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Meta-analysis of artificial intelligence in interior architecture: A new chapter for healthy building

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ABSTRACT

Aims: AI an emerging phenomenon has revolutionized the interior architecture design process, especially in the post-COVID era, when the concept of "healthy building" has become more important. The research aims to show the significant role of AI in creating interaction between "interior architecture" and the concept of healthy building.

Methods: The methodology is based on the theory of master architecture. Meta-analysis, emphasizing the statistical combination of the results of several studies, covers a large part of the analytical literature in the field of the role of artificial intelligence in interior architecture. Based on the selected research approach, in data extraction, a combination of machine learning methods such as hybrid meta-simulation, clustering, prospective interpretation of variables and extraction of effect size, variance and regression have been used.

Findings: Numerical results and quantitative findings in the review of tools developed in the field of interior architecture show that the most developed tools are related to the initial stages of design, followed by the tools related to the operation stage, and then the related tools to the final stages of architectural design.

Conclusion: The qualitative results of the research show that the set of tools developed in the field of interior architecture do not have high analytical accuracy, for this reason, it is more logical to use them in the idea generation stage. Also, the tools developed in the second part are related to the field of building chemistry, residents' health, biocomputing, etc.

Keywords: Healthy building, Bauchemie, occupant health, Material-based bio-computation, AIQ (indoor air quality), High-performance architecture

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Introduction

Whenever interior architecture is discussed, it is perceived by beginners as something decorative and unimportant. Likewise, when the healthy building is mentioned, beginners assume that it can only be found in architectural elements and details. In the approach considered in this research, the process of designing and executing interior architectural works is an interdisciplinary subject and, like any other interdisciplinary subject, requires a comprehensive research-oriented approach to reveal the mechanisms of analysis and the capacities related to it, because interior architecture plays a prominent role in influencing the architectural structure of space and the role of the user as a human being who uses the space.
Interior designers, like architects, have their own specializations. The role of the designer in shaping how a building is constructed is significant. Sometimes, designers accompany architects on design topics, and in the past, interior design was separate from architecture; today, the boundaries between 'architect' and 'interior designer' are sometimes discussed and even overlap [1].
The term 'interior design' refers to a profession that deals with the organization of interior spaces. In historical terms, the title 'interior designer' goes back about a century, while the title 'architect' has appeared for several decades in connection with interior work. In both the academic and professional domains today, the concept of interior architecture is applied [2].
It is inextricably linked with the development and application of emerging technologies and is not merely a matter of fantasy and superficiality. In other words, interior architecture is part of the design process itself.
According to the definition presented by Parastoo Anzhad, Bahram Saleh-Sadeghpour, Farhang Mozaffar, and Mohammad-Ali Khanmohammadi (2021), a considerable portion of interior architecture relates to the design and execution of interior spaces and decoration; this requires the selection and use of appropriate materials, tools, and equipment. From this perspective, a comprehensive, competency-based approach to interior architecture is necessary. Competency consists of three components: knowledge, skill, and attitude.
It is worth mentioning that when competencies are combined, the intended results are better achieved, and the desired skills are strengthened. Since the design process today is market-oriented and focuses on project delivery speed, using computer-based training is essential. If aligned with a competency-based approach, designers can achieve their goals more effectively; digital tools, as complementary instruments alongside other tools, can facilitate successful interior projects.
Including written critique [3] in interior design education creates a model that connects the process of designing and executing interior architectural works with their broader context. As Kalnberg [6] emphasizes, integrating interior architecture with a diverse range of fields is challenging. Technology is a major part of interior architecture and therefore of architecture itself. The definition of architecture—and by extension interior architecture—implies the act of 'making' in its general sense, and the interaction between architecture and interior architecture with the building's physical form highlights the user's position in space [7]. This helps define how interior architecture is understood theoretically and in terms of structure and practical content, across multiple dimensions [8].
Interior architecture is known by various names and is associated with human presence, memory, and use [9]. In recent years, virtual reality and artificial intelligence have entered this field. However, interior architecture faces many challenges with AI, and there is resistance and opposition to its application.
Most of these opposing views focus on the concept of identity. Architectural functions have a common essence that is expressed differently at different levels and according to the cultural context [10]. After the spread of AI and digitalism, architecture faces new challenges in its literature and across various dimensions [10].

The concept of interior architecture is considered by Degli as a fundamental challenge—perceived as a rupture from traditions. In practice, this challenge exists regardless of the user. Therefore, in the current era of emerging technologies and artificial intelligence, this is a challenge for interior architecture that raises questions about identity and its defining components, independent of the function.

One of the technological aspects transforming the world is artificial intelligence. As an application, artificial intelligence—like virtual reality—is present in various sectors including design, architecture, science and technology, education, entertainment, and others. In interior architecture, it has contributed to the process of designing and executing works along two main dimensions: technological and societal [11].

Over the past two decades, discussion of the dimensions and study-related issues of emerging technologies in interior architecture has been expanding in academic communities. We have witnessed various schools of thought and debates, the publication of scientific articles in specialized journals, and professional writings. However, less attention has been paid to epistemological and methodological issues—such as understanding transformations in the digital design process and recognizing why a methodological approach is necessary. Without this foundation, accurately representing these changes and analyzing the subject and its related issues would not be possible [12].

In the specialized literature on healthy indoor environments—a field that links building chemistry with interior architecture—variables such as indoor air quality, maintenance practices, and the weakening of components due to inappropriate materials are addressed as key factors in determining building health and occupant performance. Interior architecture plays a significant role in influencing indoor spatial quality [13]. Reviewing the existing literature shows that variables such as temperature control, timely window operation, and optimal lighting are among the most important factors for better space utilization [14]. Future human behavior and attitudes toward the environment will shape societies, which in turn will influence human behavior and improve the health of occupants in homes and workplaces [15].

Creativity is another dimension of the design process in interior architecture. This challenge requires creative thinking and design. It comes with its own requirements and solutions, and experience has shown that exploring innovative ideas in artificial intelligence can transform AI-based designs. Artificial intelligence can act as a creative partner for the development and enhancement of designs [16].

In the literature, the integration or interaction of artificial intelligence and creativity is recognized as a subject of study [17]. AI can transform the design process into one that is more efficient, sustainable, and effective. It can act as a starting point for dialogue and collaboration between architects and data scientists or engineers [18–21]. This important aspect of AI-based design is strengthened through the use of data reconstruction and machine learning [22].

Machine learning and artificial intelligence have created new opportunities for 'robotecture'—robotic architecture—and its development. In recent years, other technological ideas have emerged that could transform our society and built environment. The concept of interaction has been redefined, leading to innovations where elements of the built environment—such as light, sound, energy, wind, and can adapt to and interact with people without human intervention [23]. In robotic architecture, as the term suggests, technology is integrated with architecture in the design and construction of buildings and structures. In the era of artificial intelligence, this can be recognized as an age of creativity, art, science, and technology, a modern era of research and exploration—where creativity is a defining feature. Technology has introduced new artistic tendencies, resulting in innovative art models based on architecture.

The use of technology tools in art in general—and interior design in particular—has evolved especially after the era of computer animation. This shift has enabled the artist to step inside the work itself; whatever exists in the real world can be brought into the artistic process through computer tools. The potential performance of these tools is familiar as innovative methods for shaping and developing ideas. By nurturing concepts through dynamic processes, creative art can lead to transformative design outputs [24].
One of the most important concepts in design using artificial intelligence is innovation [25]. This is a key challenge in understanding the scope of research studies. Spirituality, in particular, is also an important part of the interior architectural design process. Looking at past processes of designing and executing interior architectural works, we can summarize that the emergence of new technologies plays an important role in defining the essence of interior architecture within a comprehensive perspective.
The mechanism of meaning-making plays a very important role in the concept of interior architecture and its identity, providing a field in which attention to both theory and practice is emphasized. From a perceptual perspective, meaning-making leads to symbolic references and highlights the importance of identity within the design process in the era of technological development. A review of the literature on emerging technologies summarizes four key topics: 'Preservation of Trust', 'Reflection of Tradition in Practice', 'Content Connection in Application', and 'Talent'. These are reflected in the process of creating interior architectural works, showing how tradition and talent interact, how stable conceptual elements relate to traditional elements, and how reflection of tradition manifests in the execution of works. The interaction between work and audience is a reciprocal relationship that shapes meaning and experience.
Models based on logical traditions have been presented that establish a platform for interaction between architect and audience, offering solutions in the interior architecture field.
The choice of appropriate interior materials is closely linked with concepts such as the 'healthy building' concept [26–29]. In the broader intellectual sphere, the healthy building is a highly significant concept in architecture. A review of the literature shows that in the post-COVID era, the concept of the healthy building has gained increased importance [30]. It connects to the identification of disturbing factors in the workplace and their relationship to occupant health, emphasizing the role of emerging technologies and artificial intelligence today. Symptoms such as persistent fatigue, headaches, dryness of the skin, eye irritation, itching, and other sensory discomforts can be influenced by interior architecture. Unpleasant sounds, noise, and odors are among the factors most frequently mentioned in this context, and many of these are directly related to interior architecture.
Optimal selection of 'building materials' is a key pillar in a healthy building, where inappropriate conditions can result in about 20% of occupants reporting symptoms such as headaches and eye irritation. Since the 1970s, surveys have reported increasing occupant dissatisfaction in industrial, educational, and office buildings due to indoor air pollution. Indoor pollutants may include gases released from paints, adhesives, and other construction materials, as well as volatile organic compounds, toxic gases, irritants, and suspended particles. These can originate from both indoor and outdoor sources. All of these factors are tied to interior architecture [30].
Intelligent selection of interior materials, such as color lighting and other elements, is an important topic in expert analysis systems [31–33]. Its place in the interior architectural design process is well established in the integration of modeling, real-time analysis, and building information systems with artificial intelligence.

Artificial intelligence transforms the design process [17]. Artificial intelligence and its application in architecture, in fact, refer to a new type of approach in interior architecture design that offers valuable points. In economic analysis, research based on the integration of building information modeling techniques has a role in completing systems that can strengthen the relationship between architectural design capabilities and interior design needs, and respond to them [25]. Therefore, transformation research from the perspective of various scientific fields shows that [31-33] artificial intelligence is considered one of the important approaches in interior design and architecture.
Artificial intelligence in architecture design contributes significantly to improving the quality of design and the execution of architectural works. Research indicates that in recent years, attention to the use of artificial intelligence in architecture has increased. This shows the necessity of employing artificial intelligence in interior architecture and how it can revolutionize the design and implementation process of interior architecture works.
By considering this, the present research attempts to examine how artificial intelligence in architecture and interior design interacts with traditional architecture and interior design tools, and how this integration creates complementarity.

Materials and Methods

The appropriate methodology for this group of studies, when effective, is the selection of a sample in such a way that it is collected based on "theoretical saturation". Due to this, the “snowball method” has been used in sampling. On the other hand, the required research data has been collected from 287 articles by using the PRISMA method and selecting the most relevant studies, especially in the appearance and function of architecture and interior design. This process has led to the creation of comprehensiveness and reliability in the research.
From an identification perspective, the purpose of this research is to show how the interaction between architecture and interior design in creating complementarity occurs with artificial intelligence, and how these combinations can lead to the promotion of health-oriented architecture. (Table 1)

Table 1. Summary of literature analysis on Artificial Intelligence regarding automation of design processes through algorithms, focusing on added value, safety, efficiency, and energy productivity in buildings. [18-20]

Artificial Intelligence	Generative Design	Artificial Intelligence Creativity
Artificial intelligence in digital buildings is very important and completes the building drawing process due to its ability to process various data. It helps optimize energy and comfort in buildings by predicting heating, cooling, and lighting behavior through algorithms.	Generative design through computer algorithms creates many design options based on predefined criteria. It allows designers to analyze, predict, and simulate building behavior before construction, thus improving decision-making.	Artificial intelligence creativity includes imaginative, executive, and creative functions in four steps. It focuses on idea generation, inspiration, and implementation of creative ideas. AI provides better solutions by reusing knowledge and improving design processes.

The paradigm of research methodology is grounded in epistemology and forms understanding. Epistemic paradigms shape the ways of grasping architecture and, indeed, all the ways of grasping interior architecture and space; as long as the ruling paradigm influences design, imagining and conceiving architecture does not occur merely in the mind of the designer but is affected by standards and the customary applications of architecture. Thus, for formulating a research methodology, it will be necessary to examine problems using approaches that analyze the designer's interpretive tools and information systems. [7]

In this study, the procedure includes reviewing the problem under consideration, analyzing the designer's cognitive tools and information systems, and collecting and examining assumptions in advance; the assumption being that applications of artificial intelligence can realize a program that effectively helps to develop creative skills in designers—although the results also show major challenges lying ahead for the subject. The findings indicate a current of change—from a reduction in comprehension to the emergence of new technologies—that began around 1990 and, aided by new technologies, brought about significant social changes: the emergence of new generations of media and styles of life that have altered the degree of human thinking and accompanied the growth of artificial intelligence. Research based on computer applications has therefore focused on new methods such as AI in the process of designing and executing interior architectural works. [16]

Computer analysis—of form and size, repetition, rhythm, balance, light intensity and its distribution, the movement of elements, and color—and the tuning of techniques help technology better identify design components and assist the designer in evaluating and articulating the cognitive aspects and elements of a work. Accordingly, the designer's tools can become creative instruments for discovery and experimentation, testing, and revealing the full potential of a design so that adaptive solutions can be offered in service of the design. [24]

From the perspective of specialized literature, the meta-analysis regards the application of artificial intelligence as an instrument for developing creativity. In other words, in order to enhance interior design, the paper advances innovative techniques based on AI and proposes a general constructive design scheme for interior design that—according to the analyzed samples—has been observed in practice. [22]

AI-based interior design, grounded in technology, increases the effectiveness of intelligent interior applications and helps improve the interior design experience. Jafarnejad, Reza Ahad, Hassan Abad, and Sara… (2016) report, in a study on teachers, that using decision trees for ranking and decision-making shows artificial intelligence has created significant changes in the audience's understanding of the surrounding space.

Up to now, evaluations with fixed numerical scales have sometimes led to the emergence of error, bias in evaluation processes, and the likelihood of misestimation. As a remedy from the human evaluator's side, this paper proposes using appropriate software systems and, under the rubric of "fuzzy logic" and "decision tree," employing the "AI paradigm." Perceptual analysis, through AI, is proposed as a way to document human–space relations, human–computer interactions, and, in general, to analyze and understand the qualities of space. The main goal in the proposed method is to give primacy to qualitative approaches in studying architecture; the project is based on cognitive and methodological studies of AI—new approaches such as computer vision, interactive AI, virtual intelligence, machine intelligence, and hybrid post-human tendencies—so that developments in AI can be approached commensurately, better grasping visual phenomena and horizons within methodological foundations. [12]

The literature emphasizes comprehensive cognitive analysis of the subject.

Exiting clichés and standardized routines, and attaining a precise understanding of research topics, require a paradigm-aware approach to questioning essence. In this context, the question concerns the role of AI in the process of interior architecture—its design and the execution of interior architectural works—and, indeed, the question of the very essence of this process.

Philosophical paradigms that support research have drawn attention to the need for an informed stance [7] and steer inquiry toward a kind of plurality. The research is based on a reading of **Spinoza**'s philosophy, and it turns to virtual reality and artificial intelligence in architecture. The use of advanced technologies—programs, processes, and their dependencies—has been categorized into several groups, including virtual reality in **interior**, **exterior**, and **landscape** architecture. In addition to that, studies in virtual reality in architecture discuss challenges and clarify issues for training. Overall, multiple architectural applications based on VR have been signed and released that may highlight challenges and, by addressing them, lead to successfully achieving outcomes in architecture with virtual reality—overcoming dominance of purely visual performance and attending to psychological factors [11].

Using **artificial intelligence** in **interior design** [31–35] shows that AI plays an important role in perception and in meeting user needs. According to the research methodology, the "**intelligent architecture movement**" is observed as a shift in the world on the basis of practice: a development allied with the technological revolution and new advances. Its applications have adapted and given rise to new terms and vocabularies; the language of interior and architectural design has been reshaped by resorting to new and emerging vocabulary, leading to **plural** methods and **deconstructive** forms—primary forms, spatial engineering, organic forms, composite forms of all kinds and, finally, modern digital/virtual architecture. The "intelligent architecture" movement, while adjacent to **robotic** and allied tendencies, is a progressive trend—provided these tendencies are oriented toward technology and development—whose applications and architectural design can extend into interior architecture as well [23]. The **main aim** is a comprehensive approach to interior architecture—a structural/creative stance—aligned with the era of technological development and grounded in value-adding design; together with AI and emerging technologies, this preserves the essentials needed for interior architecture, as stated in the literature [10]. Strategically, theory-based approaches have been selected; in these methods, **content analysis** is used along with common qualitative reasoning such as **inferential** argumentation. In other words, organized findings are recommended [10]. With a comprehensive approach to interior architecture, a deep study is carried out; the philosophical position of the research is taken on theoretical and methodological grounds, and the method is used accordingly.

The research structure is **multilayered and interactive**. In studies of interior architecture, each case—such as an architect or a designer—is examined on the basis of documents: written records, visual evidence and images, the works of designers and architects, retained memory, and oral sources, all of which relate to the subject. Such document-based studies are often the most effective of the qualitative types we need. With an emphasis on **case** and **field** studies in architecture and interior design, this type of research has expanded markedly in society and academia today [8]. Identifying the capacity obtained from this approach can be a key to more precise analysis of the subject [36]. The **philosophical foundation** of the research methodology rests on a comprehensive, wide-angle view tied to the development of emerging technologies and artificial intelligence. Philosophy can be rooted in observable subjects; through an interpretive reading of **Spinoza** (as some have suggested, "philosophy as a field"), and through "the continuation of thought and its transformations," it becomes possible to apply that reading to architectural interpretation so that we can consider architects' ideas as a system and a theoretical view within interior architecture. The research orientation is grounded in philosophical bases for architects' **approaches** (not persons) and architectural **approaches** (not things) [7]. The study identifies and defines **paradigms** from within the changes, so that, for the aforementioned forms, the new concept of paradigm is an **ordering of data**; it begins to design upwards with a **plural** approach [7]—one that, instead of judging tendencies as right or wrong, respects them all and then **prioritizes** them. The application of artificial intelligence, in universities of various types, confronts the subject with diverse software;

at different stages of the process they have different structures and outcomes.
In addition to design software, various types of software can be effective and influential in the **design and execution of interior architectural works**. Beyond general design tools, there are also programs with **specialized, domain-specific features**; they are themselves affected by developments in that domain. It is therefore necessary, in studies of different kinds, to make fuller use of diverse software, to be aware of the **differences in features and requirements** among programs, and to recognize how **differences in needs** arise from the subject itself. We should determine **which kinds of artificial-intelligence software** exist for the interior-architecture discipline and **which are better suited** to each subfield. For **each stage** of the interior architectural design–execution process, one may first consult a set (or "family") of software; next, the **general features and preferences** of software for the **design process** and for the **execution of interior works** are explained, and then, in a sample discussion, software used in the discipline is presented. The research methodology emphasizes **how differences in structure and content** are reflected within software. [5] In the **world of perception**, artificial intelligence appears as a **phenomenon of meaning**. With attention to the foundations of interior architecture—its **essence and formation**, and the **significations** that arise from diverse sources—AI in interior architecture has **varied applications** across many cases: **subject**, **form**, **context**, and the **manner of human presence** in interior space. Moreover, **each individual** can play an important role in **understanding** and in the **meaning-making dimensions** of design within interior architecture projects. Accordingly, paying attention to the **capacities of the minds** of different audiences in interior architecture projects—to **grasp meaning** and to **enter into discussions of meaning** during the design process—is an important issue. If we return to the architectural arena, there are times when this deserves examination; one may especially point to **interior works**, and above all, one must start from the **human** being and from **art as a work of art**, and consider their relation—features and functions that are intertwined with the architectural field. [9]

Methodologically, the research rests on an **interpretive–analytic approach**. In other words, on cognitive foundations, it **integrates** quantitative and qualitative approaches. Such a mixed approach is **recommended** for research and is recognized in other works as a valid **integration**. [3] The orientation of the study—drawing on quantitative **and** qualitative approaches—seeks, despite differences among experts, to produce a **good synthesis** in how interior architecture and interior design approach the **application of AI**. Based on methodological foundations, **integration**, with emphasis on **interpretive–analytic techniques and tactics**, yields results that can be employed in the **specialized, professional** domain of application. In a **blended system** of quantitative and qualitative approaches—within professional and contractual settings—this is recommended so that **effective applied and strategic results** may be obtained. In brief, the research methodology is founded—by **relying on meta-analysis**—upon the **theory of master architecture**. This means that **meta-analysis**, i.e., the **statistical combination** of results from multiple studies, covers a **wide expanse** of the analytical literature on the **role of AI in interior architecture**. In other words, the approach will be **wide-angle**. In the selected approach, **data extraction** combines computational methods such as **hybrid meta-simulation**, **clustering**, **foresight-oriented interpretation of variables**, and the **extraction of effect size** and **regression**—in a **combination of methods**, both **statistical and non-statistical**, **quantitative and qualitative**—to obtain an **accurate perspective** on the **depth of AI's impact** on the **design process** and the **execution of interior architectural works**. Given the selected wide-angle approach, **two key word-axes** have been chosen—e.g., **healthy building**, **occupant health**, **indoor education**, **ventilation**, **air quality**, **environment-friendly materials**—and the **excellence of process in architecture**; these have been analyzed in different **forms**, especially over **time**. The subject particularly concerns the **end user (beneficiary)** and the **relationship** of the architectural design process with that user, and it involves **multimedia technologies** relevant to use; it also relates to **co-thinking** in developing **smart ideas** for interior space. (See **Table 2**.)

Table 2. Development of technical tools in various fields at different stages based on prioritization in the field of literature subject.

Total	Meaning	Performance / Plan	Durability / Stability	Beauty & Form	Research Focus Topics
87	24	22	38	29	Research
294	2	89	108	66	Application (Focus on technical & executive tool development)

Given the fundamental approach of the research, the **ten axes** reviewed in the literature are as follows:

- **Phase 0** (pre-design / "Phase zero"): programming and needs assessment.
- **Phase 1–2**: design development and schematic design; mapping/diagramming.
- **Phase 3**: detailed design (technical design of plans).
- **Phase 4–5**: preparing execution drawings and **Phase 6** execution/implementation; technical production and fabrication.
- **Phase 7–8**: site supervision and project management during construction.
- **Phase 9–10**: maintenance/operations and **smart** operation by the end-user.

Findings

For selecting study samples in the meta-analysis, the **snowball method** was used. In summary, across all application axes of artificial intelligence—and within the design–execution process of interior architectural works—**87 works** (effects) were selected, and **394 sources** were identified as the most important references, covering the role of emerging technologies, multimedia execution, and artificial intelligence in the design process and in interior architectural works. These study axes can be consolidated under the following formats (**see Tables 3 and 4**).

A **meta-analysis of the literature** on integrating AI with architecture shows that **AI-based decision support for architects** [18] addresses design issues based on evidence—such as **water and air exposure**, exposure to **light**, and **energy consumption**—and, when used optimally, can ultimately take on tasks that would otherwise fall to the architect (i.e., **AI may assume some architectural roles**). As part of the design process, **artificial intelligence** in architecture **reflects** design intentions and solutions; it can create value by enabling forms to be shaped through knowledge-based systems of geometry and form, and through visual affordances—**color, line, space, texture, and contrast**—serving multiple tools that are versatile and multipurpose in design. Attention must be paid to use in **different content domains**; an important area of focus is **computational design** (a cognitive dimension exists alongside computation), with **specific features** for shapes, elements, colors, lines, and tactile contact, presented with **computational techniques**. In this way, design tools assist the designer in making the work **easier and faster** to carry out [24]. In other words, **AI has become a specialized part of the design process**. For **everyone**: Artificial intelligence is becoming specialized for design in a way that opens capacity even to non-specialists; this raises a question in the literature [36]: **can everyone be a designer?** Meanwhile, a number of notable **software platforms** still provide **interior design tools based on AI** to **all** on their platforms, while others remain restricted-access. Designers take positions using available tools to analyze design parameters.

Table 3. Distribution of resources used across different domains and four phases of the design and implementation process of interior architecture works

Phase Zero	Phase One	Phase Two	Phase Three	Phase Four	Total
-	11	22	29	25	87
144	30	34	68	247	394

Table 4. Distribution of resources used in different domains and stages of the four-stage design & implementation process of interior architectural works (accurate reconstruction)

Stage	1	2	3	4	5	6	7	8	9	10
Title	Idea finding	Preliminary design	Design development	Preparation of plans	Executive plans	Technical details	Supervision of execution	Project management	Repair & maintenance	Smart operations management
87	20	21	20	8	7	8	22	26	14	19
394	142	46	25	22	24	33	41	58	85	124

Development of robotics and artificial intelligence: the rise of "intelligent architecture":
The advance and expansion of robotics together with artificial intelligence has led to the progress and flourishing of the movement of **intelligent architecture**. This can include using robots for tasks such as construction, repair and maintenance, and inspection, as well as **integrating robots** with the design and performance of buildings. Such integration can increase efficiency, reduce costs, and improve the overall quality of a building. One of the most important effects on buildings has been **energy optimization** and the automation domain. By means of sensors, animation/simulation, and AI algorithms, it is now possible to **monitor interior environments in real time** and adjust, for example, light and temperature. On the basis of **occupancy**, operations can be controlled automatically; the patterns of use can be regulated in such a way as to reduce energy consumption and improve comfort. In the realm of design, **robotic–AI** systems have produced revolutionary effects in interior architecture. Attention to capable robotics and artificial intelligence allows interior designers to **automate many repetitive tasks** and tasks related to the design process and time, and thereby **free up time for creative work**. [23]

Aesthetic challenges regarding AI application:
Aesthetic and architectural aesthetics pose one of the most important challenges, raising a fundamental question about **how** artificial intelligence should be integrated into architecture. [18]

Meaning and spiritual dimensions:
A widespread view in the literature observes that the use of artificial intelligence can **reduce depth of meaning** and spiritual aspects in the design and execution process of interior architecture. At the same time, interior works are treated as bearers of certain tendencies or responses; for example, the **semantic factor** in the design and decoration of interior spaces will strengthen the perception of beauty, because the human being necessarily has a place **inside** the design. [7]

Flexibility and responsibility:
Another topic in the literature concerns **flexibility and responsibility**. Using artificial intelligence can increase flexibility and responsibility in interior-architecture projects. This factor can influence audience behavior and occupant behavior; with the entrance of diverse new technologies into interior spaces, **multipurpose** and **novel** spaces emerge, and **responsive/adaptive patterns** in interior-space design are directed toward flexibility. [15]

Personalization and alignment with user needs
Personalization and coordination with audience needs is crucial. The role of the designer here is to produce meaning and to shape the degree of its presence in the user's mind—an important part of interior architecture. Because perception depends on each individual and is interwoven with contemporary readings, **not all people necessarily read things in the same way**; nevertheless, with attention to interpretations, this must be taken into account. Analysis of the literature identifies this important point under the rubric of **"personalization and alignment with audience needs."** [9]
In short, personalization and alignment is cited as one of the most important issues. [17]

Operationalizing the design process: putting the computer to applied use the **applied** segment of the design process should be pursued through architectural studies that draw on artificial intelligence. Alongside the **theoretical/design** approach, we are faced with an **applied/executive** approach. A critical reading of the literature shows that some sources set the **human agent** against the **technological agent/current**, and then place fields such as architectural design, interior design, urban design, and the like in positions of priority and higher rank—sometimes accompanied by forgetting interior design *as an art*. On this basis, they emphasize using **AI tools** as a **practical** method for operationalizing the design process, so that interior works are treated as designed works (and not merely craft). [21]

The design "creativity crisis": A meta-analysis of the literature shows that applying AI to design has an **"inverse relationship"** with designers' **power of imagination** in the design and execution of interior architectural works; a set of warning indicators points to decline. [16] Some case-comparison studies even ask whether the **human being** has become the variable under investigation in an "age of the **creativity crisis**"—a reading present in part of the literature. Over the past **five years** of the development of emerging technologies and AI, the level of **genius** measured in children is reported as dropping from **95%** in childhood to **2%** by about age **30**. These are essentially **case-comparison** studies, examined across multiple cohorts up to maturity, on **creative development**. As a **soft human skill**, creativity is identified as all the more necessary for social welfare and economic growth as we move toward a more **uncertain and rapidly changing** future. The research findings indicate that the very advances of **digital** technology, and the age of **emerging technologies and AI**, have fueled the "creativity crisis."

Three-dimensional and multi-dimensional design using AI: Multi-dimensional (3D) design is recommended. Studies show that, in interior design, different **visual features** of form and line can be modeled from **visual information**; parts can be represented, **dependencies** can be determined and measured, and **maximum-likelihood** values can be obtained for **reconstruction** and **execution** of **3D** specifications. Effective interior design based on experimental **AI** techniques and **computational design** has been tested, and the results display distinctive **feature behavior**. A **proposed method**, **TBG** (taking/bundling several elements together), leads to more **uniform visual saturation** and **balanced contrast**; the results reach **98%** and **88.51%**, respectively, with **error = 0.06**—better than both *interior design based on multiple separate elements* and *conventional 3D design*, and offering **greater designer confidence** and **reliability**. [22]

Documents: applying AI to study and classification Studying and **classifying** documents are among the priorities of the design and **execution** process for interior architectural works. Treating **automation** as equivalent to **AI** is a new phenomenon: it has been considered in AI research, but in reality **recording information** is merely one type of data gathering—and it is *more* than simple compilation. **Design-research** is a specialized field with its own techniques and etiquette that distinguish it from merely assembling documents on a conventional basis. Here, the research orientation is **defined** and proceeds through **interviews**—structured, purposeful conversations that give the study a **coherent form** and separate it from non-scientific approaches. Using artificial intelligence for **studying and classifying documents** is a purposeful, comprehensive practice whose application in the field of **interior architecture** is **increasing day by day**.

The gap between theory and practice: In reflecting on the **gap between theory and practice**, one must point to the importance of both within the architectural design process. In addition to the importance of **design quality**, as in any project, interior architectural design has **two faces**—a **theoretical face** and a **practical face**. The theoretical face governs the **aim** and **destination** of the scheme; the practical face concerns the **common problems of execution** in architectural projects

The design of interior architectural projects requires attention to specific principles and detailed guidelines. Recording, preserving, and presenting related documents are necessary steps. Separating objective evidence from personal opinions and practices ensures accuracy and reliability. The use of artificial intelligence can reduce the gap between theoretical perspectives and practical execution in the design and implementation of interior architectural works.

Emerging Technologies and Interior Architecture Quality:

Most mixed-method studies emphasize the initial stage of interior design. For example, Mozaffar, Parastoo Anzhadi, Farhang, Mohammadali Khanmohammadi, and Bahram Saleh-Sadeghpour (2021) in their research titled *"Features and Requirements of Architectural Education in Interior Architecture"* demonstrated that technology-oriented education and training play a fundamental role in developing professional expertise. They showed that novel technologies can have a key and essential role in architecture. Particularly, using technology in interior design contributes significantly to effectiveness. These findings reveal that technology-driven approaches, especially those relying on data-driven methods, can positively impact the improvement of design processes and execution of interior architectural works. In professional practice, training workshops can be highly effective. They can reduce risks, lower potential costs, and facilitate learning activities. In these workshops, the inclusion of emerging technologies such as artificial intelligence can deepen the understanding of interior architecture challenges.

Challenges in Interior Architecture with AI Tools:

Quantitative research often indicates that tools for interior design tend to develop mainly at the beginning and end of the design spectrum. Statistical results and quantitative findings on the use of developed tools in interior architecture show that the majority are applied during the **initial design phase**, while the most advanced tools are applied at the **final stages of design**. Next in use are tools for **documentation, drafting, and implementation**, followed by tools related to **project operation, maintenance, and intelligent management**.(Figure 1, 2)

Application of Artificial Intelligence

Figure 1. Development of software and studies related to the application of artificial intelligence in the process of designing and implementing interior architectural works; including from the initial idea-finding and conceptual design phase. Phase one includes design development and preparation of design maps; phase two includes execution details and experiences; phase three includes supervision and project management; phase four includes repair and maintenance, optimal use, and smart management.

Multimedia and Digital Technologies

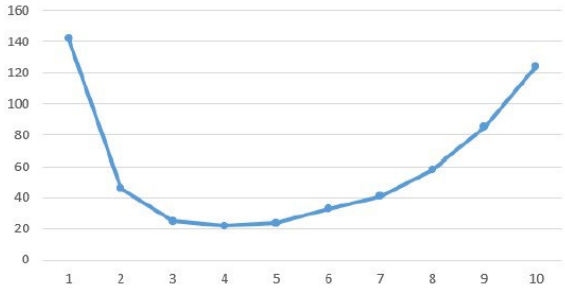

Figure 2. Expansion of the research focus on the use of multimedia and digital software in the qualitative and quantitative development of interior architecture within the design-and-execution process; including: **Phase 0** (ideation and preliminary design), **Phase 1** (design development and preparation of drawings), **Phase 2** (working/executive drawings), **Phase 3** (technical details), **Phase 4** (site supervision and project management), and **Phase 5** (maintenance and smart operations management).

Discussion and Conclusion

Studies based on **specialized design interviews**—those that treated **artificial intelligence** as a condition for creative design—have, in other words, introduced the notion of **"automating the concept"** [16]. In the age of emerging technologies and **generative AI**, a set of intelligent tools has been deployed; *design automation built on generative technologies* is, at present, highly necessary. One can employ these newly emerging technologies in such a way that they **raise the quality** of the process of designing and **executing** interior architectural works. Put differently, **AI—now in a state of ongoing development—can be advanced to the point that it reinforces the design process as a whole** and, in doing so, brings design issues to the fore.

In developed case samples from the **past two years**, **data-reconstruction procedures** based on point alignment have been tested so that, with a **lower target surface for execution**, the resulting **3D interior design model** yields a more **accurate** "inside-the-scene" of the building—closer to reality [22].

Speeding up design and reducing the time spent on repetitive tasks are among the most important applications repeatedly noted in the critical reading of the literature on this topic [23].

A critical analysis of the literature also **highlights a major challenge** between perspectives—especially where an **economic approach** to the building intersects with the **use of artificial intelligence** [24]. Likewise, within the **planning/programming** of design, AI is invoked for **modeling**, for **storing data and information**, and for **complete environmental analysis**; for **computing technical specifications** and **preparing** what is needed up to completion of construction; and for **handover, close-out, and commissioning**—shortening time and facilitating execution, so that the **designer** can make decisions and proceed. In modern technology, **plastic art** is counted among the pillars adjacent to industry; the principle of *design as production* has been newly transformed. Color labs, separators, and micro-workshops—along with country-specific, customized datasets—have helped designers and builders with precise decision-making.

A synthesis of findings **emphasizes the effect of interior lighting** on the **health of occupants** in homes and workplaces—an issue that aligns with the **application of AI** in the **design and execution** process of interior architectural works. There is also a recognized tendency within interior architecture—practiced by specialists using AI—toward producing **healthy spaces** that are **harmonized with the health needs of occupants** at home and at work.

Interior architectural space is highly adaptable to the designer. In practice, a relationship is created with elements such as the **source of light**, wall **panels/paintings**, and **temperature**, and this can be achieved in the work itself.

Research findings show—on the basis of a comparative approach—that applying **artificial intelligence** to design can affect **social/behavioral environments**: the **size of personal space**, the **arrangement of components**, the **distance between elements**, and their **orientation**; all of these, like a person's **"spatial bubble,"** influence how a space is perceived [15]. On this basis, by changing the design (layout and arrangement), we can **optimize** the **size** of a space and improve its **quality** and **use** of **light**.

One of the most important practical recommendations in the literature is to **develop creative, human–computer co-creation methods**—approaches that strengthen **creative thinking** and **design ability**. This tendency in the literature is put forward as a way to **counter the current against-the-current trend** of diminishing creativity; it treats the **application of AI** as a tool for **cultivating** creativity and, within the **architectural design process**, as a **creative capacity** in its own right [16]. The suggestion is to regard part of the design process as **creative thinking**, and to use AI as a tool for **nurturing** that process.

Even though **AI** has had notable successes, there are also **weak points**. The set of tools developed for interior architecture generally **lack high analytical accuracy**. Accordingly, as the field's technologies continue to develop, it is **more reasonable** to use many of these tools **in the ideation/early stages**, where potential risks can be **controlled** more safely.

The **first concentration** of tool development is in **two parts**:
(1) along the **design–execution process** (its early and operational phases in interior architectural works); and
(2) in **building-related domains**.
In the second part, the main areas include **building chemistry**, **occupant health**, and **environment-friendly materials** (among others). The literature expects the software frontier to keep advancing so that, across different domains, it can **coherently integrate** the **design–execution process** of interior works.

In the "**healthy building**" framework, the literature groups variables into two sets: three **building-oriented** variables—**building physiology**, **building physics/behavior**, and **(overall) building performance**—and three **occupant-oriented** variables—**energy use**, **satisfaction**, and **health**. Both sets can influence **occupant well-being** at home and at work; together, they explain how interior architecture relates to occupant health.

From the meta-analysis of **AI applications in interior architecture** aimed at a **healthy building**, the most important **outcomes** include:

- **Reducing costs and time:** technologies offered for workflow allow designers to **save time and expense**.
- **Software-based offices using AI services:** in parts of the process, **human labor can be replaced or greatly reduced**; designers and managers can adopt **new business models**, and samples/prototypes can be produced with **less manpower**, while the **range of design options** becomes **more diverse**.
- **Simultaneous collaboration in design and delivery:** design **services** and **sales** can be carried out at the **same time** with modern methods; this also **improves site operations** during project execution.
- **A change in the competency model of design: new job models and roles** are defined for designers, depending on new **problem-solving chains** ("solution loops") within design.

Artificial intelligence changes how we interpret **theoretical** and **operational**

models of the concept of **competence in design**.

From designer to design manager.
For the move into leadership, the older approach was to train **managers** so that they would *think and act like designers*. After the digital and multimedia revolution and the growth of artificial intelligence, designers now appear as **innovative managers**, curators, program-planners, and stewards of artistic processes—increasingly close to the sciences. Because of this, **designers must be able to manage** the **AI-based design and execution processes** of interior architectural works.

Super-designers, fluent in up-to-date knowledge.
Super-designers who are current with the state of the art open new opportunities for the future. With up-to-date knowledge, **the human will not be completely displaced**; the designer defines **what** can be done, **when** something is meaningful and important, **when** to continue a line of solution, and **when** to stop it. In other words, the designer's role will become **more prominent** in the future, because the designer retains the **power to approve or reject**.

Reforming the system of architectural education and training.
The trajectory of change in the era of emerging technologies shows that the **demand for AI in design** is rising; in all likelihood, the traditional model of *training "designers"* will **shrink** and **shift**—toward *training "architects"*. In the design-education process, **both process and content** must be considered. This important educational change will lead to the **formation of the architect**.

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