International Journal of Learning, Teaching and Educational Research
Vol. 23, No. 2, pp. 313-329, February 2024
https://doi.org/10.26803/ijlter.23.2.15
Received Dec 28, 2023; Revised Feb 17, 2024; Accepted Feb 22, 2024

Use of Digital Twin Technology in the Teaching-Learning Process, in the field of University Education: A Bibliometric Review

Omar Chamorro-Atalaya*, Carlos Hernán Flores-Velásquez, Richard Flores-Cáceres
Facultad de Ingeniería y Gestión,
Universidad Nacional Tecnológica de Lima Sur, Perú

José Antonio Arévalo-Tuesta, Milton Zevallos-Castañeda
Facultad de Ciencias Económicas,
Universidad Nacional Federico Villarreal, Perú

Gregório Tomás-Quispe
Facultad de Ciencias de la Salud,
Universidad Tecnológica del Perú, Perú

Carmen Cristina Aranda-Dextre
Facultad de Medicina,
Universidad Nacional Mayor de San Marcos, Perú

Yreneo Cruz-Telada
Facultad de Ciencias de la Salud,
Universidad Autónoma de Ica, Perú

Juan Caller-Luna
Facultad de Ciencias de la Salud,
Universidad Privada del Norte, Perú

Ronald Alarcón-Anco
Facultad de Derecho y Ciencia política,
Universidad Alas Peruanas, Perú

Abstract. At the convergence of artificial intelligence with pedagogy, digital twin technology is emerging as a tool that offers advanced simulations and interactive learning environments. This is because

* Corresponding author: *Omar Chamorro-Atalaya, ochamorro@untels.edu.pe*

digital twins make it possible to replicate virtually any piece of equipment or test items in a laboratory. Based on the above, the objective of this article is to explore thematic gaps regarding the use of digital twin technology in the teaching-learning process. For this reason, a bibliometric review study is developed taking as data publications indexed in Scopus, during the years 2018 to 2023. Through the search equation, 92 publications were extracted. The study was developed under a quantitative approach at an exploratory-descriptive level. The results demonstrated that there is a growing and sustained scientific production on the topic under study, showing that, during and after the COVID-19 pandemic, there was greater production compared to other years. Furthermore, although it was identified that this technology is applicable to different specialties of higher education, it was determined that, to a greater extent, the topics discussed are engineering education assisted by digital twins, virtual reality and digital twins for engineering training and simulation-based training through digital twins. However, it is concluded that there is an unaddressed gap regarding the rules and regulations that should govern the use of digital twins in higher education as well as what the teacher's competencies should be so as to guarantee the appropriate use of digital twins as part of their teaching methodology, since the impact on student learning depends on this.

Keywords: digital twin; teaching-learning process; university; bibliometric review

1. Introduction

Many organisations in the academic field recognise the importance of taking advantage of the potential of technologies through digital transformation to improve the teaching-learning process (López-Gracia et al., 2022). The major challenge facing higher education institutions is to consolidate an educational model that responds to the trends of the fourth industrial revolution, which involves transforming universities into intelligent environments (Carvajal & Arenas, 2021). Talking about digital transformation necessarily entails contextualising it within the framework of the so-called fourth industrial revolution (Camacho & Loayza, 2023; Lin, 2022; Trujillo et al., 2022). In this context, higher education institutions must adopt innovative methodologies in their teaching and learning processes, relying on digital transformation, generating creative environments for the development of academic activities (De Giusti, 2023). Therefore, universities must evolve in their structures, processes and professional profiles, attending to the needs of society and consequently training students in accordance with those needs (Carbonell et al., 2023). The use of digital transformation in the classroom has been helped, however, by a wide variety of digital services and content as a methodological and innovative proposal with the aim of generating personalised learning (Grau et al., 2022); which includes tools such as digital animation, video game development, artificial intelligence, virtual and augmented reality, 2D and 3D modeling, and digital twins (García, 2023).

A digital twin is a digital representation of a real-world entity or system (Arias et al., 2022; Cruz, 2020); that is, you have a digital object that behaves like an

entity in the physical world (Niño, 2021; Quinteros et al., 2023). Digital twins are solutions that seek to digitally represent a physical reality, generating knowledge that revolves around data (Chiquito et al., 2020; Franco 2022) with the aim of providing tools for decision-making, additionally implementing simulation and prediction capabilities (Clarke, 2023; Corredor, 2022). There are five levels or types of digital twins: the descriptive twin, the informative twin, the predictive twin, the integral twin, and the autonomous twin (Larrota & Rodríguez, 2022). Digital twins provide a safety factor for personnel who are beginning their learning in the operation of machines or equipment, since they allow simulations and evaluations of risk situations without the need to subject them to dangerous environments (Añez, 2023; Grisales, 2022).

During the COVID-19 pandemic, the need for students to use their laboratories was evident; however, social distancing meant that they were often not able to do so (De Cabrera et al., 2023; Maldonado, 2021). For example, in the field of engineering learning, digital twin technology in higher education represents an alternative in which it seeks to digitally replicate laboratory equipment or practical teaching stations and in so doing allow the student to have access to its management and understanding of functioning in a personalised way (García, 2023). Another contribution of digital twins is in the learning of medicine, which allows greater precision and efficiency in diagnosis through the simulation of different scenarios and treatments in a safe setting (Gonzales, 2023). The main problem with this digitisation of learning environments, however, focuses on the lack of tools to obtain it, ones which are open to any user, free and whose software is understandable and recognised by students so that they can develop them without problem (Torres, 2022).

In relation to the above, this study aims to identify thematic gaps based on the bibliometric analysis of the scientific production developed regarding the use of digital twin technology in the teaching-learning process, in the field of university education. In this way, the study is approached methodologically under a quantitative approach, with an exploratory-describing level. The manuscripts used for the study were extracted from the Scopus database and were published between 2018 and 2023. Likewise, data processing was carried out based on two bibliometric analysis software called Bibliometrix and VOSviewer. Mainly, this study will contribute to the field of scientific knowledge on the thematic areas less addressed and with less attention regarding the use of digital twin technology in the teaching-learning process, in the field of university education. Therefore, the research questions defined for this study are:

- Research question 1: What is the scientific production on the use of digital twin technology in the teaching-learning process, in the field of university education, during the period 2018-2023?
- Research question 2: What are the scientific sources with the highest frequency of publication on the use of digital twin technology in the teaching-learning process, in the field of university education, during the period 2018-2023?

- Research question 3: What are the topics most frequently addressed regarding the use of digital twin technology in the teaching-learning process, in the field of university education, during the period 2018-2023?

2. Methodology

2.1 Research focus

Methodologically, the study is developed under a quantitative approach; this is because the indicators to be analysed correspond to bibliometric aspects, such as scientific production by year of publication, manuscripts with the highest number of citations, and sources or scientific journals with the greatest impact based on their index. Along with their H and quartile according to Scimago Journal Rank (SJR), words with the highest number of occurrences in titles and summaries, as well as the number of bigrams most frequently identified from the summaries. In this regard, Campo-Ternera et al. (2018) point out that a bibliometric review is linked to the analysis of numerical indicators, which allow analysing the characteristics of scientific activity oriented to the documentary production of scientific production on a particular topic of study.

2.2 Research level

The level of research that this study reaches is the exploratory-descriptive level. That is to say, it is at an exploratory level because, at first, there is a limited understanding of the problems regarding scientific production on the use of digital twin technology in the teaching-learning process in the field of university education. Therefore, initially, this study starts from carrying out an investigation in the Scopus database on the existing studies and publications regarding the field of study in question. Likewise, this study reaches an exploratory level, since, having identified at an exploratory level the studies and research carried out on the use of digital twin technology in the teaching-learning process, we proceeded to extract information on important characteristics and aspects through descriptive statistics, which will allow us to understand the thematic areas less addressed and with less attention, identifying thematic gaps based on bibliometric analysis. In this regard, Noriega et al. (2022) point out that a study is at a descriptive level when it seeks to specify certain properties, characteristics and significant features in relation to a topic under study.

2.3 Search equation and exclusion inclusion criteria

The search equation was defined based on the keywords defined in accordance with the study topic addressed, these being: “Digital twins”, “education”, “higher education”, and “university”. However, it is necessary to point out that, to establish the search equation, it is necessary to first define the database from which the manuscripts will be extracted; this is because each database has a specific syntax for searching for publications. In this study, the chosen database was Scopus because it stores a large number of publications from high-impact journals and conferences that seek to disseminate studies on emerging and disruptive technologies such as digital twins in the field of higher education. In this regard, Mañas and Gonzales (2023) point out that the Scopus database stores have a greater temporal coverage, and a greater number of publications, which

allow a better bibliometric analysis study to be carried out. In this sense, Table 1 shows the search equation and the inclusion and exclusion criteria that allowed a better selection of studies, being rigorous in the identification of publications that address studies strictly focused on the topic of study, and avoiding generating biases in the results obtained.

Table 1. Search equation and inclusion and exclusion criteria

Search equation	Inclusion criteria	Exclusion criteria
((TITLE-ABS-KEY (digital AND twins) AND TITLE-ABS-KEY (education))) AND ((TITLE-ABS-KEY (higher AND education) OR TITLE-ABS-KEY (university)))	• Studies published during the years 2018 to 2023. • Studies published in the context of university education. • All types of manuscripts are considered without distinction of the language of publication.	• Studies published before 2018. • Published studies that do not focus on the context of university education.

2.4 Data extraction method

The data were collected through the method validated by Chamorro et al. (2023), which adapts certain processes of the PRISMA statement (Preferred Reporting Items for Systematic reviews and Meta-Analyses) in three stages to determine which manuscripts will ultimately be included in the bibliometric review data analysis. Applying this data extraction method to the bibliometric review study on the scientific production developed regarding the use of digital twin technology in the teaching-learning process, in the field of university education, the first stage, called "Theme, scope and eligibility", consisted of defining the topic under study, the database from which the manuscripts will be extracted, the study time frame, the types of manuscripts to be analysed and the definition of the search equation. In the second stage, called "Screening", the search equation and the inclusion and exclusion criteria were applied, from which 151 manuscripts could be identified. In the third and final phase, called "Included", it refers to the exhaustive review of the title of manuscripts and the summaries of the articles identified in the second phase. Through this it was possible to establish that only 92 manuscripts strictly focused on the topic of studies and it is on these that the bibliometric indicators analysis stage will be carried out.

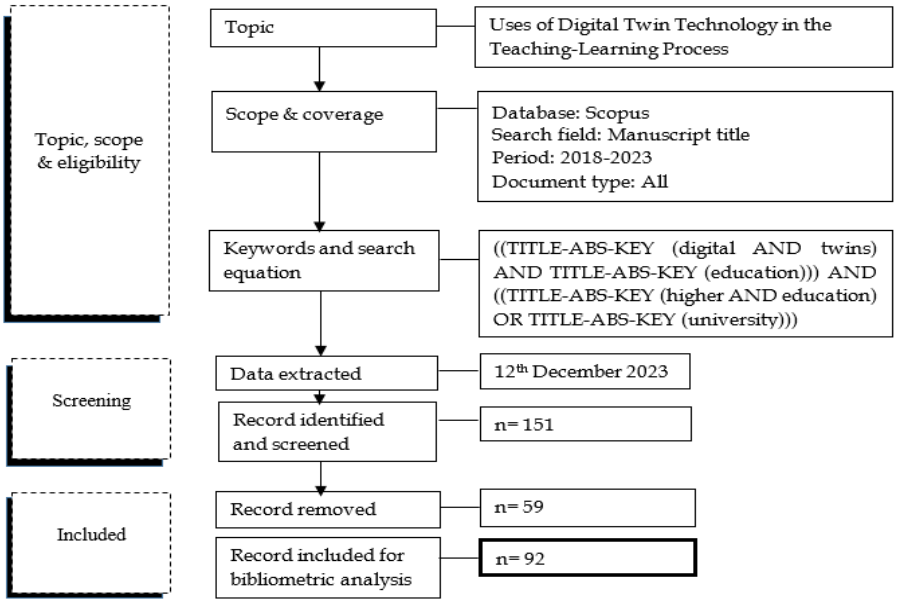

Figure 1. Method used to extract manuscripts

3. Results and discussion

3.1 Scientific production on the use of digital twin technology in the teaching-learning process, in the field of university education, during the period 2013-2023

With respect to scientific production on the use of digital twin technology in the teaching-learning process in the field of university education and using the Bibliometrix software, it was identified that, during the period between 2018 and 2023, there was a trend of sustained growth in publications from 2020 onwards, 94.57% of the total manuscripts analysed concentrated in that period of time. Furthermore, in 2022 and 2023 the highest numbers of publications were reached, with 35 and 30 manuscripts, respectively. Now, if we take as a reference point the year in which the COVID-19 pandemic began and in which different technological tools were sought to be applied to guarantee the continuity of the teaching-learning process, it is observed that five manuscripts were published before the pandemic, while 87 manuscripts were published during and after the pandemic. This result reveals that this technology is an alternative to ensure that students who cannot have access to physically experiment with laboratory equipment can do so through the digital twin of the equipment, ensuring that student learning is not limited by the lack of equipment in the laboratories; and in the case of the teacher, it will allow them to better manage their teaching strategies in which they can complement theoretical aspects with practical ones, without problems.

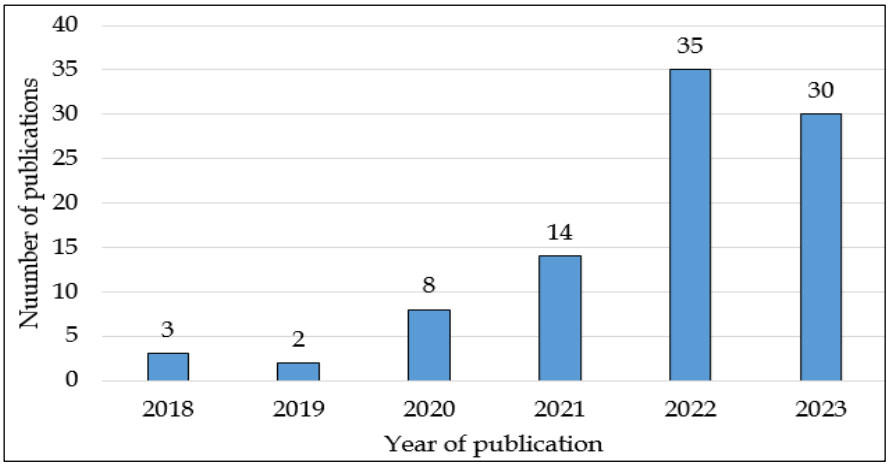

Figure 2. Distribution of manuscripts by year of publication

Other information that could also be extracted from the analysis of scientific production regarding the use of digital twins in the teaching-learning process is the total number of citations per year (TC) and the average number of citations per year (TA) with respect to the manuscripts published during the years 2018 to 2023. Through this, it was identified that there was no increasing and continuous trend in the number of citations of the published manuscripts; however, the maximum values of citations occur in the years 2020 and 2022, in which the number of citations reaches 119 and 100, respectively. On the other hand, with respect to the average number of citations per year, the maximum values were reached in the years 2018 and 2020, whose values are 25.33 and 14.88, respectively. This shows that the number of citations exceeded the number of publications made in those years. These results are then clear evidence that scientific production on digital twins is not focused solely on the number of publications but also on the quality of the studies carried out, since the TC and TA indicators are relatively high.

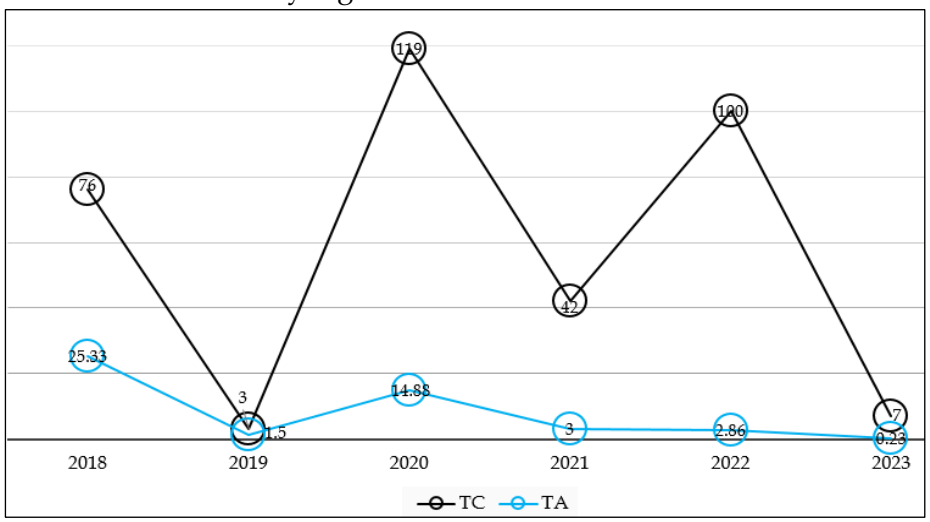

Figure 3. Total citations and average citations per year of publication

Based on these results, Area and Adell (2021) point out that, in recent years, there have been many studies and investigations that show a transformation of

teaching and learning at various levels of education, including at the university level, due to the use and massification of disruptive technologies. Furthermore, Grau et al. (2022) state in their systematic review study on digital transformation in the educational field that there is a growing rate in scientific production between the years 2017 and 2020, regarding the use of technological tools that generate the digital transformation of educational environments. It is clear that through digital inclusion, both at the level of infrastructure provision to reduce digital gaps and resources, it will facilitate the improvement of the teaching-learning process. In this same line of opinion, Gonzáles (2023) states that a clear example of the rapid introduction of technological tools in recent years is evident in the use of digital twins in different areas, for example, in medicine. In this latest research, it is evident that, although it is not strictly focused on the field of education, it is possible to deduce that digital twin technology can also be used in the teaching and learning process of medical students. In relation to the latter, Machado and Berssaneti (2023) pointed out that their literature review study concluded that, in recent years, there has been sustained growth in the scientific production of the application of digital twin technology in the health sector. Regarding those indicated by the authors, although they identified 153 manuscripts in the Scopus database, they manage to show that, between the years 2020 to 2022, the percentage of manuscripts analysed corresponds to 85.12%. This supports the result obtained in this study, since this study identified a production of 94.57% with respect to the total number of manuscripts, between the years 2020 and 2023.

3.2 Fuentes Sources with the highest frequency of publication on the use of digital twin technology in the teaching-learning process, in the field of university education, during the period 2018-2023

Regarding the sources with the highest frequency of publication on the use of digital twin technology in the teaching-learning process, in the field of university education, they were initially identified through the Bibliometrix software. Of the 92 manuscripts analysed, these have been published in 75 bibliographic sources, of which 38 are scientific journals, and 37 are conference proceedings. Table 2 shows the 10 bibliographic sources with the highest number of publications regarding the use of digital twins in higher education. As such, it was possible to identify that the scientific journal *Lecture Notes in Networks and Systems* is the one that presents a total of five publications, with an h-index of citation impact equal to 27. Likewise, the other two bibliographic sources with the highest number of publications are *Computational Intelligence and Neuroscience* with a h-index of 70 and *ASEE Annual Conference and Exposition, Conference Proceedings* with a h-index of 39; both with four publications. These results show that, although there is a significant number of bibliographic sources that allow publication on the use of digital twin technology in higher education, there is no journal that concentrates publications in this field of study to a greater extent. Furthermore, it is also possible to affirm that not many studies have been carried out in this area of knowledge, so, quantitatively, it is evident that there is a gap in this field of study to be addressed. On the other hand, these results show that these bibliographic sources are mostly of high impact, so the authors who carry out research in this field of knowledge could consider these scientific journals or conferences for the publication of future studies.

Table 2. Bibliographic sources with the highest number of publications

Source	h-Index	Total number of publications
Lecture Notes in Networks and Systems	27	5
Computational Intelligence and Neuroscience	70	4
ASEE Annual Conference and Exposition, Conference Proceedings	39	4
2022 IEEE German Education Conference, GECON 2022	1	2
ACM International Conference Proceeding Series	137	2
CEUR Workshop Proceedings	62	2
Electronics (Switzerland)	62	2
IEEE Global Engineering Education Conference, EDUCON	30	2
IFAC-Papers online	86	2
Sustainability (Switzerland)	136	2

Additionally, it was possible to identify those publications with the highest number of citations. Table 4 shows that of the total of 92 manuscripts, 12 manuscripts have a number of citations greater than seven. The two manuscripts with the highest number of citations are "A Smart Campus' Digital Twin for Sustainable Comfort Monitoring" and "Toward a Web-Based Digital Twin Thermal Power Plant" with 74 and 40 citations, respectively. It should be noted that the other manuscripts of the 92 analysed and which do not appear in the table, are distributed as follows: two manuscripts have six citations, two manuscripts have five citations, four manuscripts have four citations, three have three citations, nine have two citations, 18 have one citation, and 42 manuscripts have no citation. Another indicator to take into account is the total number of citations (TC) per year of publication and the total normalized citations (TC-N). In this case study, the manuscript "Toward a Web-Based Digital Twin Thermal Power Plant" has a TC equal to 20, which means that, since its publication date, it has been cited on average 20 times. Likewise, this same manuscript is the one that presents the highest TC-N with a value of 14, so it can be understood as that manuscript, considering the number of total citations in this field of study, is being cited 14 times on average per year.

Table 3. Manuscripts with the highest number of citations

Author	Title of the manuscript	Total Citations	TC	TC-N
Zaballos et al. (2020)	A Smart Campus' Digital Twin for Sustainable Comfort Monitoring	74	18.50	4.97
Lei et al. (2022)	Toward a Web-Based Digital Twin Thermal Power Plant	40	20.00	14.00
Autiosalo (2018)	Platform for industrial internet and digital twin focused education, research, and innovation:	37	6.17	1.46

	Ilmatar the overhead crane			
David et al. (2018)	Learning Experiences Involving Digital Twins	28	4.67	1.11
Martinez et al. (2021)	Automation Pyramid as Constructor for a Complete Digital Twin, Case Study: A Didactic Manufacturing System	20	6.67	6.67
Kuts et al. (2020)	Digital Twin: Collaborative Virtual Reality Environment for Multi-Purpose Industrial Applications	15	3.75	1.01
Anand et al. (2018)	Additive Manufacturing Simulation Tools in Education	11	1.83	0.43
Guc et al. (2021)	Digital Twins Enabled Remote Laboratory Learning Experience for Mechatronics Education	8	2.67	2.67
Cortes et al. (2020)	Digital Pyramid: an approach to relate industrial automation and digital twin concepts	8	2.00	0.54
Kalantari et al. (2022)	Developing and user-testing a Digital Twins prototyping tool for architectural design	8	4.00	2.80
Dashkina et al. (2020)	Developing a Model of Increasing the Learners' Bilingual Professional Capacity in the Virtual Laboratory Environment	8	2.00	0.54
Chen et al. (2022)	Educational 5G Edge Computing: Framework and Experimental Study	7	3.50	2.45

With respect to the bibliographic sources that frequently publish studies on the application of digital twins, Machado and Berssaneti (2023) point out in their literature review study on the use of digital twin technology that the bibliographic sources identified in the final selection and with a greater number of publications are, to a greater extent, bibliographic sources in the technological field, representing 62%. They also highlight that the review with the largest number of publications is "IEEE Access" with five publications. Based on what was stated by the researchers, and taking into account both this bibliometric review study as well as the aforementioned literature review study, we both agree in identifying that the bibliographic source with the highest number of publications has five published studies. This shows that, compared to the use of other types of technologies, their application is not becoming widespread in different areas of society such as education. For example, Chiquito et al. (2020) in

their study on the evolution of digital twin technology, point out that, based on reviewed data sources, they deduce that, although digital twin technology represents a relatively recent advance, experts assure that it has had a rapid evolution and application in various types of industry. However, it must be kept in mind that the generation of a digital twin must be assumed as a process of creating an evolutionary system over time. Likewise, Torres (2022) points out that one of the limitations that makes it difficult to use digital twin technology lies in the use of a large technological infrastructure, which includes processes that are economically costly for some organisations.

3.3 Topics most frequently addressed regarding the use of digital twin technology in the teaching-learning process, in the field of university education, during the period 2018-2023

With respect to the topics most frequently addressed in the reviewed manuscripts on the use of digital twin technology in the teaching-learning process, in an initial analysis the Bibliometrix software was used to extract information regarding bigrams (grouping of two words) that are repeated most frequently in the manuscript abstract. Figure 4 shows that, during the years 2018 to 2023, the two bigrams with the highest frequency of repetition in the summaries are "digital twin" and "digital twins", also evidencing sustained growth during the period under study. Likewise, in accordance with the search and selection of manuscripts that address the topic of study, through this analysis it was identified that the other bigrams that are most frequently repeated are "Twin technology", "Smart campus" and "Virtual reality". These results show that digital twin technology is not an isolated technology but, on the contrary, can easily be integrated with other technologies such as virtual reality or smart campuses which are tools with a very high tendency to be considered in higher education institutions, in the search for digital transformation.

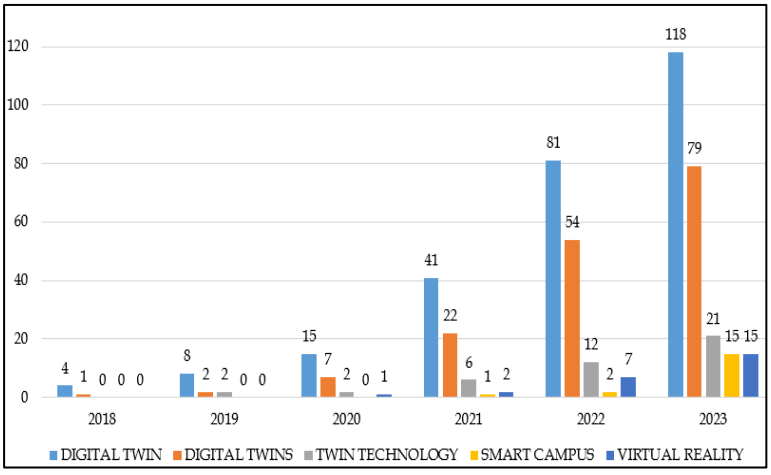

Figure 4. Bigrams most frequently identified from the abstract

Another aspect that was analysed is the relationship of topics or concepts through the co-occurrence network, this with the purpose of identifying the topics addressed with the greatest link strength on the use of digital twin technology in the teaching-learning process. This term link strength is linked to

the number of associations between two nodes (in this case each node is equivalent to a keyword) and shows the number of times they have been mentioned together in different manuscripts. Figure 5 shows that the keywords with the highest link strength, in which "e-learning" stands out with a link strength of 176, "engineering education" with 159, "digital twin" with 149, "students" with 126, "education computing" with 99 and "virtual reality" with a link strength of 82. This gives clear evidence that many virtual reality applications are being integrated with digital twin technology. Likewise, although it is true that this technology is applied to different specialties at the university level, the studies extracted show that there is a greater application of digital twin technology in the teaching-learning process in engineering specialties.

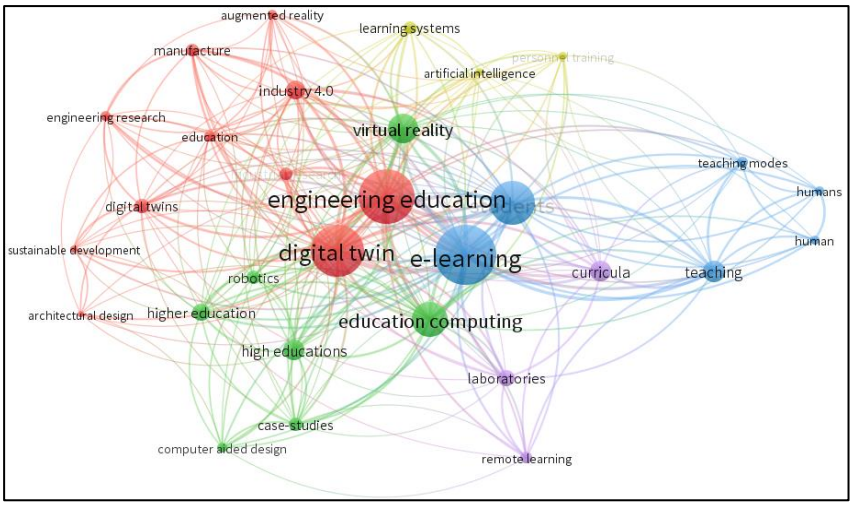

Figure 5. Co-occurrence network obtained from the keywords of the manuscripts

Furthermore, with the purpose of evidencing the specific groupings that are constituted from the keywords identified in the different manuscripts analysed, within the field linked to the use of digital twin technology, the network of density is made up of keywords. In this network it can be seen that there are two fairly defined groupings, and that would demonstrate that there is a strong interaction between these fields of knowledge. The first grouping is made up of the keywords "Digital twin", "engineering education" and "virtual reality"; while the second grouping is made up of "Education computing", "e-learning", and "students".

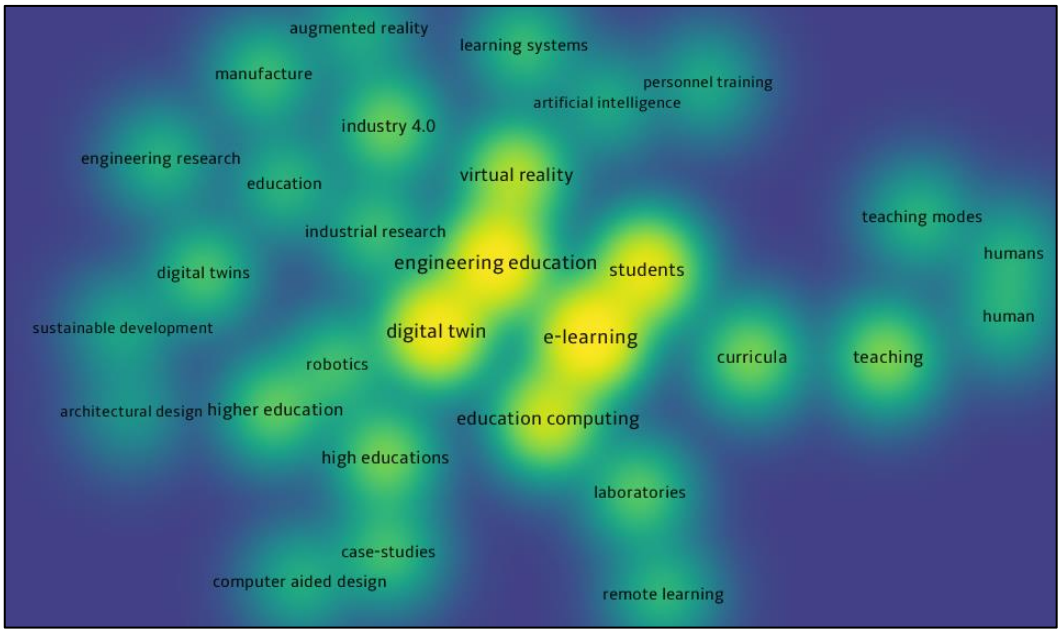

Figure 6. Density network obtained from the keywords of the manuscripts

With these results, it can be deduced that the topics that are being developed to a greater extent with respect to the use of digital twins in the teaching-learning process in the field of university education are "Engineering education assisted by digital twins", "Virtual reality and digital twins for engineering training" and "simulation-based training through digital twins". In this regard, García (2023), in his research on the application of digital twins with an immersive environment for an automation process at the Santo Tomás University, points out that the use of digital twin technology combining them with immersive environments leads to achieving the complete development of a classroom virtual, facilitating education modalities such as hybrid, this by being able to teach classes assisted by interactive and complete technologies, thus improving the teaching-learning process. Furthermore, Torres (2022) points out that projects based on digital twins help students carry out their class sessions in a better way, contributing to greater availability of laboratory equipment, since they are a basic resource for the teacher to complement his teachings. However, although the bibliometric analysis identified that it focuses to a greater extent on the area of engineering education, it should be noted that digital twin technology is also applied in other areas or specialties. In this regard, Gonzáles (2023) points out that the implementation of virtual models based on digital twins allows the behaviour and physiology of patients to be replicated, helping doctors make more informed and precise decisions in the diagnosis, treatment and monitoring of diseases.

4. Conclusions

In relation to the scientific production on the use of digital twin technology in the teaching-learning process in the field of university education, it was identified that, during the period between 2018 and 2023, there was a trend towards sustained growth of publications from 2020 onwards, 94.57% of the total manuscripts analysed concentrated in that period of time. This shows that,

during and after the COVID-19 pandemic there was greater scientific production than in other years. Likewise, in relation to which are the sources with the highest frequency of publication regarding the use of digital twins in the field of university education, it was identified that of the 92 manuscripts analysed, these have been published in 75 bibliographic sources of which 38 are scientific journals and 37 are conference proceedings. Furthermore, the scientific journal *Lecture Notes in Networks and Systems* is the one that presents the largest number of studies, with a total of five publications. Finally, in relation to which are the topics most frequently addressed regarding the use of digital twin technology in the teaching-learning process, it was identified that these are "Engineering education assisted by digital twins", "Virtual reality and digital twins for engineering training" and "simulation-based training through digital twins". In this sense and considering the findings identified in this bibliometric review study, it is concluded that there is an unaddressed gap regarding the standards and regulations that should govern the use of digital twins in higher education; as well as what the teacher's competencies should be to guarantee the appropriate use of digital twin technology in their teaching methodology since the impact on student learning depends on this.

5. Future research

Taking into account the results and conclusions reached in this bibliometric review study, it is recommended that future studies linked to this line of research focus on: "Guidelines for the development of standards that regulate the use of digital twins in the higher education", "Teacher training and competencies in technologies for managing digital twins", "Evaluation and feedback in educational environments based on digital twins", and "Equity and access to education assisted by digital twins".

6. References

Anand, S., Ghalsasi, O., Zhang, B., Joshi, S., & Morris, G. (2021). Additive Manufacturing Simulation Tools in Education. *2018 World Engineering Education Forum - Global Engineering Deans Council, WEEF-GEDC, 12-16 November 2018*. https://doi.org/10.1109/WEEF-GEDC.2018.8629689

Añez, R. J. (2023). *Modeling and virtual commissioning of the digital twin of a Flowpack machine with the Melsoft Gemini tool.* Ms. Thesis, Control Engineering, Automation and Robotics, Universidad de País Vasco, Bilbao, Spain. https://addi.ehu.es/handle/10810/62801

Area, M., & Adell, J. (2021). Digital technologies and educational change. A critical approach. *REICE, Ibero-American Journal on Quality, Efficiency and Change in Education*, *19*(4), 83-96. https://doi.org/10.15366/reice2021.19.4.005

Arias, F. J. T., Zuñiga, K. M., Zambrano, M. M. T., & Cruzatty, J. E. Á. (2022). Digital twins in the industry. *PentaCiencias Multidisciplinary Refereed Scientific Journal*, *4*(1), 75-83. https://editorialalema.org/index.php/pentaciencias/article/view/29

Autiosalo, J. (2018). Platform for industrial internet and digital twin focused education, research, and innovation: Ilmatar the overhead crane. *IEEE World Forum on Internet of Things, WF-IoT 2018 - Proceedings, 2018-January*, 241–244. https://doi.org/10.1109/WF-IoT.2018.8355217

Cabrera, N. S. D., Fernández, N. A., & Portillo, M. B. (2023). Use of digital tools in times of COVID-19, in the Polytechnic Faculty of the UNA. *Paraguayan Journal of*

Distance Education, *4*(1), 60-72. https://revistascientificas.una.py/index.php/REPED/article/view/3284

Camacho, J. P. C., & Loayza, L. M. H. (2023). *Development of a digital twin of the handling and sorting stations of the Festo MPS 500 modular production system*. Thesis, Electronic Engineering Career, Salesian Polytechnic University, Cuenca, Ecuador. https://dspace.ups.edu.ec/handle/123456789/24619

Campo-Ternera, L., Amar-Sepúlveda, P., Olivero Vega, O. E., & Herazo, H. S. (2018). Entrepreneurship and innovation as a driver of sustainable development: Bibliometric study (2006-2016). *Social Sciences Journal*, *24*(4), 26-37. https://produccioncientificaluz.org/index.php/rcs/article/view/24907

Carbonell, M. R., Fontanillas, T. R., Catasús, M. G., & Quemada, P. B. (2023). Digital transformation in higher education: The case of the UOC. *RIED-Ibero-American Journal of Distance Education*, *26*(1), 163-179. https://doi.org/10.5944/ried.26.1.33998

Carvajal, C. A. R., & Arenas, N. A. G. (2022). Approach to digital transformation in higher education institutions through the theory of change. *En Contexto Journal*, *10*(17), 229-263. https://doi.org/10.53995/23463279.1163

Clarke, H. A. (2023). *Urban digital twins*. Thesis. Higher Technical School of Architecture and Building, Polytechnic University of Cartagena, Cartagena, Colombia. https://repositorio.upct.es/handle/10317/12665

Chamorro-Atalaya, O., Olivares-Zegarra, S., Sobrino-Chunga, L., Guerrero-Carranza, R., Vargas-Diaz, A., Huarcaya-Godoy, M., Rasilla-Rovegno, J., Suarez-Bazalar, R., Poma-Garcia, J., & Cruz-Telada, Y. (2023). Application of the Chatbot in University Education: A Bibliometric Analysis of Indexed Scientific Production in SCOPUS, 2013-2023. *International Journal of Learning, Teaching and Educational Research*, *22*(7), 281-304. https://doi.org/10.26803/ijlter.22.7.15

Chen, Q., Wang, Z., Su, Y., Fu, L., & Wei, Y. (2022). Educational 5G Edge Computing: Framework and Experimental Study. *Electronics (Switzerland), 11*(17), 1-22. https://doi.org/10.3390/electrónica11172727

Chiquito, V. M, Plua, G. J. C., Chong, B. M; Chong, B. C. (2020). Digital twins and their evolution in the industry. *Scientific Journal World of Research and Knowledge*, *4*(4), 300-308. https://doi.org/10.26820/recimundo/4.(4).noviembre.2020.300-308

Corredor, S. D. F. (2022). *Industry 4.0 and digital twins in construction*. Thesis. Faculty of engineering, Militar University of New Granada, Bogotá, Colombia. https://repository.unimilitar.edu.co/handle/10654/43852

Cortes, D., Ramirez, J., Villagomez, L., Batres, R., Vasquez-Lopez, V., & Molina, A. (2020). Digital Pyramid: an approach to relate industrial automation and digital twin concepts. *Proceedings - 2020 IEEE International Conference on Engineering, Technology and Innovation, ICE/ITMC 2020, 15-17 June 2020*. https://doi.org/10.1109/ICE/ITMC49519.2020.9198643

Cruz, K. A. (2020). *Digital Twin in Solar Parks: approach using time series and deep learning*. Ms. Thesis. Universitat Jaume I. https://repositori.uji.es/xmlui/bitstream/handle/10234/193565/TFM_2020_ArafetK.pdf?sequence=1

David, J., Lobov, A., & Lanz, M. (2018). Learning experiences involving digital twins. *Proceedings: IECON 2018 - 44th Annual Conference of the IEEE Industrial Electronics Society*, 3681–3686. https://doi.org/10.1109/IECON.2018.8591460

Dashkina, A. I., Khalyapina, L. P., Kobicheva, A. M., Odinolaya, M. A., & Tarkhov, D. A. (2020). Developing a Model of Increasing the Learners' Bilingual Professional Capacity in the Virtual Laboratory Environment. *Applied Sciences (Switzerland)*, *10*(20), 1–20. https://doi.org/10.3390/app10207022

De Giusti, A. E. (2023). Digital Transformation in Higher Education. Possibilities and Challenges. *Ibero-American Journal of Technology in Education and Technology Education*, *35*(1), 9-15. https://doi.org/10.24215/18509959.35.e1

Franco, R. G. (2022). *Digital Twins and Virtual Worlds: Driving Workplace Transformation*. Thesis, Tecno Campus, Universitat Pompeu FaBra, Barcelona, Spain. https://repositori.tecnocampus.cat/handle/20.500.12367/2323

Garcia, D. S. E. (2023). Digital twin in AR of the Automation Plant of the Santo Tomás University. Thesis, Mechatronics Engineering, Universidad Santo Tomás, Bucaramanga, Colombia. https://repository.usta.edu.co/handle/11634/53052

González, C. M. T. (2023). Digital twins applied to biomedicine. *Canarian Pediatric Journal*, *47*(2), 128-134. https://scptfe.com/gemelos-digitales-aplicados-a-la-biomedicina/

Grau, F. G., Bautista, C. V., & Cantabrana, J. L. L. (2022). Strategies for the Digital Transformation of an Educational Center: a systematic review. *RiiTE Interuniversity research magazine in Educational Technology*, *13*(1), 157-172. https://doi.org/10.6018/riite.533971

Grisales, G. A. D. J. (2022). Prospects for appropriation of digital twins in learning factories for decision-making. *EDUTEC 2022, Palma XXV International Congress*, 73-77. https://dspace.uib.es/xmlui/handle/11201/160460?show=full

Guc, F., Viola, J., & Chen, Y. (2021). Digital Twins Enabled Remote Laboratory Learning Experience for Mechatronics Education. *Proceedings 2021 IEEE 1st International Conference on Digital Twins and Parallel Intelligence, DTPI 2021*, 242–245. https://doi.org/10.1109/DTPI52967.2021.9540196

Kalantari, S., Pourjabar, S., Xu, T.B., & Kan, J. (2022). Developing and user testing a Digital Twins prototyping tool for architectural design. *Automation in Construction Journal*, *135*(1), 1-14. https://doi.org/10.1016/j.autcon.2022.104140

Kuts, V., Otto, T., Bondarenko, Y., & Yu, F. (2020). Digital twin: Collaborative virtual reality environment for multi-purpose industrial applications. *ASME International Mechanical Engineering Congress and Exposition, Proceedings (IMECE)*, November 16–19, 2020, 2B-2020, 1-7. https://doi.org/10.1115/IMECE2020-23390

Larrota, J. P. B., & Rodríguez, D. E. L. (2022). *Development of a digital twin using reality augmented with cloud management for the bank of fluid transportation tests and cuttings drilling of the Colombian petroleum institute.* Thesis, Faculty of Engineering, Autonomous university of Bucaramanga, Bucaramanga, Colombia. https://repository.unab.edu.co/handle/20.500.12749/20332

Lei, Z., Zhou, H., Hu, W., Guan, S., & Feng, X. (2022). Toward a Web-Based Digital Twin Thermal Power Plant. *IEEE Transactions on Industrial Informatics, 18*(3), 1716-1725. https://doi.org/10.1109/TII.2021.3086149

Lin, J. (2022). *Development of digital twins of simple linear elastic structures*. Thesis, Barcelona School of Engineering, Universidad Politécnica de Catalunya, Barcelona, Spain. https://upcommons.upc.edu/handle/2117/389759

López-Gracia, A., González-Ramírez, T., & Pablos-Pons, J. D. (2022). Key factors in the educational digital transformation of educational organizations. *Profesorado Scientific Journal*, *26*(2), 75-101. https://doi.org/10.30827/profesorado.v26i2.21222

Machado, T. M., & Berssaneti, F. T. (2023). Literature review of digital twin in healthcare. *Heliyon, 9*(1), 1-12. https://doi.org/10.1016/j.heliyon.2023.e19390

Maldonado, N. E. L., López, S. R. R., Rodríguez, I. S. R., & García, M. A. C. (2021). Digital Tools in COVID-19 Times: Perception of Higher Education Teachers in Mexico. *Ibero-American Journal for Educational Research and Development*, *12*(23), 1-28. https://doi.org/10.23913/ride.v12i23.1108

Martinez, E. M., Ponce, P., Macias, I., & Molina, A. (2021). Automation Pyramid as Constructor for a Complete Digital Twin, Case Study: A Didactic Manufacturing System. *Sensors*, *21*(14), 1-29. https://doi.org/10.3390/s21144656

Noriega, M. D. L., & Avila, A. C. (2022). The COVID-19 Pandemic Impact on Mexican Middle Higher Education Students. *Ibero-American Journal for Educational Research and Development*, *12*(24), 1-27. https://doi.org/10.23913/ride.v12i24.1141

Niño, D. L. F. J. (2021). *Development of the digital twin of a steam ejector using machine learning techniques.* Thesis, School of Industrial Engineering, University of Valladolid, Valladolid, Spain. https://uvadoc.uva.es/handle/10324/46200

Olmo, M. M., & Alba, B. G. (2023). Training in digital competence for primary and early childhood education teachers in Spain: A bibliometric review of the literature. *Publications*, *53*(1), 137–162. https://doi.org/10.30827/publicaciones.v53i1.27990

Quinteros, A. J. E., Parra, C. N. J., Paspuel, G. E. A., Orbe, V. M. A., & Chuquitarco, Y. S. A. *Creation of digital twins of heritage assets, through the use of digital geotechnologies and their dissemination in disruptive VR virtual environments*. Thesis, Geospatial engineering career, Universidad de las Fuerzas Armadas, Ecuador. https://repositorio.espe.edu.ec/bitstream/21000/36182/1/T-ESPE-058027.pdf

Torres, R. B. (2022). F*MS200 flexible manufacturing cell station 3 digital twin*. Thesis, School of electronic engineering, Jaen University, Jaen, Spain. https://crea.ujaen.es/bitstream/10953.1/19855/1/MEMORIA-GEMELO-DIGITAL-ESTACION-8-CELULA-DE-FABRICACION-FLEXIBLE-FMS200-firmado%20-%20Oscar%20Espejo%20Quesada.pdf

Trujillo V. G., Rodríguez A. L., Mejía A. D., & López P. R. (2022). Digital transformation in Latin America: a systematic review. Venezuelan Management Journal, 27(100), 1519-1536. https://doi.org/10.52080/rvgluz.27.100.15

Zaballos, A., Briones, A., Massa, A., Centelles, P., & Caballero, V. (2020). A Smart Campus' Digital Twin for Sustainable Comfort Monitoring. *Sustainability*, *12*(1), 1-33. https://doi.org/10.3390/su12219196