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REVIEW

Digital Transformation of Architecture: A Retrospective Analysis

Transformación Digital de la Arquitectura: Un Análisis Retrospectivo

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ABSTRACT

Introduction: in recent years, technology profoundly tiransformed architecture. Digitisation, through tools such as 3D rendering and virtual reality, redefined the way architects designed and presented projects. This evolution responded to new social and market demands for more efficient, accurate and immersive processes. Although the initial investment was high, its long-term profitability justified its implementation.
Development: trend analysis showed that concepts such as 'digital architecture' and 'virtual reality' were increasingly sought after, especially in leading countries such as the United States and China. In Colombia, although growth was slower, stability was observed, reflecting continued interest. Searches on platforms such as Google Trends and academic databases such as ProQuest showed the rise of these topics, not only at the professional level, but also at the academic level. Scientific output increased significantly, with more than 26 000 publications on digital architecture and more than 64 000 on virtual reality by 2022. Several studies applied these technologies in education, cultural mediation and architectural design, highlighting their usefulness and practical applicability.
Conclusions: t was concluded that digitisation was no longer an option but a strategic necessity. These tools redefined architectural practice and enhanced interaction with users. Digital architecture and virtual reality consolidated their role as fundamental elements for the future of the profession, providing competitive advantages, improving the client experience and opening up new opportunities for innovation.

Keywords: Digital Architecture; Virtual Reality; Technology; Trends; Innovation.

RESUMEN

Introducción: en los últimos años, la tecnología transformó profundamente la arquitectura. La digitalización, mediante herramientas como el renderizado 3D y la realidad virtual, redefinió la forma en que los arquitectos diseñaron y presentaron proyectos. Esta evolución respondió a nuevas exigencias sociales y del mercado, que reclamaban procesos más eficientes, precisos e inmersivos. Aunque la inversión inicial resultó elevada, su rentabilidad a largo plazo justificó su implementación.
Desarrollo: el análisis de tendencias demostró que conceptos como "arquitectura digital" y "realidad virtual" fueron cada vez más buscados, especialmente en países líderes como Estados Unidos y China. En Colombia, aunque el crecimiento fue más lento, se observó una estabilidad que reflejó interés continuo. Las búsquedas en plataformas como Google Trends y bases académicas como ProQuest evidenciaron el auge de estas temáticas, no solo a nivel profesional, sino también académico. La producción científica aumentó significativamente, con más de 26 000 publicaciones sobre arquitectura digital y más de 64 000 sobre realidad virtual en 2022. Diversos estudios aplicaron estas tecnologías en educación, mediación cultural y diseño arquitectónico, resaltando su utilidad y aplicabilidad práctica.

Conclusiones: se concluyó que la digitalización dejó de ser una opción para convertirse en una necesidad estratégica. Estas herramientas redefinieron la práctica arquitectónica y potenciaron la interacción con los usuarios. La arquitectura digital y la realidad virtual consolidaron su papel como elementos fundamentales para el futuro de la profesión, brindando ventajas competitivas, mejorando la experiencia del cliente y abriendo nuevas oportunidades de innovación.

Palabras clave: Arquitectura Digital; Realidad Virtual; Tecnología; Tendencias; Innovación.

INTRODUCTION

Technological development has profoundly transformed various disciplines in recent years, with architecture being one of the most impacted. Integrating digital tools such as 3D rendering, virtual reality (VR), and other emerging technologies has given rise to digital architecture. This trend has gained relevance both globally and nationally. This evolution has been primarily driven by new social and market demands for more immersive, accurate, and efficient experiences in the design and presentation of architectural projects.[1,2]

Digitization has enabled architects and companies to respond more quickly to their client's requirements, facilitating more effective communication and, in many cases, reducing operating costs. Although the initial investment in technology can be high, the long-term profitability and reusability of tools justify its implementation. This transition to digital has generated growing interest in the study of trends, as evidenced by searches on platforms such as Google Trends and academic databases such as ProQuest.[3,4]

In this context, digital architecture and virtual reality searches have experienced steady growth, particularly in technologically advanced countries such as the United States and China. Although growth has been more moderate in Colombia, stability indicates sustained interest in these technologies. The scientometric analysis shows that scientific production on these topics has also increased considerably, highlighting the importance that academic and professional institutions have given them.[5,6]

In addition, initiatives have been identified that have sought to apply virtual reality in architectural education and project presentation, demonstrating its potential to enrich the learning experience and visual communication. Recent research explores how these technologies transform professional practice and open up new possibilities for innovation and interaction with users.[7,8]

In short, this overview reveals a clear trend towards the consolidation of digital architecture and virtual reality as key tools for the discipline's present and future. This document delves deeper into these dynamics, analyzing market behavior and scientific production to support a business model focused on digitalized architectural services.[9,10]

DEVELOPMENT

Market trends

Trends

Trends in society have stimulated demand for services incorporating digital architecture, such as rendering and virtual reality. Similarly, architects have promoted digital architecture, making it more widely accepted and bringing it closer to realistic architecture through digitalization, thus responding to society's needs. As a result, companies and independent architects have faced the constant challenge of improving their experiences and offering products and services based on technology. Based on the above, the most searched words on the web in the last twelve months and five years that have marked a trend in topics related to the main proposals of this business plan were evaluated.[11,12]

Over the last five years, searches related to key factors in virtual reality in professional fields, especially in 'digital architecture,' have highlighted the need to offer digitalized media containing professional architectural design services. This is because of the dynamism of proposal presentations, the ease of understanding client requirements, and the cost avoided. However, it is essential to note that a digital approach to a service does not always involve a lower investment; it can even be higher. The advantage lies in long-term profitability, as it is possible to continue working and satisfactorily meet demand with the same tools used in the initial version without generating additional costs.[13,14]

Globally, the dynamic graph of publications shows the trends over the years in abstract form. There is a general increase in searches for the product, which also declines but does not exceed the increase. Similarly, at the national level, the dynamic publication graph shows that from 2017 to the present, searches for digital architecture have remained stable, i.e., the percentages do not show significant increases or decreases (figure 3).

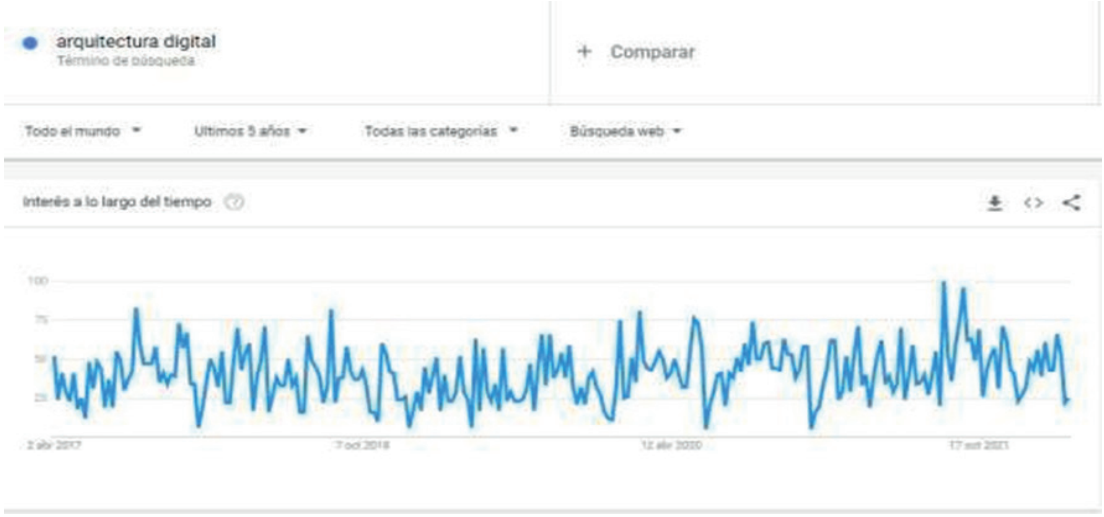

Figure 1. Digital architecture around the world
Source: taken from Google Trends https://trends.google.com/trends/explore?date=today%205-y&q=arquitectura%20digital

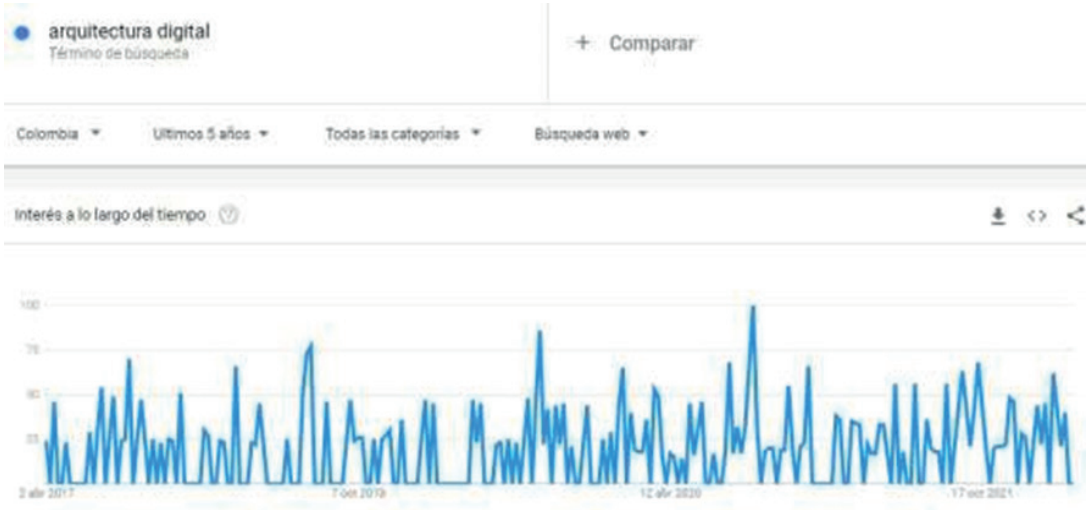

Figure 2. Digital architecture in Colombia
Source: taken from Google Trends https://trends.google.com/trends/explore?date=today%205-y&q=arquitectura%20digital

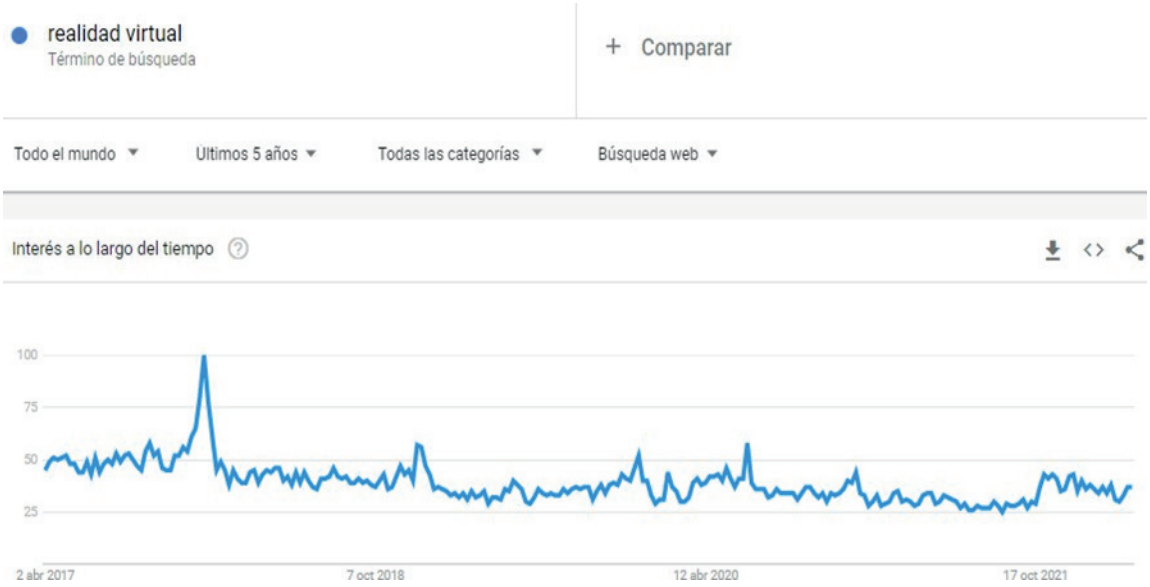

Figure 3. Virtual reality around the world
Source: taken from Google Trends https://trends.google.com/trends/explore?date=today%205-y&q=arquitectura%20digital

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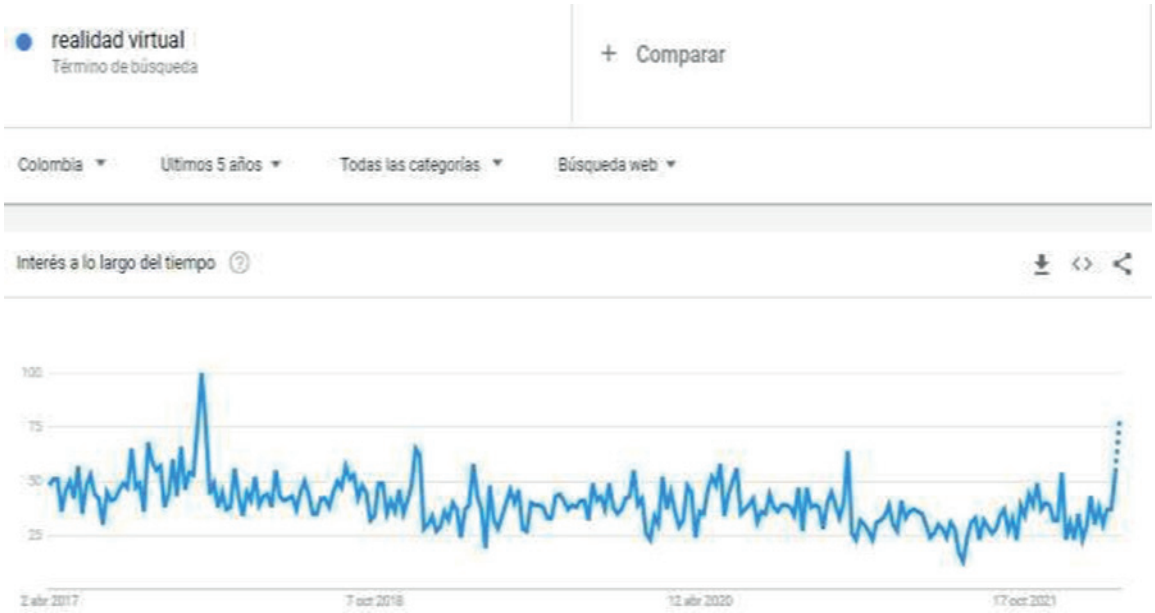

Figure 4. Virtual reality in Colombia
Source: taken from Google Trends https://trends.google.com/trends/explore?date=today%205-y&q=arquitectura%20digital

Over the last five years, the behavior of searches for 'virtual reality' has seen various initiatives raise awareness of the issue. For example, the use of virtual reality in architecture has increased worldwide. There is a global trend towards the transition from services to digital media, with virtual reality providing a way to address all those services requiring specific support to achieve user credibility. In architecture, 3D and virtual reality tools have increased the exposure of concepts previously only possible through face-to-face exhibitions. (15,16)

Figure 5. Comparison between virtual reality and digital architecture in Colombia
Source: taken from Google trends. https://trends.google.com/trends/explore?date=today%205-y&geo=CO&q=realidad%20virtual,arquitectura%20digital

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Figure 6. Comparison between virtual reality and digital architecture around the world
Source: taken from Google trends. https://trends.google.com/trends/explore?date=today%205-y&geo=CO&q=realidad%20virtual,arquitectura%20digital

The graphs clearly show the difference between searches for virtual architecture and virtual reality. Virtual reality lags far behind, as it is a recent phenomenon and not well known in Colombia or the rest of the world. [17,18]

Scientometrics

Searches in ProQuest

Globalization has led to the creation of knowledge networks. Managing business processes has changed because companies are now recognized as valuable structures for creating new concepts linked to productivity and economic growth. Technological advances have played a fundamental role throughout this transformation, as they automate processes that previously required higher investment costs. In the specific case of this study, improvements in the way a profession is approached and presented to the public are taken as an advantage of the model's viability. These tools for facilitating and improving work in different areas provide solutions that make it possible to offer a satisfactory service. [19,20]

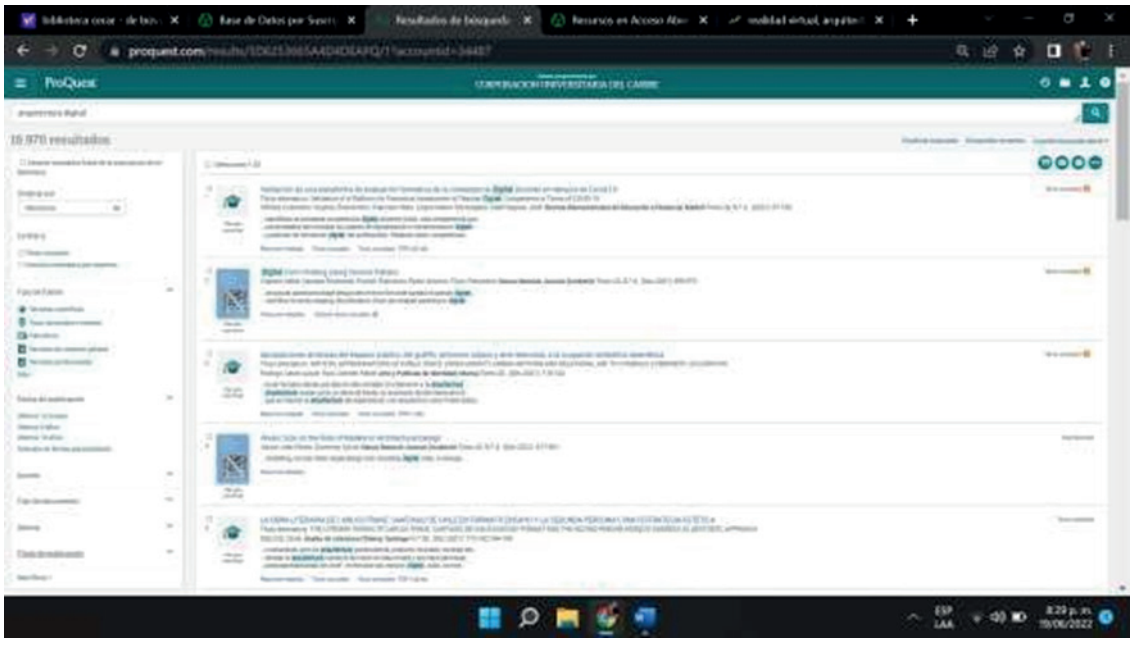

Figure 7. Search for digital architecture in ProQuest
Source: taken from ProQuest. https://www.proquest.com/results/5D6253665A4D4DEAPQ/1?accountid=34487

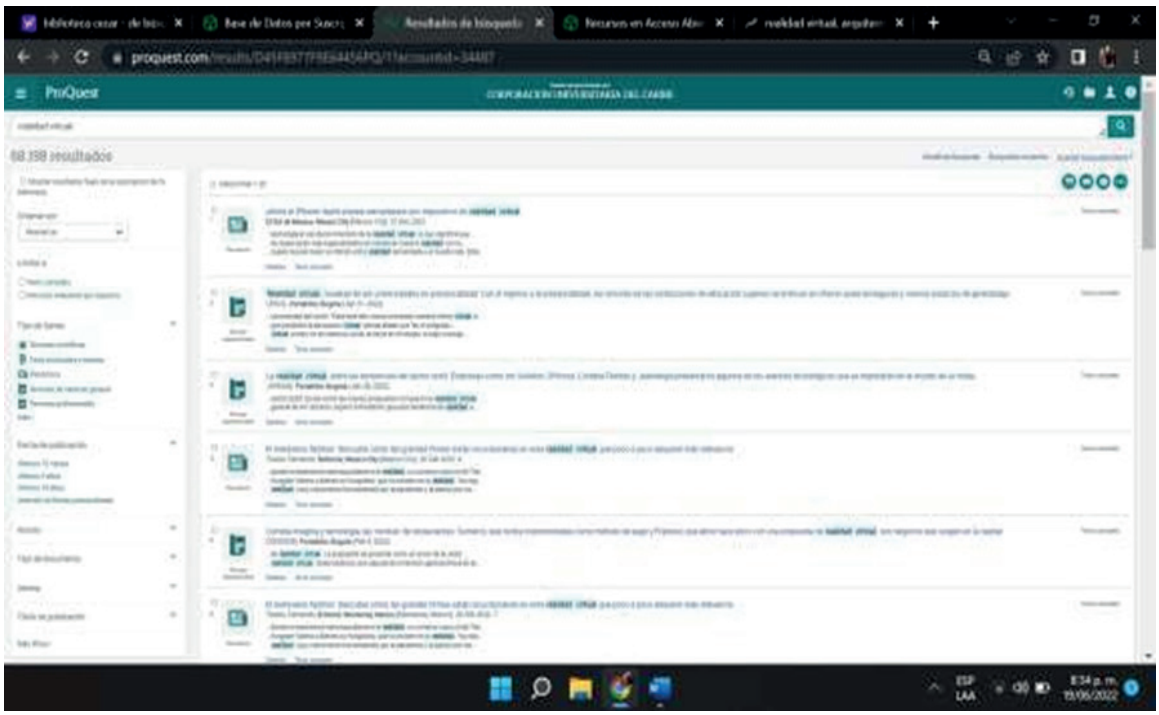

Figure 8. Virtual reality search in ProQuest
Source: taken from ProQuest. https://www.proquest.com/results/5D6253665A4D4DEAPQ/1?accountid=34487

A search for 'digital architecture' on the ProQuest website revealed that very few services of this type are available, suggesting that they are not widely offered on the Internet.[21,22]

Scientific behavior of publications

Scientific behavior has been consistent with research into digital architecture and virtual reality, adapting to the digital concept as a new area of architectural study and seeking to interpret the interaction of human societies. Thus, by 2022, there were more than 26 509 publications (figure 9) reporting on research in digital architecture and more than 64 705 publications (figure 10) reporting on research in virtual reality, providing some indications of specific activities related to the central idea of the project.[23,24]

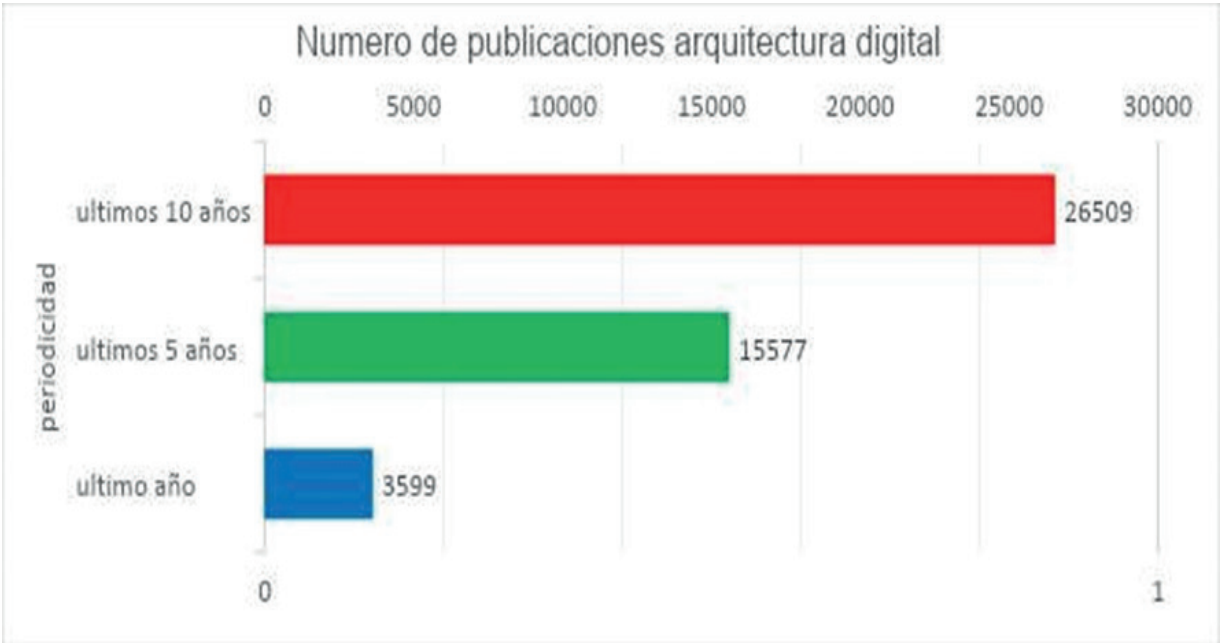

Figure 9. Behaviour of digital architecture publications
Source: taken from ProQuest. https://www.proquest.com/results/5D6253665A4D4DEAPQ/1?accountid=34487

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Figure 10. Behaviour of virtual reality publications
Source: taken from ProQuest. https://www.proquest.com/results/5D6253665A4D4DEAPQ/1?accountid=34487

Scientific focus of publications

Books and newspapers have become too dominant in the production of information related to digital architecture, followed by press services, scientific journals and websites (figure 11). The importance of the results focuses on the development of digital architecture through the publication of content related to the integration of new technologies and applications.[25,26]

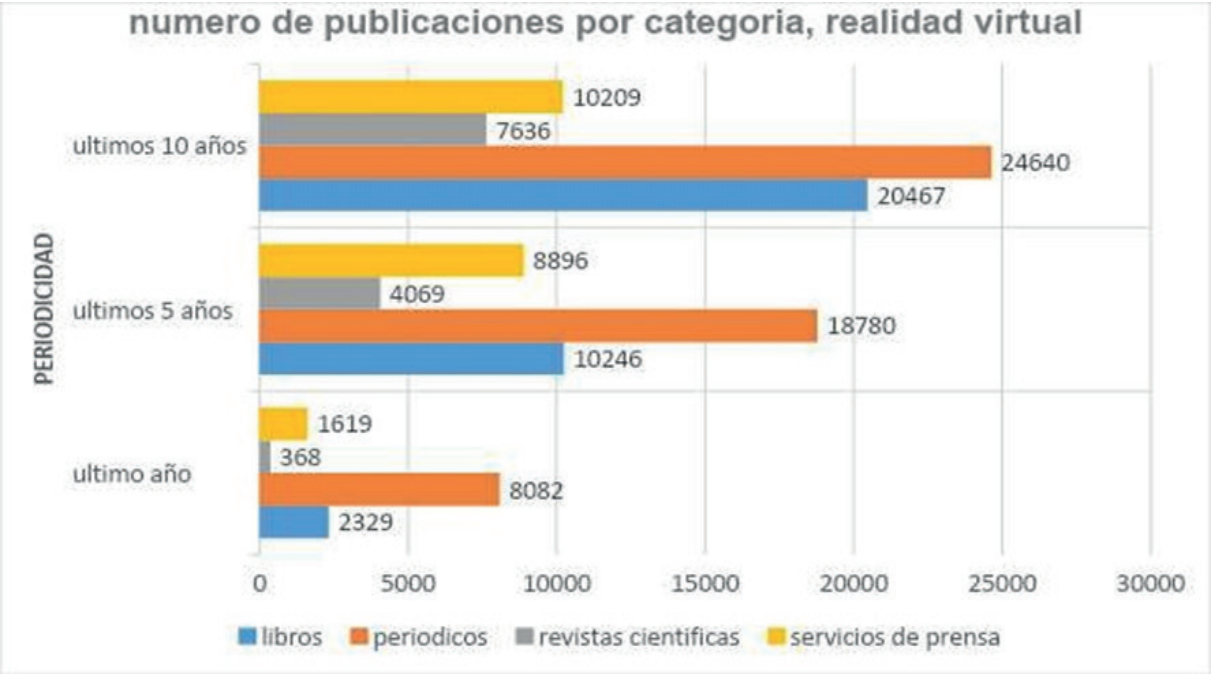

Figure 11. Scientific focus on virtual reality
Source: taken from ProQuest. https://www.proquest.com/results/D45F8977F9E64456PQ/1?accountid=34487

Books and newspapers have gained significant momentum in the production of information related to virtual reality, followed by scientific journals and press services (figure 12). The importance of the results focuses on the development of virtual reality through the publication of content related to the integration of new technologies and applications.[27,28]

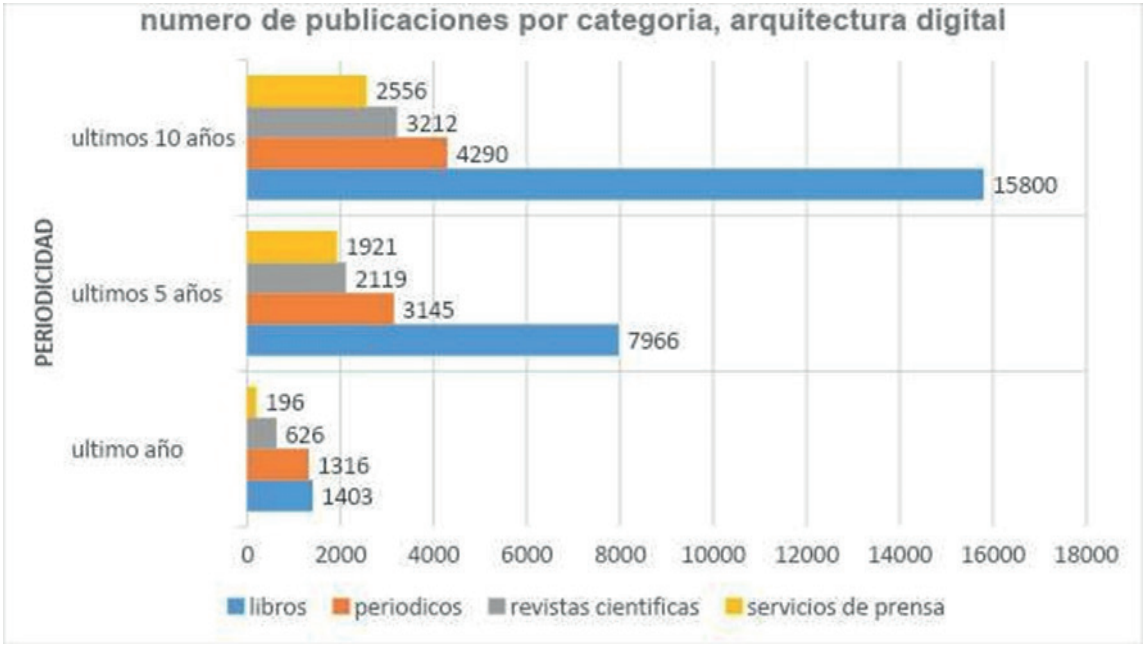

Figure 12. Scientific focus of digital architecture
Source: taken from ProQuest. https://www.proquest.com/results/D45F8977F9E64456PQ/1?accountid=34487

It was understood that virtual reality today is constantly improving, as technology and technological advances are greater every day, seeking solutions or facilitating humanity's day-to-day problems. As such, there are several documents in ProQuest where we can observe these advances.[29,30]

Gonzalez and Olivares launched a 'virtual reference service, which used reality and perspectives to venture into a revolutionary model of the modern library, offering a current reality of optimal services provided in the shortest possible time'.[31,32]

The pilot project launched by Orellana et al. for the 'improvement of learning based on multimedia resources, given at the Faculty of Architecture and Urbanism of the University of Cuenca, to apply it to digital expression,' directing their efforts towards the search for and applicability of virtual tools for teachers and students, allowing them to optimize development time.[33,34]

Rojas et al. applied the characteristics of immersive technologies in complete geoparks: virtual reality, augmented reality, mixed reality, visualization technologies, and games. To 'find the ideal technologies for those involved in the Geopark publication process to move from content transmission to the transformation of mediation interactions and, therefore, to deep learning, comprehensive systematic documentation is used. From bibliographic analysis with R Studio and the Bibliometrics library, with text analysis in Nvivo software. These results are discussed based on recent literature.' It should be noted that augmented and virtual reality are emerging as champions of mediation in informal environments, such as science centers. However, we must not forget that technology is only a tool that enhances the teaching and learning process.

Val created a conceptual model in parametric architecture: digital matter as code. 'The structural nature of parametric systems introduces integrated management for process improvement into the project. While developing the architectural project, Eisenman took this grammatical direction, embracing the self-referential nature of conceptual art and dealing with the denial of context and the importance of process as a consequence'.[35,36]

Tapias create a 'contemporary, digitally manufactured design. Architectural models have been questioned since the advent of CAD/CAM technology in the 1990s. New forms of representation have been introduced in architecture studios, such as Gehry's office and others, which were among the first to implement digitally-based design processes.' These events help bring these technologies into educational practice and create the first digital production laboratories that question architects' new role in the design and construction process while opening the way to a world of possibilities through workshops that allow the exploration of diverse spaces and scales. As in the various laboratories set up in several universities, the possibilities are few.[37]

Scientific behavior by country

Within this context, it is essential to note that publications on digital architecture and virtual reality have increased considerably over the years, with the United States leading the way, followed by China, demonstrating that these are world powers that are at the forefront of these types of issues, It is also essential to understand that the technological field has been enhanced by modernity in the quest to improve life and create a broad environment for business and people.

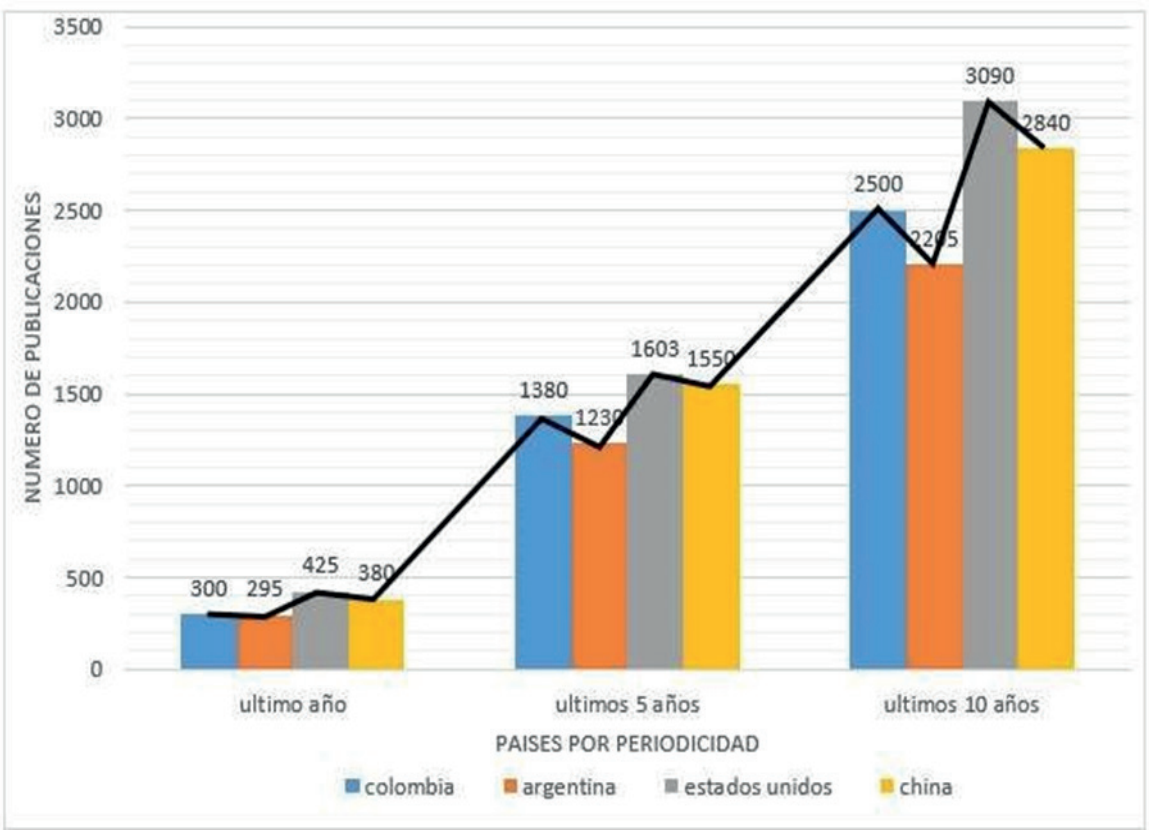

Figure 13. Scientific behaviour by country in relation to digital architecture searches
Source: taken from ProQuest. https://www.proquest.com/results/5D6253665A4D4DEAPQ/1?accountid=34487

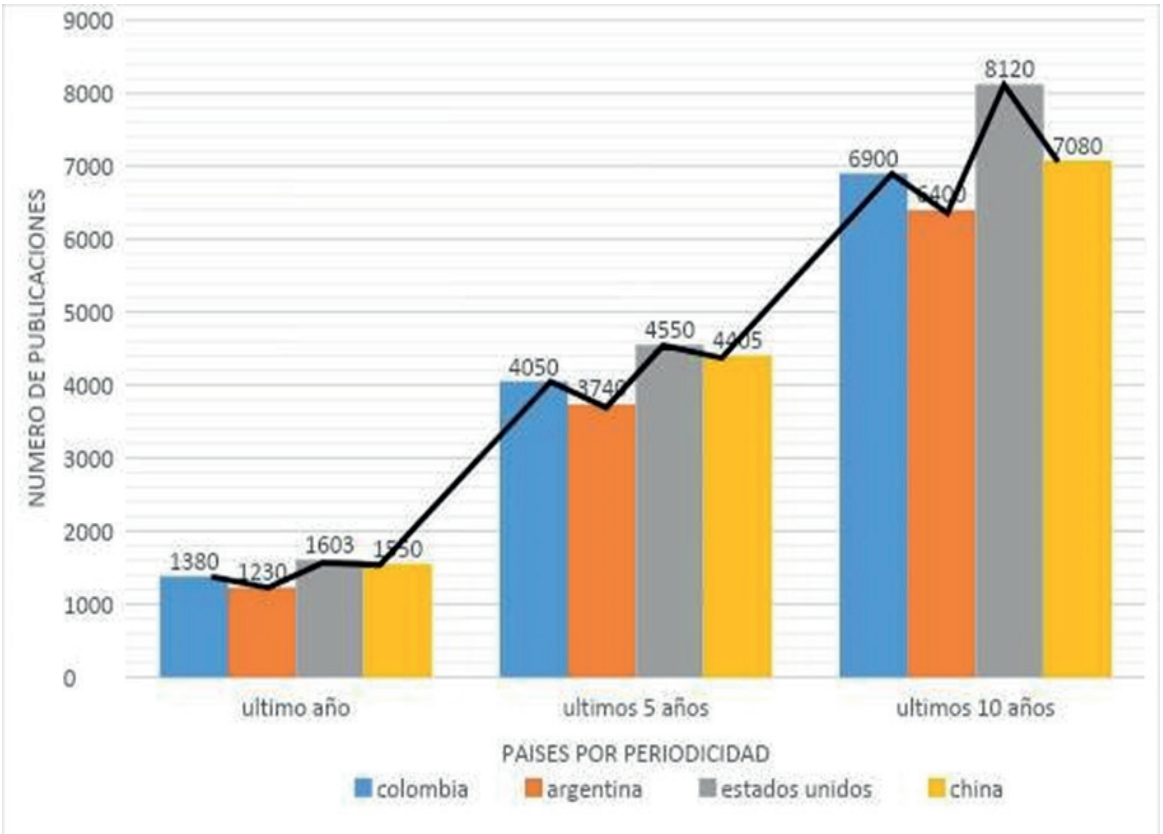

Figure 14. Scientific behaviour by country in relation to virtual reality searches
Source: taken from ProQuest. https://www.proquest.com/results/5D6253665A4D4DEAPQ/1?accountid=34487

CONCLUSIONS

In conclusion, the analysis in this document highlights the profound impact that digital technologies have had

on the field of architecture, consolidating digital architecture and virtual reality as key tools in the discipline's transformation.

Digitalization is no longer a mere trend but a necessity, both in education and the professional sphere, as it optimizes design processes, facilitates communication with clients, reduces long-term costs, and offers more realistic and efficient immersive experiences.

Based on the study of global and national trends, using platforms such as Google Trends and ProQuest, there has been sustained growth in interest related to 'digital architecture' and 'virtual reality.' Although Colombia shows more moderate development compared to powerhouses such as the United States and China, there is stability that reflects constant interest from the domestic market. This stability represents an opportunity to promote the implementation of these tools within the Colombian context, especially as a competitive advantage for architects and emerging companies.

In scientific terms, the considerable increase in academic production demonstrates the recognition of these technologies as valid and expanding fields of study. The publications reviewed indicate theoretical interest in the subject and the practical applicability of these tools, with projects focused on education, design visualization, and mediation in cultural contexts. Likewise, the focus on books, scientific journals, and websites shows that a solid body of knowledge is being generated that supports the viability of business models centered on digitalized services.

Although more recent in its adoption, virtual reality has begun to position itself as a revolutionary tool for representing architectural spaces. It allows for more intuitive interaction with users and facilitates more informed design decisions. This technology complements traditional 3D rendering, creating a more complete experience.

Therefore, the future of architecture is strongly linked to technological evolution. Integrating digital tools responds to market demand and redefines the architect's role in society. Investing in these resources and promoting their research and use represents not only an improvement in service quality, but also an opportunity for innovation and differentiation in an increasingly competitive and digitalised market.

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