań University of Technology, ul. Jacka Rychlewskiego 2, 60-965 Poznań, Poland; oleg.kaplinski@put.poznan.pl

Abstract: The current Special Issue is a synthetic overview of 21 published articles. The contact point of architecture–art–engineering is multidimensional, and therefore, this synthesis of works takes into account three criteria: (a) research subject indication, (b) research problem identification, and (c) sublimation of the research techniques and instrumentality used. Research problems, scientific values, and utility values have been highlighted. This synthetic tripartite is intended to make it easier for the reader to find an interesting subject and instrumentality. As the topics of the articles overlap, guided by the dominant values of each article, five subject groups have been sublimated. These are: structural aspects and design, digitization, architectural heritage, aesthetics and emotions vs. engineering, and interior architecture. The characteristic values of each subject group are presented. The indicated new design and research tools do not separate but combine the subject industries; they connect the entities of the investment process.

Keywords: architecture; art; building engineering; research methods; synthesis



Citation: Kapliński, O. Architecture: Integration of Art and Engineering. *Buildings* **2022**, *12*, 1609. <https://doi.org/10.3390/buildings12101609>

Received: 23 September 2022

Accepted: 28 September 2022

Published: 5 October 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2022 by the author. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Art and engineering integration is a process taking place before our eyes, in a dynamically changing reality. Architectural IQ is not only a theory, whereas modelling and digitization have become commonplace in everyday activities and, above all, in design and implementation, i.e., in architecture, art, and engineering. The importance of knowledge-based design is systematically growing. Once modest and restrained, research in various areas of life is now permanently interwoven into our reality as the basis of creativity, resourcefulness, and efficiency of human existence. It is favoured and even forced by new design requirements (e.g., integrated design) or simply by the paradigms of sustainable development. Contemporary challenges grow in importance: they make architects react to climate change or they demand a reaction (now generally accepted) to energy consumption limitations.

Concepts such as researcher and AECO (architect–engineer–contractor–owner) have become inseparable. The set of publications in the current issue confirms the observation that spectacular achievements are the result of the cooperation of all entities in the investment process and all industries, and the concept of research should be present at all stages of this process in advanced design. This current Special Issue is about the interlacing of research and the importance of its presence in architecture.

This edition follows on from an earlier Special Issue [1], which shows a tendency to make connections rather than disconnect architecture and engineering. A comprehensive summary is provided in [2].

2. Contributions

The current Special Issue includes 18 research articles, one review, one project report, and one communication. A total of 60 authors or co-authors took part.

The distribution of authors (and co-authors) by country is presented in Figure 1. Participants originate from 11 countries, with participants from Poland, the United Arab Emirates, and China dominating.

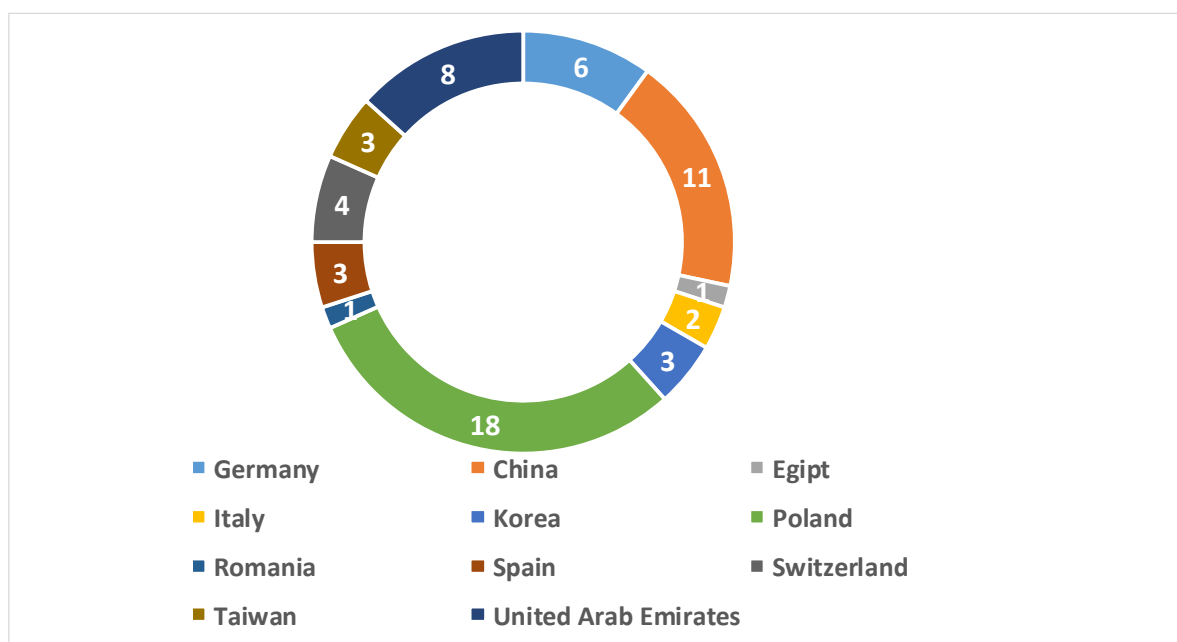


Figure 1. Distribution of authors by countries.

Each of the presented works contains interesting values. A synthetic summary of the values of all 21 works is presented in Table 1. The synthesis of works takes into account three criteria: (a) indication of the research subject, (b) identification of the research problem, and (c) sublimation of the research techniques and instrumentality used. As part of the subject of research, not only parts of buildings, types of structures, and city districts were indicated but also the researched phenomena. As part of exposing the research problem, not only the aim of the research and the relationships sought but also scientific values have been indicated.

The characteristic research tools are presented in the third column of Table 1. They are extremely diverse: from bibliometric analysis, through the online questionnaire, to elements of artificial intelligence. This synthetic tripartite is intended to help the reader find answers to questions of interest, also in terms of topics and instruments.

The last column (on the right side of Table 1) shows the subject group to which the article has been classified. Obviously, the topics of the articles overlap. Guided by the dominant values of each article, five subject groups have been sublimated. They are: structural aspects and design, digitization, architectural heritage, aesthetics and emotions vs. engineering, and interior architecture. Characteristic values of individual subject groups are presented below.

Four papers have been qualified for the *structural aspects and design* group. Article [3] is a good example of seamless integration between the disciplines of architecture and structural design. The geometry of a light spatial installation called Canop is discussed. Scientific support for new architectural forms is included in [4]. The side surfaces of various *Conoid*-type structures used in architectural engineering are considered. A proprietary calculation procedure, based on differential geometry, is proposed. This paper should be of particular interest to lovers of Antonio Gaudi's architecture. Architectural and construction forming of all-glass objects is the content of the next article [5]. The reader will find relations between functional-spatial aspects, form, and structure. Identifying the carbon neutrality effect is the domain of work [6], presenting the results of post-competition projects of a 15-building housing estate in China. A case study of a cable-driven facade installation robot is presented in [7].

Table 1. The content of the Special Issue “Architecture: Integration of Art and Engineering”. Synthetic collation.

Author	Subject of the Research	Research Problem	Research Techniques Instrumentality	Subject Group
Wang et al.	The Canopy—a lightweight spatial installation The design and fabrication process of the temporary installation	The geometry of the perforated hanging membrane	Graphic statics Relationship between form diagram and force diagram.	Structural aspects and design
Cabeza-Lainez, J.	The Conoid The Antisphera A revolution of forms	The evolution of new architectural forms Calculus of surface areas	A differential geometry procedure. Parametric design	
Jóźwik, A.	Glass structures All-glass pavilions, extensions, and links	Indication of the relationship between functional and spatial aspects, form and structure. Shaping all-glass structures in buildings	EN 1990:2002 + A1 Eurocode-Basis of structural design—Section 5.2 Design assisted by testing.	
Li et al.	The Third Solar Decathlon China (SDC)	Architecture vs. carbon dioxide emissions. Defining active and passive technologies	Scoring of 15 competition solutions	
Hu et al.	Facade installation. Curtain wall modules;	A case study of a cable-driven facade installation robot, cost–benefit analysis (CBA)	Single-task construction robots (STCRs)	
Zhang & Liu	Thermal comfort. The Universal Thermal Climate Index (UTCI) Two districts in Beijing	The study of buildings’ outdoor thermal comfort in urban areas	Longer-term, digital techniques Grasshopper 3D and Rhinoceros 3D. Three-dimensional models	Digitization
Maksoud et al.	The University of Sharjah’s (UoS) campus	Improving the visual and environmental conditions of the interior Optimize daylighting and solar radiation exposure	Parametric design. The Ladybug tool for Grasshopper. Rhinoceros 3D. Solar radiation analysis	
Kołata & Zierke	Designer position in architecture The replacement of humans by machines	Will computers eliminate the human factor in the design?	Literature review Artificial General Intelligence (AGI)/Strong Artificial Intelligence (SAI) Active Augmented Reality	

Table 1. Cont.

Author	Subject of the Research	Research Problem	Research Techniques Instrumentality	Subject Group
Butelski, K.L.	Odeons: form, function. The Odeon in Biała Podlaska, Amphitheater in the Royal Baths Park in Warsaw	Mobile forms of roofing	Typology of open cultural spaces	Architectural Heritage
Taraszkiewicz et al.	Medieval Bourgeois Tenement Houses The historical centre of Gdańsk	Archetype for contemporary architectural and construction solutions	Iconographic analysis. 3D modelling of structural systems	
Targowski & Kulowski	The European Solidarity Center. Corten plates usage	Influence of material homogeneity on room acoustics	Reverberation time Flutter echo	
Niebrzydowski, W.	Brutalist architecture	Identification and characterization the most important ideas and principles common to avant-garde art	Historical interpretative studies. Studies of buildings in situ	
Anghel et al.	Historical origins modern architecture in East Asia. Space syntax	Preserving the architects' legacy Historical research	Syntactic approach to architectural composition	
Liu et al.	The Tainan bus station construction project Artistic symbol of urban architectural	Modern urban renewal Balancing the cultural value of historic buildings	The Delphic Hierarchy Process (DHP). The AHP expert questionnaire. The MATLAB, a compiling software.	
Malewczyk et al.	Multi-family housing Aesthetics-expectations of recipients	The degree of the composition regularity of the facade elements	Online questionnaire Social network (Facebook) Psychology and neurosciences elements	Aesthetics and emotions vs. engineering
Lee, K.	An emotional connection between space and the body. A phenomenological understanding of interior space	How people experience interior space Which aspects improve the quality of spatial and emotional experience	Multi-sensory experience and emotional connection: A review	
Celadyn & Celadyn	The sustainability of building skins. The building's enclosure as an active boundary Aesthetical longevity	Technical durability and aesthetical longevity of building skins	The proposed Apparent Destruction Architectural Design (ADAD)	
Park & Lee	Design studio Creative design pedagogy	Increasing the creativity of students in the design studio.	Bibliometric analysis	

Table 1. Cont.

Author	Subject of the Research	Research Problem	Research Techniques Instrumentality	Subject Group
Celadyn & Celadyn,	Aesthetic functionalism; Sensorial experiences	Improving the Environmental Performance of Interiors	creative introduction of advanced construction techniques	Interior architecture
Jung et al.	The Seniors' Happiness Centre in Ajman UAE. Architectural design for elderly with depression	Colour therapy The physiological and psychological responses Colour preferences	A survey using the Geriatric Depression Scale (GDS) Electroencephalogram (EEG)	
Chen et al.	Informal learning space (ILS)	The relation between users' perceptions and the spatial environments	Visual perception analysis. Eye tracking technique	

Several articles are candidates for the *digitization* subject group (some of them have been allocated in the remaining groups). The use of parametric modelling and digital simulation techniques to ensure continuous and effective assessment of the buildings' outdoor thermal comfort is presented by Zhang and Liu [8]. Here, digital tools such as Grasshopper 3D and Rhinoceros 3D are used to create three-dimensional models. The article by Maksud et al. [9] is discussed in the Interior Architecture group, but instrumental richness should be indicated here. Two sets of codes are designed: for environmental simulations (sun path, solar radiation, wind rose diagrams), and for generating Islamic geometric patterns. Parametric design techniques include The Ladybug tool for Grasshopper and Rhinoceros 3D.

This subject group includes the above-mentioned article on the construction of all-glass objects (see [5])—the use of Eurocodes and, above all, the article [4] for parametric design and the new differential geometry procedure for creating conoidal surfaces.

In the *architectural heritage* group, cultural heritage is intertwined with historical heritage. Under the provocative title 'Can a Computer Design Fine Architecture without Human Input', the authors of Kołata and Zierke [10] prophesy the decline of architects. Fortunately, they withdraw from the ruthless statement about the decline of the designer's position in architecture, leaving the reader with concepts such as Active Augmented Reality, Artificial Super Intelligence, Artificial General Intelligence (AGI), and Strong Artificial Intelligence (SAI). Nonetheless, it does not preclude further polemics.

Butelski [11] introduces us to open cultural spaces, from amphitheatres to odeons (roofed theatres, membranes, and canopies). It is an example of cultural heritage with a tendency to support form and function. A striking example of cultural heritage is the paper [12] about the historic centre of Gdańsk, including burgher residential buildings in the context of archetypes of contemporary architectural and construction solutions. Targowski and Kulowski [13] present the European Solidarity Centre Building in Gdańsk. The relationship between a strong architectural vision and expectations regarding acoustics is described here. The importance of the finishing material is emphasized, which underlines the importance of cultural heritage. However, the European Solidarity Centre itself is already a historical legacy today.

Brutalist architecture is also culture and history. These are the 60s and 70s of the last century. The greatest impact on brutalism was exerted by such avant-garde trends as *art autre*, *art brut*, and *musique concrète*. Details can be found in [14]. Historical heritage dominates the next two articles. Anghel et al. [15] examine and recall two European architects (acting independently) who influenced the form of modern architecture in East Asia. Liu et al. [16] combine historical and cultural layers with architectural engineering, thus balancing the cultural value of historic buildings with the concept of a bus station (in aiwan).

Aesthetics and Emotions vs. Engineering is the fourth subject group. Malewczyk et al. [17] introduce us to the world of facade composition, aesthetics, and neurosciences. They indicate the importance of adapting the visual dimension of architecture to the expectations of its recipients. Multi-family housing in Poland is an example here. The title of the article [18] is significant: 'An Emotional Connection between Space and the Body'. Therefore, it is about the way people perceive inner space. This issue is clearly related to the interior architecture subject group. Technical durability and aesthetical longevity of building skins are the subjects of Communication [19]. The apparent destruction of the building material is the basis for further consideration. Park and Lee [20] glorify creative thinking. The slogan of creativity covers the pedagogy of creative design in a design studio. The topic may be useful in planning college syllabuses.

Interior architecture is the fifth subject group. The above-mentioned problems of emotions and ethics have their consequences, visible in interior design. An example is an aforementioned article [18] which presents quite sensitive research: how the problems of interior architecture are influenced by multi-sensory space and how this space is connected with the emotional experience of the user. The influence of advanced construction

techniques and the physical properties of materials on the aesthetics and increasing the functionality of designed interiors is the domain of research presented in the article by Celadyn and Celadyn [21]. The article by Maksoud et al. [9] is also mentioned in the *digitization* subject group because of its instrumental richness. In this article, the issues of interior design are strongly highlighted. The research concerns daylighting and exposure to solar radiation in desert climates. The results are used to improve the visual and environmental conditions of corridors in one of the universities in UEA.

Colour therapy is closely related to interior design. Colour therapy is a widely accepted treatment for depressive symptoms in the elderly. Jung et al., a team of researchers, presents the results of the analysis of physiological and psychological reactions of patients to the proposed colour preference in [22]. The research was carried out using electroencephalograms. This research serves to improve the quality of life of the elderly. Relationships between the users' perception and the spatial environment are the subject of research by Chen et al. [23]. In this case, interior architecture is supported by visual perception analysis and instrumentally armed with eye tracking. This technique should be used more often in architectural studies. In Chinese universities, learning spaces constitute the subject matter of research.

3. Discussion and Comments

The division into subjects presented in Table 1 is a working version, but to a large extent, it shows the state of knowledge covered by this Special Issue. At the same time, it indicates that the issues are multi-threaded and multi-layered. In all subject groups, there are technical (construction) problems, there is a clear attitude fostering sustainable development, and economic issues are present. What is important is that all the works (articles, reviews, project reports, and communications) are research-based or discuss research.

The presented research emphasizes the fact that new design and research tools do not separate but combine subject sectors. They constitute a strong trend that binds together and inspires various disciplines of science and technology. The review of works presented in the current SI has shown and confirmed that looking for divisions between engineering and art is unnecessary: it is important that the structures are both beautiful and functional while meeting human needs.

The digital techniques presented (especially in the *digitization* subject group) greatly enrich the view of architecture, engineering, and art. Parametric engineering is the best example of this, five works can be mentioned here [4,5,7–10]. The human–computer interactions type thread appeared against this background (see [10]). It concerns not only digitization but, above all, artificial intelligence. It is worth engaging in polemics on this subject (not only with the authors). This is what inevitably awaits us.

Clearly, shared research areas have emerged, but it is less about design paradigms as such, especially Integrated Project Delivery (IPD) and Building Life Cycle Modelling (BLCM). The current Special Issue does not give the problem closure, but in the near future, it will also be worth paying attention to VR/AR (virtual and augmented reality), design paradigms based on the neurosophic approach, and taking into account biometric systems. On the other hand, in the current SI, there is the quality of the built environment (including the quality of life and the quality of spatial experiences): [8,15,17,22,23].

In the articles in the Aesthetics and Emotions vs. Engineering subject group, the role of the senses in architecture came up (e.g., [18]). Obviously, intuition helps to make choices but the observation–evaluation–feeling relationship is important. We enter a delicate and sensitive field of sensuality, i.e., perceiving stimuli using senses. This is where unsolved problems arise at the interface between engineering and art. Not denying the importance of sensuality, it must be said that, in architecture, nonetheless, sight is decisive. We receive about 80 percent of information about the environment through sight. [24]. Architects call it the “sixth sense of architecture”, which means that, e.g., a construction drawing has a lower rank than the context of a location. There is a slight analogy to the human–computer interaction issue mentioned above. Nevertheless, it is necessary to take into

account empathy [25]. This is a step towards empathic design, which not only stresses the attitude of sensitizing users, these are also procedures and methods.

There are two interesting and important aspects of this issue worth mentioning here. Architecture responds to climate change; in this case, clear examples are [6,9]. The reaction presented there is in line with the mission of ‘ARCHITECTURE 2030’ [26]. It is worth using these experiences in the light of climate change around the globe and the international movement: architecture in the age of climate change. Another aspect, interior design, is an increasingly attractive topic among architects because architect-researchers use sophisticated instrumental measures more and more often, and they also use brain-waves [22]. New, interesting instruments dramatically increase the usefulness of their designs—see [9,18,21–23].

4. Conclusions

The issues emerging at the interface of architecture–art–engineering are very broad and open-ended. This review of 21 articles shows that these problems are multi-threaded and multi-layered. The research techniques presented here are of great importance, as they significantly enrich the core of the matter and the view on architecture, engineering of a building, and art. All the studies presented here are aimed at improving the quality of life.

It is clear that the methods known in other disciplines, such as psychology or artificial intelligence, are now successfully transferred to the field of architecture. Hence, the scope of the research presented in this book is quite wide: from parametric engineering to the role of the senses in architecture.

Taking over the instrumentality as well as the presented research emphasizes the fact that new design and research tools do not separate but combine individual industries and connect the entities of the investment process. The very process of the research in question, research techniques, technological progress in construction, and integrated design combined with life-cycle modelling means that not only research is collaborative but design itself has become a team game.

All this is meant to improve the quality of the built environment, fostered by empathic design. All this creates new challenges.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Acknowledgments: The author expresses his gratitude to the *Buildings* journal for offering an academic platform for researchers where they can contribute and exchange their recent findings in architecture and engineering.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Kapliński, O.; Bonenberg, W. (Eds.) *Architecture and Engineering: The Challenges—Trends—Achievements*; MDPI: Basel, Switzerland, 2020; 362p. Available online: <http://www.mdpi.com/books/pdfview/book/3233> (accessed on 1 January 2021.).
2. Kapliński, O.; Bonenberg, W. *Architecture and Engineering: The Challenges—Trends—Achievements*. *Buildings* **2020**, *10*, 181. [CrossRef]
3. Wang, S.; Bertagna, F.; Ohlbrock, P.O.; Tanadini, D. The Canopy: A Lightweight Spatial Installation Informed by Graphic Statics. *Buildings* **2022**, *12*, 1009. [CrossRef]
4. Cabeza-Lainez, J. Architectural Characteristics of Different Configurations Based on New Geometric Determinations for the Conoid. *Buildings* **2022**, *12*, 10. [CrossRef]
5. Jóźwik, A. Application of Glass Structures in Architectural Shaping of All-Glass Pavilions, Extensions, and Links. *Buildings* **2022**, *12*, 1254. [CrossRef]
6. Li, B.; Guo, W.; Liu, X.; Zhang, Y.; Caneparo, L. The Third Solar Decathlon China Buildings for Achieving Carbon Neutrality. *Buildings* **2022**, *12*, 1094. [CrossRef]

7. Hu, R.; Iturralde, K.; Linner, T.; Zhao, C.; Pan, W.; Pracucci, A.; Bock, T. A Simple Framework for the Cost–Benefit Analysis of Single-Task Construction Robots Based on a Case Study of a Cable-Driven Facade Installation Robot. *Buildings* **2021**, *11*, 8. [CrossRef]
8. Zhang, Y.; Liu, C. Digital Simulation for Buildings' Outdoor Thermal Comfort in Urban Neighborhoods. *Buildings* **2021**, *11*, 541. [CrossRef]
9. Maksoud, A.; Mushtaha, E.; Al-Sadoon, Z.; Sahall, H.; Toutou, A. Design of Islamic Parametric Elevation for Interior, Enclosed Corridors to Optimize Daylighting and Solar Radiation Exposure in a Desert Climate: A Case Study of the University of Sharjah, UAE. *Buildings* **2022**, *12*, 161. [CrossRef]
10. Kołata, J.; Zierke, P. The Decline of Architects: Can a Computer Design Fine Architecture without Human Input? *Buildings* **2021**, *11*, 338. [CrossRef]
11. Butelski, K.L. Contemporary Odeon Buildings as a Sustainable Environment for Culture. *Buildings* **2021**, *11*, 308. [CrossRef]
12. Taraszkiewicz, A.; Grębowski, K.; Taraszkiewicz, K.; Przewłócki, J. Medieval Bourgeois Tenement Houses as an Archetype for Contemporary Architectural and Construction Solutions: The Example of Historic Downtown Gdańsk. *Buildings* **2021**, *11*, 80. [CrossRef]
13. Targowski, W.; Kulowski, A. Influence of the Widespread Use of Corten Plate on the Acoustics of the European Solidarity Centre Building in Gdańsk. *Buildings* **2021**, *11*, 133. [CrossRef]
14. Niebrzydowski, W. The Impact of Avant-Garde Art on Brutalist Architecture. *Buildings* **2021**, *11*, 290. [CrossRef]
15. Anghel, A.A.; Cabeza-Lainez, J.; Xu, Y. Unknown Suns: László Hudec, Antonin Raymond and the Rising of a Modern Architecture for Eastern Asia. *Buildings* **2022**, *12*, 93. [CrossRef]
16. Liu, W.-F.; Tzeng, C.-T.; Kuo, W.-C. Historical Cultural Layers and Sustainable Design Art Models for Architectural Engineering—Took Public Art Proposal for the Tainan Bus Station Construction Project as an Example. *Buildings* **2022**, *12*, 1098. [CrossRef]
17. Malewczyk, M.; Taraszkiewicz, A.; Czyż, P. Preferences of the Facade Composition in the Context of Its Regularity and Irregularity. *Buildings* **2022**, *12*, 169. [CrossRef]
18. Lee, K. The Interior Experience of Architecture: An Emotional Connection between Space and the Body. *Buildings* **2022**, *12*, 326. [CrossRef]
19. Celadyn, M.; Celadyn, W. Apparent Destruction Architectural Design for the Sustainability of Building Skins. *Buildings* **2022**, *12*, 1220. [CrossRef]
20. Park, E.J.; Lee, S. Creative Thinking in the Architecture Design Studio: Bibliometric Analysis and Literature Review. *Buildings* **2022**, *12*, 828. [CrossRef]
21. Celadyn, M.; Celadyn, W. Application of Advanced Building Techniques to Enhance the Environmental Performance of Interior Components. *Buildings* **2021**, *11*, 309. [CrossRef]
22. Jung, C.; Mahmoud, N.S.A.; El Samanoudy, G.; Al Qassimi, N. Evaluating the Color Preferences for Elderly Depression in the United Arab Emirates. *Buildings* **2022**, *12*, 234. [CrossRef]
23. Chen, Y.; Wu, J.; Zou, Y.; Dong, W.; Zhou, X. Optimal Design and Verification of Informal Learning Spaces (ILSs) in Chinese Universities Based on Visual Perception Analysis. *Buildings* **2022**, *12*, 1495. [CrossRef]
24. Średniawa, P. Szósty zmysł architektury. *Zawód Architekt* **2022**, *86*, 80–83.
25. Walter, H. Social cognitive neuroscience of empathy: Concept, circuits and genes. *Emot. Rev.* **2012**, *4*, 9–17. [CrossRef]
26. AIA 2030 Commitment: Architects Prepare to Meet the Challenge. Available online: <https://www.aiachicago.org/images/uploads/pdfs/2030-housing-focus-presentation.pdf> (accessed on 2 September 2022).