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Inclusion of Metaverses in the Development of the Flipped Classroom in the University environment: Bibliometric Analysis of Indexed Scientific Production in SCOPUS

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Abstract. The flipped classroom as a teaching strategy implies a change in the traditional class dynamics; however, in recent years the use of metaverses has been incorporated in the development of flipped classrooms, seeking to provide a more immersive and interactive environment for the student. Therefore, it is necessary to analyze and

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identify the existing gaps in the scientific production that investigate the inclusion of metaverses in university education. In this sense, the purpose of this study is to examine and present currents of study related to the integration of metaverses in the development of the flipped classroom, in university environments, using bibliometric analysis regarding academic works indexed in the Scopus database, between 2013 and 2023. The results obtained show a constant growth in scientific production. This increase is influenced by the context of the COVID-19 pandemic and the search for more immersive and effective solutions in virtual education. The predominant thematic areas focus specifically on the use of virtual reality and augmented reality as key elements for the design and construction of metaverses, which, combined with gamification techniques, lead to the development of flipped and immersive classrooms. In this sense, based on the identified results, it is concluded that there is a gap in the research corpus that needs to be addressed in terms of guidelines and good practices for the effective integration of metaverses in flipped classrooms.

Keywords: flipped classroom; metaverse; augmented reality; virtual reality; higher education

1. Introduction

Although distance education has existed for many years, the pandemic accelerated the immersion into the virtual world of the teaching and learning processes, making the implementation of virtual platforms vitally important (Roller, 2022). Although educational trends are leaning more towards digitisation, higher education systems seem to have a lot to offer a very diverse audience that has just faced a pandemic (Villamarín, 2023). We can clearly see that COVID-19 contributed to the resurgence of various technologies, including the metaverse, giving rise to the development of immersive and interactive environments (Chavez, 2022; González et al., 2022). A metaverse is a virtual environment capable of simulating both a real physical environment and a digital world (Chediak, 2023; Vallejos, 2023) whose application to the educational field focuses on offering virtual education solutions generating new collaborative learning models, and thereby encouraging interactive student participation (Ruiz-Campo et al., 2022). Currently, the metaverse is considered as a universal, unified and interoperable 3D space with the capacity for immersion, corporeality and persistence (Mendiola, 2022; Quiroz et al., 2023). In this way, immersiveness means that users are immersed in the virtual world and can feel the experience, on the other hand, corporeality allows users to be represented by avatars that personify the user experience and persistence means that continues execution, even without being connected (Barráez-Herrera, 2022).

Both virtual reality and augmented reality are means for the development of metaverses with great potential to represent knowledge and display interaction processes with a greater degree of immersion and interactivity (Carrizo, 2021; Silva-Díaz et al., 2021). Virtual reality is defined as the creation of a synthetic virtual environment, whose initial purpose is to physically deceive each of the senses of the human body, changing its perception of being in reality to being in

the developed synthetic environment (Montoya & León, 2018). In contrast, augmented reality offers a direct or indirect perspective of a physical environment in the real world, where real elements are mixed with virtual elements to generate a combined reality (Lechtaler et al., 2015; Padilla et al., 2019). Thus, the main difference between virtual reality and augmented reality is that the first approach creates a completely virtual world without the need to insert virtual elements into real environments, as is the case with augmented reality (Aznar-Díaz et al., 2018). However, with the arrival of the metaverse in the classroom, the teacher must have a holistic and technological perspective since entering this world implies knowing, managing and designing classrooms in the virtual world (Mujica-Sequera, 2022; Suco et al., 2021). This implies that the student is incorporated into a simulated or artificial environment, in which the virtual environment is examined in the same way as it is presented in the real world (Ramos et al., 2019); stimulating their senses and motivating them to live an experience different from traditional education, encouraging their curiosity and creativity, favouring the understanding and assimilation of content in each subject (Olmos, 2022). However, the incorporation of these technological tools in educational institutions has generated difficulties for teachers facing considerable obstacles when trying to implement them due to their limited training and knowledge about the possibilities and effectiveness of these tools (Miguélez-Juan et al., 2019).

In accordance with what was stated above, it is necessary to modify the teacher must configure his traditional teaching scheme, since, in many cases, technological innovation requires this change (Araya-Moya et al., 2022); and so it is that, currently, the teacher is in need of integrating emerging technologies in learning since he offers more content options for redefining class time (Calle & Martínez, 2018; Gaviria-Rodríguez et al., 2019). In this reality of urgent change, more active didactic strategies and collaborative spaces arise that innovate the type of teacher-student interaction, such as the pedagogical model termed flipped classroom (Benites et al., 2021). The flipped classroom is presented as a valuable technique available, which requires teaching commitment, so its education, training and self-learning will set the tone for entering new learning models (Cedeño-Escobar & Viguera-Moreno, 2020). The flipped classroom requires integrating different digital applications so that students can access information favourably (Díaz & Díaz, 2021). In this way, it is implemented in a simple way and processed in a cooperative way that contributes to obtaining relevant and useful knowledge (Sánchez-Cruzado et al., 2019).

In this sense, the purpose of this study is to examine and present currents of study related to the integration of metaverses in the development of the flipped classroom, in university environments, using bibliometric analysis regarding academic works indexed in the Scopus database, between 2013 and 2023. Therefore, this study seeks to contribute to generating updated knowledge regarding the integration of the metaverse and flipped classrooms in university education, at the same time, which will allow the identification of gaps in the literature that can be addressed in future research. This will help inform the academic and educational community about the possibilities and challenges that

this combination offers. In this sense, the research questions (RQ) defined for this study are:

- RQ1: What is the scientific production and what types of manuscripts have been published regarding the inclusion of metaverses in the development of the flipped classroom in the university environment?
- RQ2: What are the most cited manuscripts regarding the inclusion of metaverses in the development of the flipped classroom in the university environment?
- RQ3: What are the sources with the largest number of publications regarding the inclusion of metaverses in the development of the flipped classroom in the university environment?
- RQ4: What words have the highest occurrence in the titles of the manuscripts regarding the inclusion of metaverses in the development of the flipped classroom in the university setting?
- RQ5: What words have the highest occurrence in the abstracts of the manuscripts regarding the inclusion of metaverses in the development of the flipped classroom in the university setting?
- RQ6: What are the thematic areas with the highest incidence that have been published regarding the inclusion of metaverses in the development of the flipped classroom in the university environment?

2. Literature review

Metaverses, also called MDV3D (3-Dimensional Virtual Digital Worlds), are three-dimensional virtual spaces mediated by computers and composed of real or proper symbols and icons (Bonales-Daimiel et al., 2022). They represent a virtual and online world in which different avatars interact, but which, unlike massive multiplayer games, do not have a competitive purpose based exclusively on a level system (Nieto, 2022). These avatars are configurable digital bodies that represent the materialisation of the users (Galea, 2023). Communication within the metaverse is considered as a socialisation network that allows interaction between users from anywhere in the world, with greater technological innovations, tools available to any user, and a greater variety of content (Menéndez-Aponte et al., 2023). However, for the construction of the metaverse, a series of base technologies are needed, these being virtual reality or augmented reality (Erazo & Sulbarán, 2022; Espinoza, 2022). It can be said that virtual reality is a technology that enables the user, through the use of viewers and other gadgets, to immerse themselves in three-dimensional scenarios, in the first person and in 360° (Maldonado et al., 2020); with the feeling of being immersed inside them and even being able to interact with the elements that compose them (Barragán-Perea, 2023; Sánchez et al., 2022). Augmented reality, on the other hand, refers to that technology that allows information from the virtual world, or virtual reality, to be incorporated into the real world (Bohmer, 2021).

The flipped classroom is an educational strategy that contributes to developing, among other things, of self-management skills, teamwork, and informational skills of students (Fernández & Gaytán, 2019). Its objective is to provide the student with an active role in relation to their own learning, leaving aside the

passive postures of reception and memorisation of information (Ocampo et al., 2021). The flipped classroom does not imply that a physical blended attendance is necessary with respect to classical teaching, which is sometimes misinterpreted as reducing contact hours by half; what is blended is the activity that the student develops outside and within the classroom (Jiménez-Serranía, 2022). Although the student is the main actor in their learning in the flipped classroom, the teacher is the guide, facilitator and above all planner of all the activities that are going to be used for the development of their skills (Espinoza & Robalino, 2022; Quinto-Román, 2022). In other words, the teacher must be flexible in his teaching strategies, be responsible for the material to promote the previous study of the students and their reflection about it, as well as promote a change in the role of the student towards a more active role (Arias & Mon, 2022; Ros & Laguna, 2021). To develop the flipped classroom, technological tools are used so that students, before class, can incorporate the topics that will later be developed in a more practical way in the face-to-face class (Verón et al., 2021); thus leaving more time for consultations, exchanges of opinions and learning by doing (Prieto et al. 2021).

3. Manuscript extraction method

The manuscript extraction method used in this bibliometric review study regarding the inclusion of metaverses in the development of flipped classrooms in the university setting is based on the method used and validated in Chamorro-Atalaya et al. (2023). This method used is an adaptation of the steps established in the PRISMA declaration (Preferred Reporting Items for Systematic reviews and Meta-Analyses). This extraction method encompasses the development of three phases. In the first phase, the subject of study is defined, as well as the scope with which the "identified manuscripts" will be determined. In the second phase, the inclusion and exclusion criteria will be applied with which the "manuscripts in projection" will be determined. Finally, in the third phase, the abstracts and content of each manuscript will be thoroughly reviewed, thus determining the "included manuscripts" for the analysis phase.

3.1 Phase 1: Definition of the subject of study, scope and identification of manuscripts

In relation to this first phase, we proceeded to define the subject under study and with it the keywords that were used to build the search equation for the manuscripts, in the Scopus database. Scopus was used due to the composition of the data it provides regarding the extracted manuscripts. In other words, it segments the bibliometric fields of each manuscript, facilitating the analysis. Other aspects that justify the selection of the Scopus database is that it stores different types of publications such as conference papers, review articles or scientific articles (Vaicondam et al., 2022); it also provides publications from a large number of scientific journals indexed to this database (Prahani et al., 2022, 2023). Table 1 shows the search equation used to extract the so-called "identified manuscripts". As a result of the implementation of this first phase, 127 manuscripts were identified.

Table 1: Search equation through Boolean indicators

Database	Search equation
Scopus	(TITLE-ABS-KEY (flipped AND classroom)) AND ((TITLE-ABS-KEY (metaverse) OR TITLE-ABS-KEY (virtual AND reality) OR TITLE-ABS-KEY (augmented AND reality)))

3.2 Phase 2: Manuscripts in projection

In relation to this second phase, the inclusion (IC) and exclusion criteria (EC) were applied to the 127 manuscripts identified in the previous phase. These criteria were defined with the purpose of reducing the bias present when using only the search equation. In other words, aspects such as whether the studies were carried out at the level of university education or at the primary or secondary level are relevant in order to have precise results regarding the subject under study. Another consideration that was taken into account for the construction of the IC and EC was whether the manuscript was open access, and, if the manuscript had not been accessed, the bias in the results would have been high. Having the possibility of downloading the entire content of the manuscript allowed a more in-depth review of its content and thus determining if there is a close relationship with the topic under study. Table 2 shows the inclusion and exclusion criteria in order to determine the manuscripts in projection. As a result of the implementation of this second phase, 88 manuscripts were identified.

Table 2: Criteria used to identify manuscripts

IC	EC
Manuscripts whose results are linked to the university environment	Manuscripts whose results are linked to the primary or secondary level of study of a school
Open access manuscripts	Manuscripts that do not have access to their content
Manuscripts published in the period of years between 2013 and 2023	Manuscripts published before the year 2013

3.3 Phase 3: Manuscripts included for the analysis stage

Finally, in the third phase, a review of the abstract as well as the content of the manuscript was carried out, thus establishing which manuscripts are closely related to the subject of study. Through this phase, it was possible to remove 32 manuscripts of the 88 manuscripts determined in the previous phase. Figure 1 shows the flowchart of the manuscript extraction method used, which specifies that there are 56 manuscripts finally included in the bibliometric review phase.

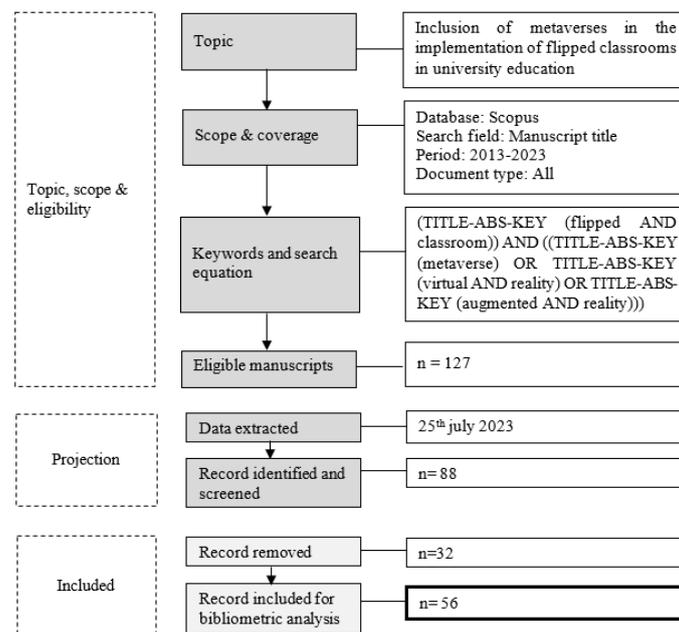


Figure 1: Flowchart of the method used for the extraction of manuscripts

4. Results

4.1 Scientific production and types of published manuscripts regarding the inclusion of metaverses in the development of the flipped classroom in the university environment

In relation to the scientific production of published manuscripts on the application of metaverses in the implementation of flipped classrooms in university education, it was identified that, in the period between 2013 and 2023, 56 manuscripts were published according to the Scopus database. Figure 2 shows that, between the years 2017 and 2023, the scientific production of manuscripts has had a permanent growth, that is, of the total number of manuscripts identified and included for this study, only six manuscripts were published between the years 2013 and 2016, representing 10.71% of the total scientific production. However, the manuscripts published from 2017 to date represent 89.29%. An important indicator to take into account is the average number of manuscripts published in the last ten years; in this study it was identified that the average is five manuscripts per year. Based on this average, it was possible to identify that the annual scientific production from 2020 to date exceeds the average. Here it is relevant to link these results with the context of the COVID-19 pandemic, in which the implementation of virtual class sessions was widespread, supported by the use of teaching strategies such as the flipped classroom. Likewise, in recent years, with the purpose of making these class sessions more immersive, artificial intelligence tools such as metaverses have been applied, which allow students to be taken to virtual learning environments in which they can have greater interaction with equipment, tools and supplies, consistent with the thematic content developed in a flipped class session.

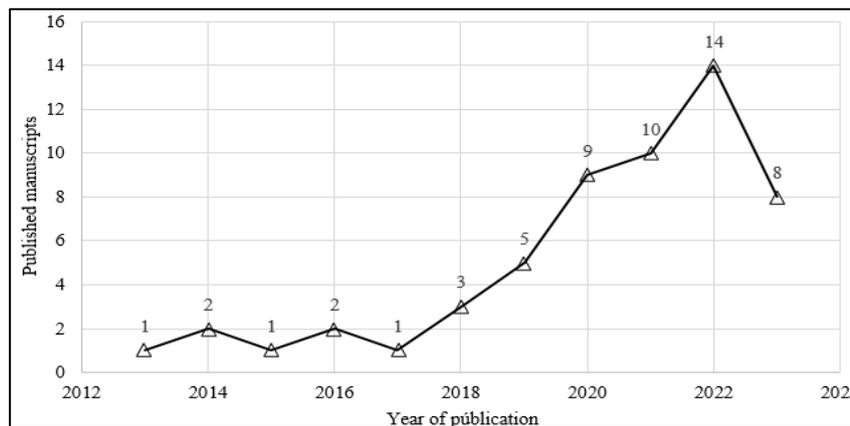


Figure 2: Production of manuscripts by year of publication

Likewise, in relation to the type of manuscripts published on the inclusion of metaverses in the development of the flipped classroom in university education, it was possible to identify four types, these being: "Review article", "Conference paper", "Book chapter" and "Scientific article". Of the 56 manuscripts chosen for the bibliometric review study three are review articles, 25 are conference papers, two are book chapters, and 26 are scientific articles. Figure 3 shows the percentage distribution of the types of manuscripts published in the Scopus database, during the period between 2013 and 2023, in which it can be seen that the types of manuscripts that have been published on the topic under study are, to a greater extent, scientific articles and conference papers.

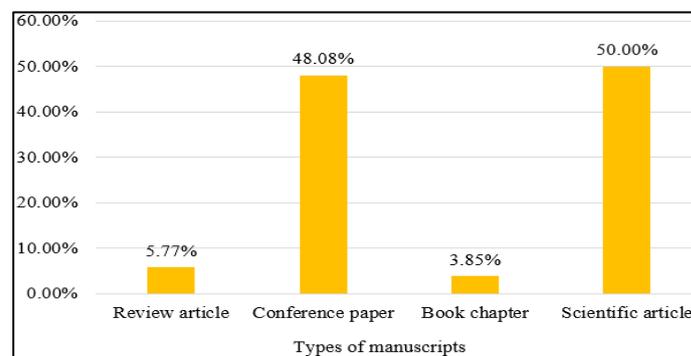


Figure 3: Percentage distribution by type of manuscript

4.2 Most cited manuscripts regarding the inclusion of metaverses in the development of the flipped classroom in the university environment

In relation to the most cited manuscripts, it is important to take into account the findings by Repiso and Moreno-Delgado (2020) who established that the citation is one of the main elements when establishing the repercussion of a research and, together with the scientific production, allows the study at an aggregate level of the knowledge generated by authors, journals and institutions. In this sense, and in accordance with what is shown in Table 3, of the 56 manuscripts included for this bibliometric review study, 23 were identified that were cited at least four times. The study with the highest number of citations is that developed by Ibañez and Delgado-Kloos (2018), titled "Augmented reality for

STEM learning: A systematic review” with 432 citations and an average annual citations per year of publication of 72. Also, in second place is identified the study developed by Guze (2015) entitled “Using technology to meet the challenges of medical education” with 158 citations and an average annual citation per year of publication of 17.56. Both mentioned manuscripts exceed one hundred citations. Likewise, it was identified that 19.64% of the total manuscripts analysed exceeded 10 citations. Table 3 shows all the manuscripts with more than four citations. As can be seen, the average number of citations per year is specified, with the highest average number of citations being 72 years while the manuscript with the lowest average of citations per year is that by Noor (2013), whose value is 0.36.

Table 3: Manuscripts with the highest number of citations

Reference	Total citations (TC)	Average citations per year
Ibáñez and Delgado-Kloos (2015)	432	72.00
Guze (2015)	158	17.56
Ferrer-Torregrosa et al. (2016)	86	10.75
Hsu (2018)	69	11.50
Liou (2016)	49	6.13
Sotgiu et al. (2020)	34	8.50
Teo et al. (2022)	33	16.50
Xiao-Dong and Hong-Hui (2020)	24	6.00
Shin et al. (2022)	18	9.00
Proskura and Lytvynova (2020)	14	3.50
Ji & Han (2019)	13	2.60
Mikułowski and Brzostek-Pawłowska (2020)	9	2.25
Huang et al. (2019)	8	1.60
Campos-Mesa et al. (2022)	7	3.50
Pozo-Sánchez et al. (2021)	7	2.33
Kalavally et al. (2014)	6	0.60
Im et al. (2019)	6	1.20
Hsu et al. (2017)	6	0.86
Lin et al. (2023)	5	5.00
Jiao et al. (2020)	5	1.67
Fidan et al. (2021)	4	1.33
Tang et al. (2021)	4	1.33
Noor (2013)	4	0.36

4.3 Sources with the largest number of publications regarding the inclusion of metaverses in the development of the flipped classroom in the university environment

In relation to the most relevant journals or sources linked to the largest number of publications regarding the inclusion of metaverses in the development of the flipped classroom in the university environment, it was identified that these sources are not strictly associated with scientific journals but also have records of conferences. Table 4 shows the first 10 sources with the highest number of publications indexed to Scopus, in which the journals "Lecture Notes in

Computer Science", "BMC Medical Education", "Computers and Education" and "IEEE Access" have two publications. Of these journals, the one with the highest H index is "Lecture Notes in Computer Science" whose H index is equal to 446, and, according to the Scimago 2022 ranking, it is located in quartile Q3. Likewise, the source with the largest number of conference papers is "ASEE Annual Conference and Exposition, Conference Proceedings" with two publications and whose H index is equal to 26. Although the H indexes of journals are relatively high, the number of publications on the subject of study in particular is quite low.

Table 4: Most relevant sources linked to the largest number of publications

Sources	Number of publications	H-index	Scimago SJR - Quartile 2022
Lecture Notes in Computer Science	2	446	Q3
ASEE Annual Conference and Exposition, Conference Proceedings	2	26	No quartile
BMC Medical Education	2	87	Q1
Computers and Education	2	215	Q1
IEEE Access	2	204	Q1
2023 11th International Conference on Information and Education Technology, ICIET 2023	1	No H-index	No quartile
29th International Conference on Computers in Education Conference, ICCE 2021 - Proceedings	1	No H-index	No quartile
Advances in Intelligent Systems and Computing	1	58	No quartile
American Society of Mechanical Engineers, Fluids Engineering Division (publication) FEDSM	1	27	No quartile
Anatomical Sciences Education	1	64	Q1

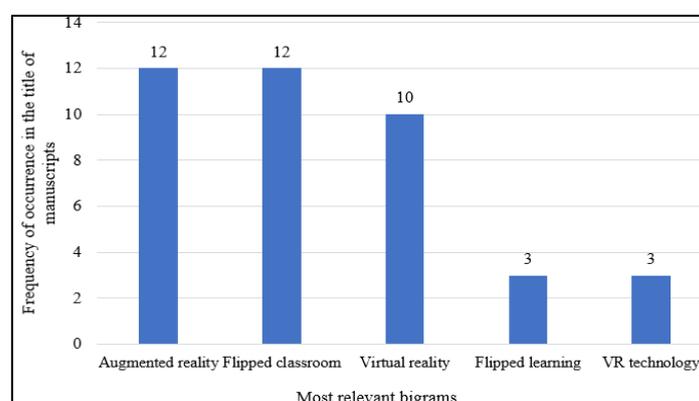
4.4 Words with the highest occurrence in the titles of the manuscripts on the inclusion of metaverses in the implementation of flipped classrooms in university education

In order to identify the words with the highest rate of occurrence in the titles of the 56 manuscripts included in this bibliometric review study, the Bibliometrix application was used. By this it was possible to identify that the words "flipped", "reality" and "learning" appear at least 20 times in the titles of the manuscripts. Likewise, when analysing the words that appear at least 10 times in the titles of the manuscripts, it was determined that these are "classroom", "education", "teaching", "virtual", "augmented" and "technology". Table 5 shows the words with the highest occurrence identified in the titles of the manuscripts; considering that the total number of these nine words add up to 146 occurrences, it was possible to obtain the percentage of frequency with which each of these words appears in the titles of the analysed manuscripts, thus determining that the word "flipped" presents a percentage of occurrence of 16.44%.

Table 5: Words with the highest occurrence identified in the titles of the manuscripts

Words	Occurrences	Percentage
Flipped	24	16.44%
Reality	22	15.07%
Learning	21	14.38%
Classroom	16	10.96%
Education	14	9.59%
Teaching	13	8.90%
Virtual	13	8.90%
Augmented	13	8.90%
Technology	10	6.85%

However, in order to achieve greater precision on the joint occurrence between one and another word shown in Table 5, the Bibliometrix application was configured to provide the bigrams or set formed by two words that frequently appear in the titles of the 56 manuscripts analysed. In this way, it was identified that these bigrams are "augmented reality", "flipped classroom", and "virtual reality". Thus, it was also determined that there are other words conceptually linked to those mentioned above but with a lower level of occurrence such as "flipped learning" and "VR technology". Figure 4 shows the occurrences of the bigrams, in which "flipped classroom" and "augmented reality" have a frequency of occurrence of 12, followed by the "virtual reality" bigram with 10 occurrences. These results help to understand the terms used by the authors to refer to the same Metaverse as is the case of "VR technology" and "virtual reality".

**Figure 4: Bigrams with the highest occurrence identified in the titles of the manuscripts**

Although the results shown above give an idea of how independently the words or grouping of two words that occur simultaneously (bigrams) are presented in the titles of the manuscripts, it is also important to know the relationship that exists between all the words that are present in the titles. Based on what is indicated in Figure 5, the co-occurrence network of the words contained in the manuscript titles is shown. Through this co-occurrence network, the words with the highest occurrence or repetition frequency are identified, the same ones that are represented by nodes or points, with the largest nodes being those with the

occurrences, it was possible to obtain the percentage of frequency with which each of these words appears in the abstracts, thus determining that the word "learning" presents a percentage of occurrence of 17.74%.

Table 6: Words with the highest occurrence identified in the abstracts of the manuscripts

Words	Occurrences	Percentage
Learning	207	17.74%
Students	160	13.71%
Teaching	132	11.31%
Flipped	119	10.20%
Classroom	95	8.14%
Education	87	7.46%
Reality	85	7.28%
Virtual	66	5.66%
Technology	57	4.88%
Online	55	4.71%
Augmented	52	4.46%
Study	52	4.46%

In addition, the occurrence of the search was analysed to identify which grouping formed by two words are presented simultaneously (bigrams) in the abstracts of the manuscripts, for which, through the Bibliometrix application, it was identified that the bigram with the highest occurrence is "flipped classroom" with 62 occurrences, followed by "augmented reality" with 46 occurrences and "virtual reality" with 36 occurrences. To a lesser extent, the bigrams "flipped classrooms" and "flipped learning" were identified, both with 18 occurrences. Figure 6 shows the bigrams with the highest occurrence identified in the abstracts of the 56 manuscripts included in this bibliometric review.

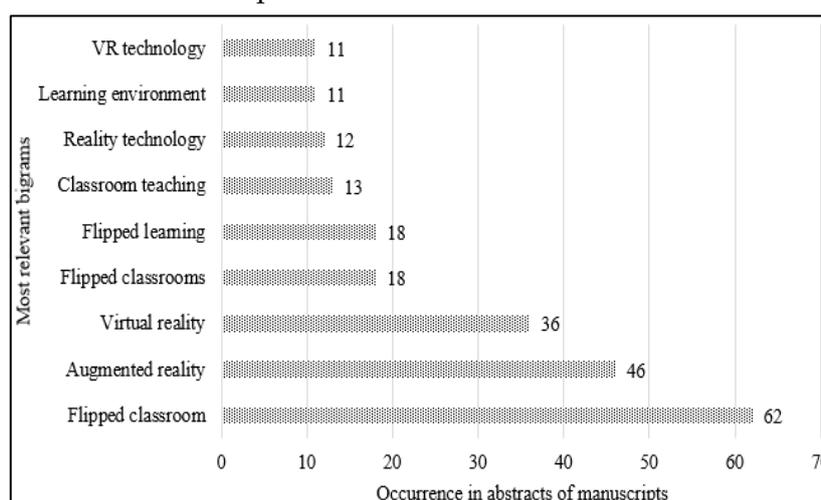


Figure 6: Bigrams with the highest occurrence identified in the abstracts of the manuscripts

Figure 7 shows the network of co-occurrences of the most relevant words of the "manuscript abstracts", which shows that of the 56 manuscripts analysed, the

words with the greatest link strength are made between the words "Flipped classroom", "Virtual reality" and "Augmented reality". This shows that, in the period in which this study is developed, there are publications that include metaverses such as virtual reality and augmented reality related to the development of flipped classroom learning strategies at the university level.

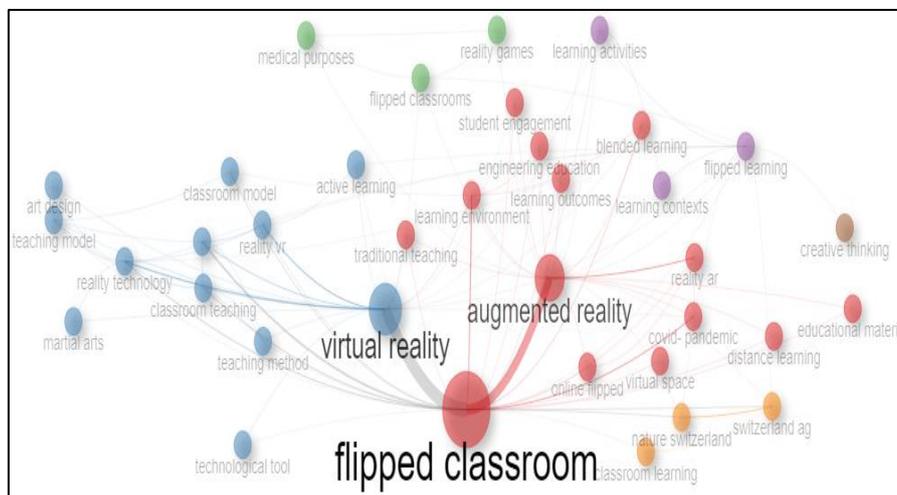


Figure 7: Network of co-occurrence of the most relevant words of the abstracts of the manuscripts

4.6 Thematic areas with the highest incidence that have been published regarding the inclusion of metaverses in the development of the flipped classroom in the university environment

For this specific point, the "thematic evolution" was previously analysed taking as reference the 56 manuscripts extracted from the Scopus database, from 2013 to 2023. Using the Bibliometrix application four quadrants were obtained made up of: "Emerging or declining topics", "Niche topics", "Basic topics" and "Motor Themes". In relation to the category of "Emerging or declining topics", it was identified that the topic associated with web-based technology is a topic that is not very developed and is emerging recently. On the other hand, in relation to the category "Niche topics", it was identified that topics such as active participation, learning tools and video conferences are topics with a low presence in terms of frequency among the reviewed manuscripts. In addition, in the category "Basic topics" topics such as augmented reality and flipped learning, flipped classroom, virtual reality and reality technology were identified with greater relevance and whose degree of development is high in the existing literature. Finally, in relation to the "Motor Themes" category, they are made up of the themes: Online flipped classrooms, educational technology and VR (virtual reality) technology. These last themes are those that have a high frequency of appearance and have received increasing attention in the literature over time.

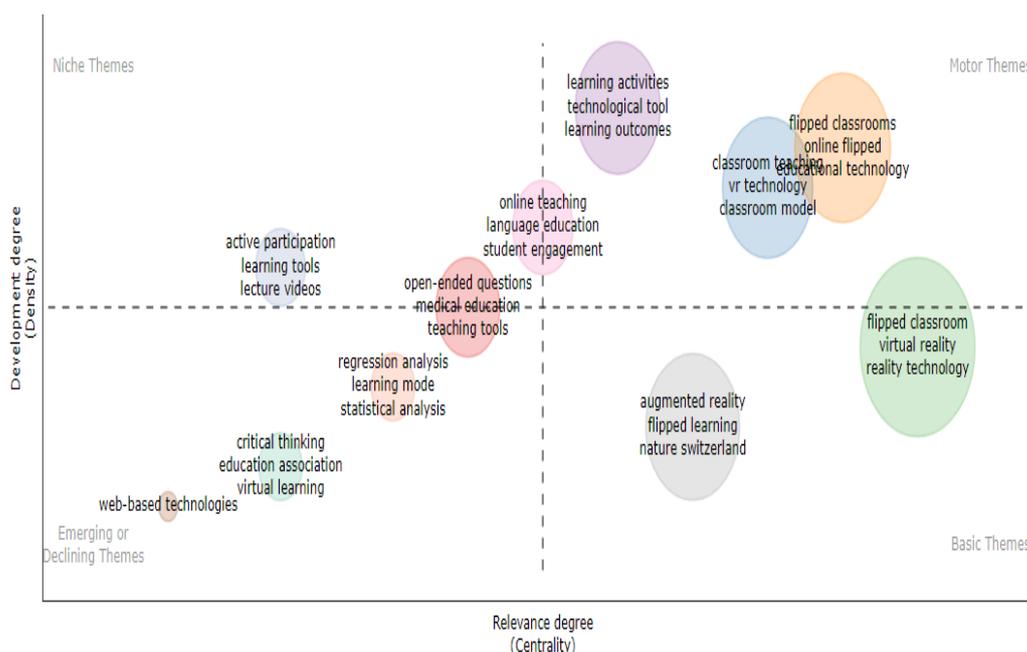


Figure 8: Categorisation of the thematic evolution regarding the inclusion of metaverses in the development of the flipped classroom

Based on what was indicated and reviewing the titles and abstracts of the manuscripts, it was possible to identify the fields of study with the greatest number of publications. In this way, it was determined which of the various types of technology are those by which metaverses can be developed to a greater extent; the reviewed publications make use of virtual reality, followed by augmented reality technology. In this way, when quantifying the number of manuscripts that make use of the various technologies for the design and construction of metaverses, it is found that of the 56 manuscripts reviewed, 30 manuscripts link in their studies "environments based on virtual reality in the development of the flipped classroom", while 21 manuscripts link in their studies "environments based on augmented reality in the development of the flipped classroom", and only five manuscripts make use of both technologies (augmented reality and virtual reality) in the development of the flipped classroom. Figure 9 shows the percentage distribution of the specific themes identified in the manuscripts analysed.

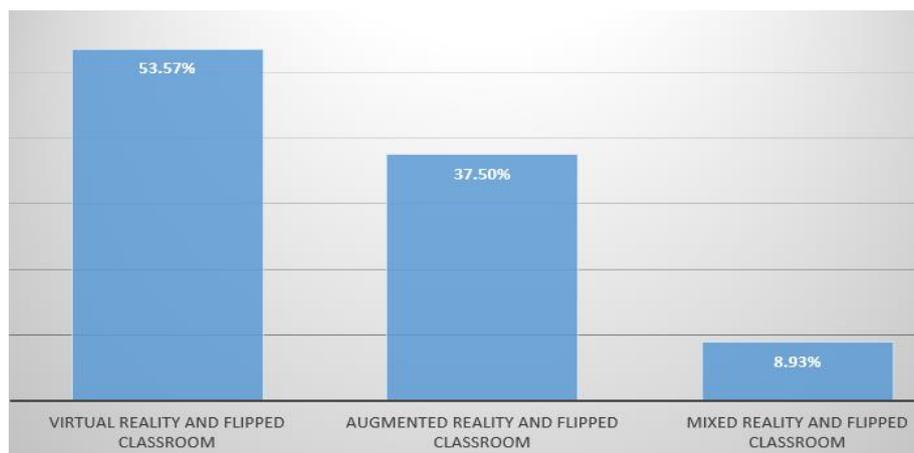


Figure 9: Percentage distribution of specific thematic areas developed in the manuscripts analysed

5. Discussion

In relation to the scientific production regarding the inclusion of metaverses in the development of the flipped classroom in the university environment, it was determined that, in recent years, particularly since the pandemic period, there has been a significant increase on this topic under study. The massification of virtual class sessions supported by simulation tools on account of social distancing due to COVID-19, has led us to represent a scenario in which many researchers seek to evaluate the contributions and difficulties that this type of modality of teaching generated in the learning of university students. Although working with simulators on a computer helped to give continuity to the teaching and learning process, they did not offer the student immersion. That is why, with the rise of virtual reality and augmented reality, it is intended that students be inserted into a world of experience very close to a real environment and thereby increase the ability of interactivity and student participation in the construction of their own learning. In this regard George-Reyes et al. (2023) indicate that learning processes must adapt to the new challenges of evolving educational environments, as has been evidenced in the context of the pandemic, where such environments may undergo transformations. Therefore, it is imperative to take advantage of the opportunities offered by technological trends, not only in emergency situations, but also to achieve a transformation that makes use of technologies such as metaverses as an essential component to achieve disruptive learning. In this way, with the massification of tools for the implementation of the metaverse, together with the possibility of incorporating them into the educational context, it raises the urgency of examining the accessible scientific research and publications in the educational field, in order to build a comprehensive analysis of the state of the currently available art (López-Belmonte et al. 2023).

Thus, it was also identified that the most cited manuscript regarding the inclusion of metaverses in the development of the flipped classroom in the university environment is the study developed by Ibañez and Delgado-Kloos (2018) entitled "Augmented reality for STEM learning: A systematic review" with 432 citations and with an average of 72 annual citations per year of

publication and having the sources with the largest number of publications, "Lecture Notes in Computer Science", "BMC Medical Education", "Computers and Education" and "IEEE Access" contain and "ASEE Annual Conference and Exposition, Conference Proceedings" all of them with two posts. This result is evidence that not many research papers have been published regarding the inclusion of metaverses in the development of the flipped classroom, which is why it represents an area in which researchers can explore, develop, investigate and contribute to its implementation in the different university educational institutions establishing the necessary conditions for its implementation. In this regard, Avila and Tapia' (2020) systematic review study concluded that, according to the analysis of a selected sample, the flipped classroom methodology currently has a low rate of scientific contributions, likewise, it presents few publications in databases' scientific data. On the other hand Gea (2021) specified that virtual reality is currently understood as a gamified educational resource in the field of educational technology, and whose application at different levels of education confirms the growing interest of the academic community to analyse in depth the specific impact of virtual reality in education.

In addition, in relation to which are the words with the highest occurrence in the titles of the manuscripts analysed regarding the inclusion of metaverses in the development of the flipped classroom in the university environment, it was possible to identify that these words are "flipped", "reality" and "learning" with a frequency of occurrence of 20 times. While, when carrying out the same analysis, seeking to identify the words with the highest occurrence in the abstracts of the manuscripts, it was possible to identify that these words are "learning", "students", "teaching" and "flipped" which appear at least 119 times in the abstracts of the manuscripts. Here it is denoted that of these 56 manuscripts analysed, the authors focus their main attention on linking flipped learning with virtual reality and augmented reality technology, the purpose of which is to improve the indicators present in the teaching and learning process. This is evidenced in the subsequent analysis that was carried out regarding the exploration of the frequency of occurrence of bigrams present in the titles and abstracts of the manuscripts, identifying that these are "flipped classroom", "virtual reality" and "augmented reality". In this regard, Anacona et al. (2019) established that the emphasis on virtual reality applied to teaching is adapting technologies such as the flipped classroom where it has a high quality of pedagogical potential, strengthening the way of education of educators towards their students. Likewise, Larreategui et al. (2021) point out that most of the research concludes that the implementation of the flipped classroom improves student learning, strengthens autonomy, encourages collaborative work, self-regulates learning and improves academic performance, so teachers must place their bets on new methodologies.

Finally, related to the most prominent thematic fields that have been addressed in research regarding the inclusion of metaverses in the development of the flipped classroom in the university environment, it was determined that, to a greater extent, these focus on the inclusion of virtual reality in the flipped

classroom. In addition, another specific thematic area identified is the inclusion of augmented reality in the development of the flipped classroom. While to a lesser extent, manuscripts that mention both technologies were identified. In relation to those indicated by Chamorro-Atalaya et al. (2023), different technologies used in the design of metaverses for their use in university education were identified, in which it was determined that there is a considerable inclination towards research focused on the application of virtual reality, unlike other technologies such as augmented reality and lifelogging, which are used to a lesser extent. Highlighting the importance of these technologies in the implementation of metaverses, Rodríguez (2020) concluded that the increased steps of technology are managing to maximise motivation in different fields of education by creating digital environments based on virtual reality and augmented reality.

6. Conclusion

In relation to the results obtained from the research questions defined in this bibliometric review study, several important conclusions can be drawn that show the evolution of studies linked to the integration of metaverses in the development of the flipped classroom in the university setting. First of all, a constant growth is observed in the production of scientific manuscripts in this field of study from 2017 to date. This increase becomes even more evident when compared to previous years, where production was significantly lower. This suggests that the use of metaverses in the context of flipped teaching has gained relevance and attention in recent years, the increase in which seems to be influenced by the pandemic scenario that accelerated the adoption of virtual class sessions and innovative practices of teaching strategies. Therefore, the implementation of artificial intelligence tools, such as metaverses, has allowed the creation of more immersive and participatory educational experiences, taking students to virtual environments that enrich their learning and participation; however, it is important to highlight that, despite the increase in scientific production, research in this field of study is still at an early stage. Finally, it is concluded that the predominant thematic areas focus specifically on the use of virtual reality and augmented reality as key elements for the design and construction of metaverses, combining them with gamification techniques, which, in their integration, give rise to the development of the classrooms as inverted and immersive. At the same time, a lack in scientific research has been determined regarding the following thematic areas: "Success factors that show the contribution of the metaverse in the development of flipped classrooms", and "Guidelines and good practices for the effective integration of metaverses in the flipped classroom".

7. Limitations

This study focused on bibliometric analysis on publications indexed only in the Scopus database, excluding other relevant databases such as ERIC, SAGE or IEEE Xplore. Furthermore, metaverse applications in the flipped classroom in the field of primary or secondary education were not taken into account. Therefore, future studies could delve deeper into these fields of research in order to continue contributing to closing the gaps on the state of the art in the entire

educational field without limiting themselves only to the university field, and considering databases other than Scopus.

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