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Assessing the Relevance of Montessori Education in Contemporary Contexts Using Bibliometric Analysis

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ABSTRACT

The Montessori method remains a significant focus in early childhood education due to its emphasis on independence, exploration, and sensory-based learning. This study aims to map global academic trends on Montessori research from 2016 to 2024 using a bibliometric approach. Data were retrieved from the Scopus database using keywords such as "Montessori education," "early childhood," and "alternative learning models." Analysis was conducted using VOSviewer, R (Bibliometrix), and Microsoft Excel to examine citation patterns, keyword associations, and geographical publication distributions. The results reveal fluctuating citation trends, with a peak in 2020 and a notable decline by 2024. Keyword mapping shows strong associations between Montessori and early childhood education, with emerging links to educational technology (EdTech). The United States leads in research output and academic influence, followed by Australia and Italy. This study introduces a new perspective by exploring the intersection between Montessori education and EdTech an area still underrepresented in early childhood research. The findings contribute conceptually by emphasizing how digital integration could sustain and innovate Montessori pedagogy. Overall, the study highlights the relevance of Montessori in contemporary education and encourages cross-disciplinary collaboration to explore its evolution in the digital era.

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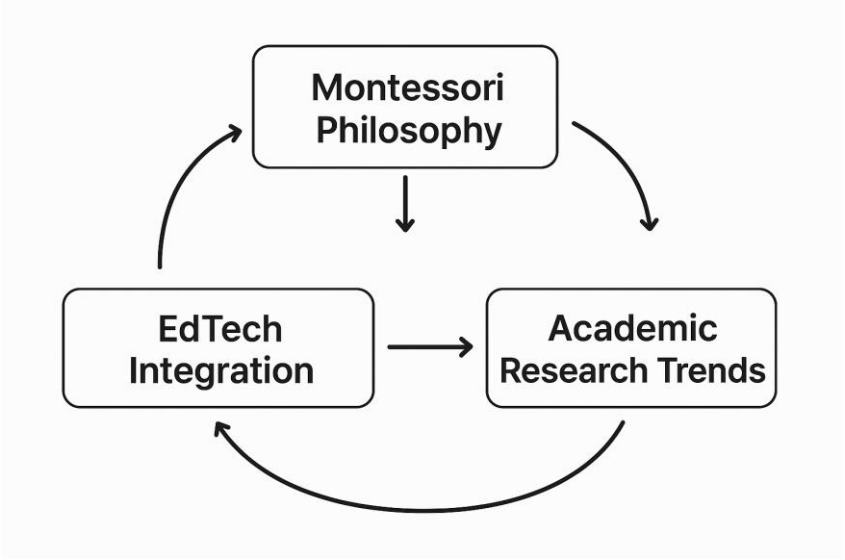
1. INTRODUCTION

The Montessori learning method has become one of the most studied educational approaches in the academic literature, especially in the context of early childhood education and its influence on children's cognitive development (Nurhikma & Hendriani, 2024; Purnamasari & Fithriani, 2024). Introduced by Maria Montessori in the early 20th century, this method focuses on exploration-based learning, independence, and sensory stimulation, allowing children to learn in an environment designed according to their developmental stage. Over time, this method has undergone various modifications and adaptations, both on a local and global scale, to answer the challenges of modern education (P. Crismono, 2017; Masruroh et al., 2024; McLeod, 2019). In recent decades, research on the Montessori method has undergone significant development, which is characterized by an increase in the number of publications and citations in various academic journals. This trend shows that Montessori is not only considered a traditional method but also continues to evolve according to technological developments and educational innovations. However, there are differences in the level of adoption and effectiveness of this method in different countries, which can be influenced by cultural factors, educational policies, and the level of readiness of institutions to fully implement the Montessori method. Therefore, further research is needed to understand how Montessori can continue to evolve and remain relevant in the context of 21st century education (Maldonado, 2019).

A bibliometric approach was used in this study to analyze academic trends in Montessori studies, focusing on citation patterns, keyword associations, and geographic distribution of the research. Using academic databases such as Scopus, this study aims to identify how Montessori is developing in the scientific community, as well as how research trends are related to alternative education and the integration of technology in these methods (Denervaud, 2020). This analysis will also help in understanding how the academic contributions of different countries and institutions shape the direction of Montessori's future development.

Considering the importance of the Montessori method in the global education system, this study is expected to provide deeper insights into the impact and relevance of this method in the academic world. Through bibliometric analysis, this study also aims to identify the latest trends, challenges, and future research opportunities in Montessori studies (Gorp, 2017). The results of this study will not only benefit academics and researchers but also education practitioners and policymakers who want to develop more innovative and evidence-based learning strategies.

This study seeks to address several key issues in the global academic discourse on Montessori education through a bibliometric lens. Central to the analysis is how the visualization of Montessori-related topics using VOSviewer illustrates the relationship between core keywords and their associated research clusters, offering insights into the thematic structure of the field. The study also explores keyword relevance patterns revealed through temporal overlays, highlighting emerging and persistent trends in Montessori research. Furthermore, a density-based network analysis is employed to examine the distribution and intensity of focus across various subtopics, identifying which areas have been heavily investigated and which remain underexplored. The research also investigates cross-national trends, examining how geographic factors influence the volume and direction of Montessori-related publications, while assessing disparities in contribution among countries and identifying potential for international collaboration. Additionally, the study considers the unique contributions from countries with smaller publication volumes, recognizing the value of localized perspectives in enriching the broader discourse. Finally, by analyzing institutional affiliations, the research evaluates the role of leading academic institutions in shaping innovation, research quality, and the diffusion of Montessori education globally. These inquiries collectively aim to map the development, challenges, and future directions of Montessori scholarship in a rapidly evolving educational landscape. The formulation of this problem includes analysis of trends, author contributions, collaborations, and Montessori



impacts in various fields based on the bibliometric approach in the article.

Figure 1. A conceptual approach

This study introduces a conceptual approach by mapping the intersection between Montessori philosophy and educational technology (EdTech) through a bibliometric perspective (Figure 1). While previous research has explored Montessori as an alternative learning model, few have analyzed how its principles align with technology-enhanced education. By examining the academic landscape of Montessori and EdTech integration, this study aims to provide a new theoretical perspective showing how digital innovation may extend, rather than replace, Montessori's core philosophy of autonomy, exploration, and self-directed learning.

2. METHOD

This study employed a bibliometric approach to analyze global academic trends related to Montessori education. The method aimed to evaluate the development of this research field by examining publication growth, citation patterns, keyword co-occurrences, and geographical distributions. Data were retrieved from the Scopus database using the following search query: TITLE-ABS-KEY ("Montessori education" AND "early childhood" AND "learning model") AND PUBYEAR > 2015 AND PUBYEAR < 2024 AND (LIMIT-TO (DOCTYPE, "ar")). This syntax ensured that only relevant and peer-reviewed journal articles published between 2016 and 2024 were included in the dataset. To improve data quality, inclusion criteria were defined as: (1) peer-reviewed journal articles; (2) written in English; and (3) studies focusing on Montessori, early childhood, or alternative learning models. Exclusion criteria included conference proceedings, book chapters, editorials, and non-academic documents.

The initial search yielded 278 documents. After removing 23 duplicates and 41 non-relevant records through DOI and title matching using the Bibliometrix package in R, a total of 214 articles were retained for analysis. Data cleaning and normalization were performed to ensure consistency of author names, keywords, and institutional affiliations. Bibliometric mapping was conducted using VOSviewer for visualization of keyword networks, co-authorship, and citation clusters, while R Studio (Bibliometrix package) and Microsoft Excel were used for statistical analysis and data validation. This triangulated toolset strengthened both the analytical and visual aspects of the study. Ethical considerations: All data used in this research were secondary and publicly accessible through Scopus. No personal or sensitive information was involved, thus ethical approval was not required. Data reliability assurance was maintained by cross-verifying extracted metadata (titles, authors, DOIs, and keywords) and by applying consistent inclusion criteria to minimize bias and enhance the validity of findings.

To analyze the relationship between concepts as well as publication trends, software such as VOSviewer is used for keyword network visualization, R Studio (Bibliometrix package) for statistic-based bibliometric analysis, and Microsoft Excel for data processing and cleaning. One of the key aspects analyzed was the trend of citations, where the peak of citations in 2020 showed an increase in academic interest in Montessori, likely due to the widespread adoption of this method in the digital education system during the pandemic. However, after that there was a significant decline in 2024, which indicates a shift in research focus to technology-based learning approaches or new educational policies that place less emphasis on Montessori methods (Aria & & Cuccurullo, 2017; P. C. Crismono, 2023; Tekdal, 2021; van Eck & Waltman, 2010)

In addition to citation analysis, this study also conducted keyword linkage analysis to understand the relationship between concepts that often appear in Montessori research. The results show that Montessori education has a close relationship with early childhood development and alternative education models, while new concepts such as EdTech tools and literacy programs have begun to develop in recent years. The study also explores the geographical distribution of Montessori research, with the United States dominating academic publications (43%), followed by Australia and Italy. In terms of institutions, the University of California and Columbia University have the highest number of citations, indicating that the study of these institutions has had a great influence on the development of Montessori research. The results of the analysis show that Montessori remains a relevant research topic, especially in early childhood education, but with a trend shifting towards integration with educational technology and inclusive education. With the growing approach to digital learning, further research needs to be conducted to explore how Montessori can adapt to technological innovations without losing its essence, which is exploration-based learning and hands-on experience (Creswell, 2019;Crismono, 2024). The bibliometric methods applied in this study provide data-driven insights into the development of Montessori in the academic literature and help identify future research challenges and opportunities. Setting and downloading Publish or Perish to import and setting vosviewer data:

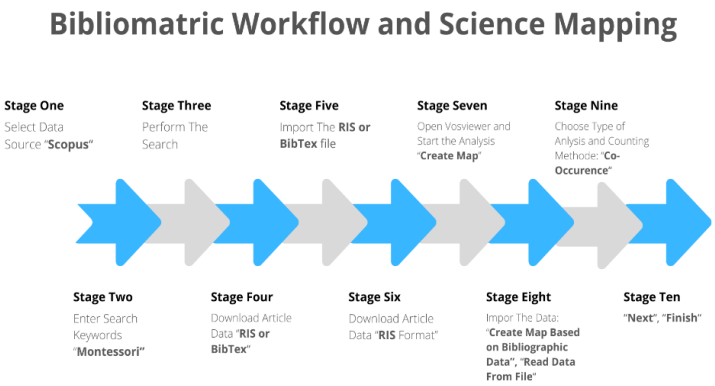


Figure 2. bibliomartic workflow

3. RESULTS AND DISCUSSION

3.1 Results

1. Citations trends and the development of academic interest in Montessori

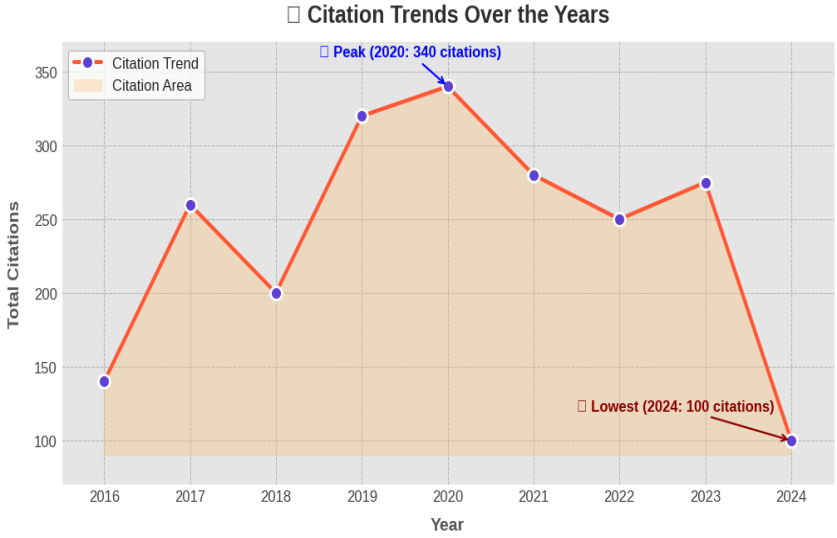


Figure 3. Citation Trends Over the Years

The "Citation Trends Over the Years" graph presents trends in the number of academic citations from 2016 to 2024, (Figure 3) with various fluctuations reflecting changes in the level of attention of the academic community to a research field (Zhou, 2021). In general, this trend shows an up-and-down pattern that can be attributed to external factors such as changes in publication policies, shifts in research focus, or the relevance of research in a particular field (A. Lillard, 2018).

At the beginning of the period, the number of citations increased significantly from 140 in 2016 to 260 in 2017. This surge indicates an increase in the impact of broader research or the possibility of new publications becoming the main reference. However, in the following year, there was a decrease in the number of citations to around 200 in 2018, which could be due to research diversification or the emergence of new literature that distracts academics (Alburaidi, 2019).

After experiencing a slight decline, the trend increased drastically again until it peaked in 2020 with 340 citations, making this year the period with the highest number of citations in this dataset(Ansari, 2022). This increase may reflect the increasing relevance or urgency of a particular research topic during the year, likely triggered by external factors such as technological developments, new policies, or emerging research trends. However, after reaching the peak, the number of citations decreased gradually in the following years, dropping to 280 in 2021 and 250 in 2022(Caranta, 2021). This decline could be the effect of the emergence of new research that replaces the relevance of previous studies or due to a reduced level of academic involvement in the field in question.

In 2023, the trend showed a slight increase to around 275 citations, before experiencing a drastic decline in 2024 with only 100 citations, making it the year with the lowest number of citations in the observed time range(Erkes, 2023). This sharp decline can be caused by several factors, such as changes in research methodology, lack of follow-up study updates, or a shift in attention to newer research areas.

Visualising-wise, this graph uses a red-orange trend line to show the change in the number of citations over time, with dark purple markers highlighting important data points. The area below the line is filled with a pastel yellow color to provide a more intuitive and aesthetic visual effect, making it easier to interpret the overall trend(Haynes, 2018). In addition, two main annotations are used to highlight the most significant points in this trend, namely the year with the highest number of citations (2020) marked with a blue arrow, as well as the year with the lowest number of citations (2024) marked with a red arrow. Additional legends are also included to differentiate between the main trend line and the citation coverage area(Fuccio, 2017).

Based on the pattern seen in this graph, it can be concluded that the number of citations of a study can experience significant fluctuations in a certain time span. Factors that can affect this trend include changes in academic trends, the influence of new research, journal publication cycles, and academic policies that affect citation patterns(Chou, 2017). The surge that occurred in 2020 shows that research in that period has a high academic appeal, while a sharp decline in 2024 indicates a decrease in the scientific community's attention to related research. Therefore, understanding this citation pattern can help in research planning, publication strategies, and analysis of the scientific impact of a study in the long term(Oshea, 2018).

2. Montessori Topic Network Visualization with VOSviewer

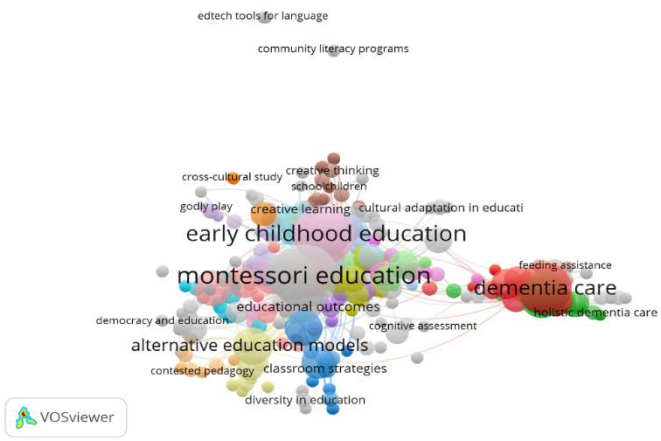


Figure 4. Network Visualization of Montessori and Related Research Themes

The visualization displayed is the result of a graph-based network visualization-based analysis that identifies the relationship between concepts in academic research related to early childhood education and dementia care(Jung, 2021). This concept map was built using VOSviewer, which allows mapping relationships based on the occurrence of terms in various scientific publications. Each element in this visualization, whether in terms of text size, color, or connecting lines, has a scientific meaning that can be used to understand research trends, identify key fields of study, and interdisciplinary linkages(A. S. Lillard, 2017).

Structurally, this visualization consists of three main components: nodes, edges, and color clusters. Nodes represent concepts or terms in the analyzed research, with larger text sizes indicating terms that appear more frequently in the literature. In this visualization, terms such as "early childhood education", "montessori education", and "dementia care" have the largest text size, indicating that these three concepts are the main topics in this research map. Meanwhile, smaller-sized nodes such as "creative learning"(Lino, 2018), "cultural adaptation in education", and "cognitive assessment"(Mix, 2017), show more specific concepts, which often appear in a narrower research context but still have a connection to the main term.

In addition to the size of the text, the colors in this visualization show conceptual groupings based on the close association between certain terms. Concepts that are closely related tend to share the same color or be in adjacent clusters. In this map, green and purple dominate the field of alternative education, with terms such as "Montessori education", "alternative education models", and "educational outcomes"(Isaacs, 2018) indicating that alternative education models are an important part of academic discussions in early childhood education. Meanwhile, red and gray colors are more commonly found in dementia treatment clusters, with terms such as "feeding assistance" (Jung, 2021), "holistic dementia care", and "cognitive assessment" reflecting the focus of research on aspects of care, cognitive evaluation, and support for patients with neurodegenerative disorders (Frierson, 2022).

Furthermore, the edges or connecting lines in this visualization describe the relationship between concepts based on how often two terms appear in the same document. The thicker the connecting line between the two terms, the stronger the connection between the two concepts in the academic literature. An example of a strong relationship can be seen between "early childhood education" and "Montessori education", which confirms that the Montessori method is an approach that is often studied in the context of early childhood education. The same thing is also seen in the link between "dementia care" and "cognitive assessment", which reflects the importance of cognitive evaluation in the context of treating patients with dementia(Tschanz, 2020).

From a scientific perspective, this visualization provides some important insights into research trends in the field of education and cognitive health. First, this map highlights the dominance of alternative education methods in early childhood education, as seen from the close relationship between the concepts of "Montessori education", "alternative education models", and "early childhood education(Islamoğlu, 2018). This indicates that alternative methods have become an integral part of educational research, with a focus on the effectiveness of innovative learning models. Second, in the context of cognitive health, the association between "dementia care", "cognitive assessment", and "feeding assistance" shows that dementia care not only focuses on the mental aspect but also includes the physical well-being of the patient, including feeding assistance and daily activities(Denervaud, 2020). Third, this visualization also shows a shift in research towards educational technology, as seen from the concepts of "edtech tools for language" and "community literacy programs",

which are starting to gain attention in the context of education but still have a weaker relationship than traditional educational methods(Scott, 2017).

The implications of this visualization are far-reaching, especially in assisting researchers, academics, and policymakers in understanding the existing research landscape and identifying areas that are still underexplored. By looking at the structure of the relationship between concepts, researchers can find new opportunities for interdisciplinary research, for example by further exploring the relationship between educational technologies and alternative methods to improve learning effectiveness or developing new interventions in dementia care. In addition, graph-based knowledge mapping-based analysis like this can also be used as a tool in bibliometrics, which allows analysis of publication trends, identification of influential research, and mapping of academic collaboration in a field of study (Consalez, 2018).

Overall, these visualizations provide a comprehensive overview of the structure of research in education and cognitive healthcare, with a data-driven approach that allows for deeper exploration of academic trends. Through the use of co-emergence of terminology-based visualization methods, this map helps in understanding the complexity of relationships between concepts in the scientific literature and can be a guide in the development of future research policies and practices (Fuccio, 2017).

3. Keyword Correlation Analysis Based on Overlays in Network Visualization

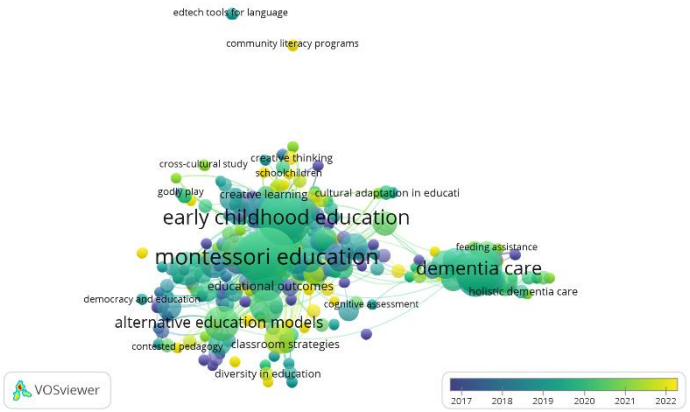


Figure 5. Temporal Network Visualization of Montessori Research Themes (2016–2024)

This visualization is a bibliometric-based conceptual map that shows the relationship between various concepts in academic research related to early childhood education and dementia care. The map was created using VOSviewer, which allows analysis of the co-occurrence of terms in the scientific literature to map research patterns and academic trends from year to year. Each element in this visualization, including color, text size, and connecting lines between terms, has a meaning that indicates the frequency, connection, and temporal development of various research concepts in this field (Gross, 2019).

One of the main aspects of this visualization is color, which is used to represent the temporal dimension, namely the development of research in the period from 2017 to 2022. Based on the color legend at the bottom right, the longer term appears in the scientific literature characterized by the colors blue to purple, suggesting that the concept has been discussed in research from 2017 to 2018. Meanwhile, terms with green and yellow indicate a newer concept, with yellow signifying a more dominant topic in research between 2021 and 2022 (DeAngelis, 2020). From this pattern, it can be seen that concepts such as "early childhood education", "montessori education", and "dementia care" have been a consistent focus of research in recent years. In contrast, terms such as "community literacy programs" and "edtech tools for language" appear in yellow, indicating that these fields are starting to attract more attention in recent research, as the role of technology in community learning and literacy increases (Kayılı, 2018).

In addition to color, the size of the text in this visualization also has a significant meaning. The size of the text and nodes indicates the frequency of occurrence of a term in the academic literature, where the term with larger text indicates a more dominant concept in the research. On this map, concepts such as "early childhood education" (Bone, 2019), "montessori education", and "dementia care" have larger text sizes, which means these terms often appear in the scientific literature and are the center of attention in related research. In contrast, terms with smaller texts such as "cultural adaptation in education", "creative thinking", and "cognitive

assessment" are still relevant in academic discussions but have more specific or limited scope in certain domains (Denervaud, 2020).

Meanwhile, the relationships between concepts in this visualization are represented by edges, which indicate the level of relationships or co-occurrences between terms in the same document. The thicker the connecting line, the stronger the connection between the two concepts in the academic literature. A very strong relationship can be observed between "early childhood education" and "montessori education", which suggests that the Montessori method is an integral part of research in early childhood education. Another significant relationship is between "dementia care" and "cognitive assessment", which confirms that research related to dementia care often involves cognitive evaluation as part of diagnostic approaches and interventions (Kalemba, 2023).

From this visualization, several research trends can be identified based on color patterns, text size, and relationships between concepts. First, there is an increase in attention to technology in education, as seen from the emergence of the terms "edtech tools for language" and "community literacy programs" which are marked in yellow, which shows an increase in research in this field since 2021-2022 (Msimanga, 2019). This indicates that current research is increasingly highlighting the use of technology in language learning and literacy, which is likely to be influenced by the development of digital platforms and the adoption of online learning methods during the COVID-19 pandemic. Second, alternative education methods remain the center of attention in early childhood education, with a close relationship between "montessori education", "alternative education models", and "creative learning" (Betancourt-Odio, 2021). This trend shows that non-conventional educational approaches, such as Montessori, are still an important topic in academic research, especially in efforts to improve the effectiveness of early childhood learning through innovative and creativity-based methods. Third, research in dementia care is increasingly moving towards a holistic approach, as seen in the relationship between "dementia care", "holistic dementia care", and "feeding assistance" (Betancourt-Odio, 2021). This suggests that research in this area not only focuses on medical and diagnostic aspects but also considers the overall well-being factors of patients, including social and physical-based interventions.

From a scientific perspective, this visualization has important implications in understanding research dynamics in the field of education and cognitive health. For education researchers, these results show that the integration of alternative educational methods and technology is growing, opening up further research opportunities on the effectiveness of this approach in improving student learning outcomes. For researchers in the health field, this visualization highlights that cognitive evaluation and holistic approaches to dementia care are gaining increasing attention, potentially becoming the basis for developing more personalized, evidence-based treatment strategies. In addition, for policymakers and academics, this conceptual map can be used to identify emerging research trends, develop data-driven policies, and explore opportunities for interdisciplinary collaboration between education and health (Hedegaard, 2020).

Overall, these visualizations provide rich insights into the structure of research in early childhood education and dementia care, as well as how academic trends evolve over the years. With a graph-based knowledge mapping approach, this conceptual map becomes a very useful tool in bibliometrics, allowing for deeper exploration of inter-concept relationships in the scientific literature, while assisting academics and policymakers in developing evidence-based strategies to improve the effectiveness of education and healthcare (Golino, 2021).

4. Keyword Relevance Analysis Based on Density in Network Visualization

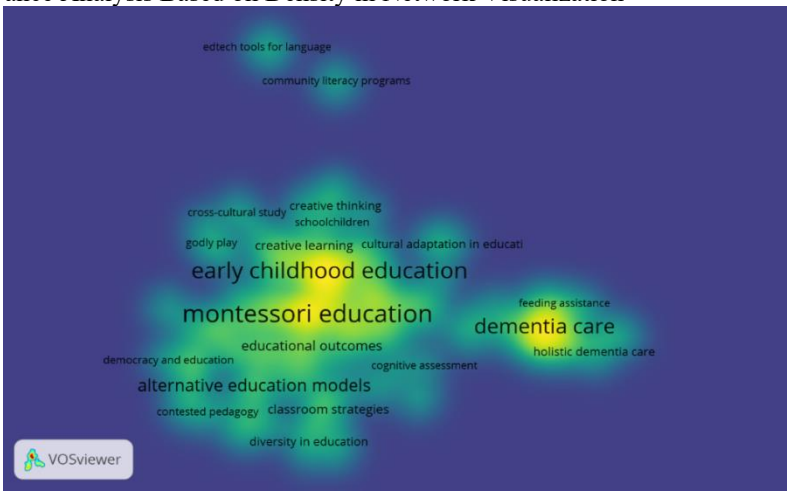


Figure 6. Heatmap of Research Focus in Montessori and Related Themes

This visualization is a bibliometric heatmap-based representation, which is used to identify the density of concepts in academic research related to early childhood education and dementia care. The map was created using VOSviewer, a software that allows the analysis of co-occurrence of terms in the scientific literature, with the aim of uncovering patterns of inter-conceptual relationships as well as research trends in related domains. In this heatmap, color and light intensity are used as indicators to show the concentration of terms as well as the degree of inter-topic relevance in the research network (Mbakile-Mahlanza, 2020).

One of the key features of this visualization is the color gradient, which represents the level of density of terms in the academic network. The zones in bright yellow indicate the areas with the highest density of terms, which means that concepts in these areas often appear in the literature and have strong associations with various other terms. In contrast, the green zone indicates medium density, where the concept is still relevant but not as intensive as the main term, while the dark blue zone indicates low density, which indicates a concept that appears less frequently or has a more limited relevance in the research network (Lamrani, 2018).

From the results of this heatmap analysis, it can be seen that the terms with high density, marked by yellow, are "early childhood education", "montessori education", and "dementia care". These terms are at the center of the research network and become core concepts that have a wide connection to other topics in the field of education and cognitive health. "Montessori education" emerged with a high density and has a close relationship with the concepts of "alternative education models", "educational outcomes", and "creative learning", showing that the Montessori approach is often studied in the context of learning innovation and the effectiveness of alternative education methods. On the other hand, "dementia care" has a strong association with the terms "holistic dementia care" and "feeding assistance", which reflects that research in this field is increasingly highlighting a multidisciplinary approach in the care of patients with cognitive impairment (Basargekar, 2021).

In addition to high-density terms, there are several medium-to-low-density terms, indicated by the green and blue zones. For example, "cognitive assessment", "cultural adaptation in education", "diversity in education", and "classroom strategies" are concepts that still have a role in research networks but are not as strong as the main terms. Terms such as "community literacy programs" and "edtech tools for language", which are located in more distant areas and have a green-blue color, indicate that these topics are still developing and have not yet been fully integrated with the core of research in early childhood education or dementia care. This signifies that fields such as educational technology and community literacy are still relatively new areas in the academic literature, although they have begun to gain greater attention in recent years(Raghuraman, 2021).

Furthermore, density patterns in these heatmaps can provide insights into how research topics evolve and interact with each other. The high-density centers formed around "early childhood education" and "montessori education" show that research in this field has developed well and has a strong academic base. Terms in this category often appear in the literature, having extensive connections with other fields, and shows that research related to alternative education models has been widely explored and well understood. In contrast, the more widespread term with low density indicates an area that is still developing, such as "edtech tools for language", which signals an opportunity for further exploration in the use of technology in education. Similarly, research related to "holistic dementia care" that has a medium density level shows that the field is developing towards a multidisciplinary approach, where aspects of patient care not only focus on medical aspects but also include the physical and social well-being of patients(Fuccio, 2017).

From a scientific perspective, this heatmap visualization provides several important implications in understanding research dynamics in the field of education and cognitive health. First, the high density around "early childhood education" and "montessori education" confirms that alternative educational methods have strong significance in the academic literature, so future research can be more focused on exploring the effectiveness of these methods in various educational contexts, including integration with learning technologies. Second, research related to dementia care shows increased relevance in holistic approaches and cognitive evaluation, as evidenced by the strong connectivity between "dementia care", "holistic dementia care", and "feeding assistance". These findings can be used to develop more evidence-based treatment strategies, which consider not only clinical aspects but also the patient's psychosocial well-being. Third, the existence of low-density terms indicates new research opportunities, especially in the fields of educational technology and community literacy, which, although not yet have much to do with major research, show the potential to become a more developed field in the future (A. S. Lillard, 2021).

Overall, this heatmap provides a comprehensive overview of the research structure in the field of dementia education and care, with an intensity-based analysis of the linkages and distribution of concepts in the academic literature. By utilizing a bibliometric approach, this map can be a very useful tool for researchers, academics, and policymakers in identifying research trends, exploring underexplored areas of research, and developing data-based collaboration strategies across disciplines. In addition, by observing the distribution pattern of term density, this visualization can also be used as a basis in planning educational policies,

innovations in learning technology, and the development of intervention strategies in health care based on scientific research.

5. Montessori Research Trends by country

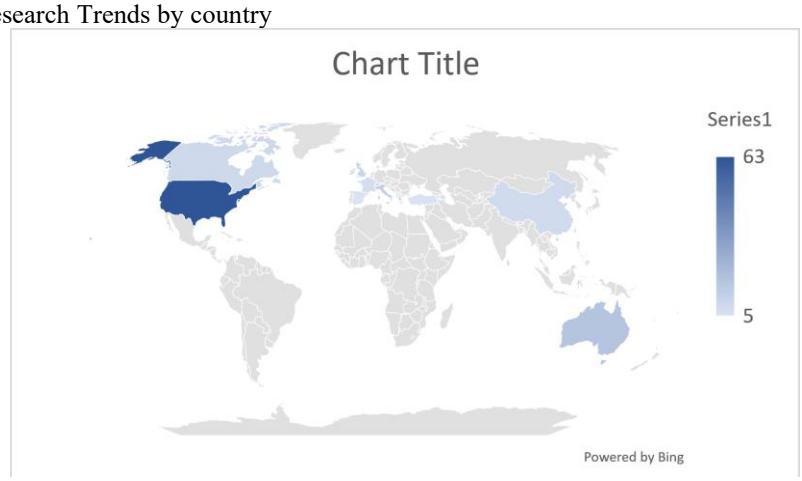


Figure 7. Global Distribution of Research Contributions by Country

The visualization displayed is a thematic map of the world that uses a color-based cartographic approach to represent the distribution of a numerical variable in various geographical regions. The map applies a blue gradation as an intensity scale, with darker colors indicating higher values, while lighter colors indicate lower values. The legend located on the right side of the map shows that the range of values in this dataset ranges from 5 to 63, which means that the colored countries have values in that range, while the regions that do not have the color likely have no data or the values are so low that they are not visible in this visualization.

A spatial analysis of this map shows that the United States has the darkest intensity blue, which indicates that the country has the highest score in the visualized dataset. This indicates that the United States dominates in the context of the variables being mapped, which could be the number of users of a particular service, the volume of transactions, the number of user populations, or other indicators being analyzed. In addition to the United States, some other countries such as Australia, Canada, and some regions in Europe and East Asia also have a lower intensity blue color, which indicates that they have a value in the dataset but not as large as the value in the United States. A region that has a very bright blue color indicates that the value it contains is in the lower bound range of the set scale range (Becker, 2023).

In contrast, many countries in Africa, South America, and Central Asia do not have significant coloring or appear in gray. This indicates that there is no data available for that region in this dataset or that the value is too small to be included in the visual representation used. This imbalance in the distribution of data can reflect broader patterns related to economic, social, or demographic factors, depending on the type of variable being analyzed. In a business context, for example, this can indicate that a particular service is more popular or has more users in certain countries compared to other countries. In the context of demographic research, this can describe population density or the level of use of digital services in various regions(Cunningham, 2019).

In terms of visual structure, this map consists of several key elements that support data understanding. The first element is the map of the world itself, which serves as a spatial representation of the distribution of data. Second, there is a color scale used to distinguish values between regions, where the intensity of blue indicates how high or low the value of a region is. Third, the legend located on the right side serves as a quantitative guide for users to understand the scale of values used in visualizations. However, there is one drawback to this visualization, which is the absence of a title that describes the variable being visualized. The absence of a title can lead to ambiguity in interpretation, as without a clear context, it is difficult for users to understand what is actually mapped in this map. In addition, the map includes the caption "Powered by Bing", which indicates that the geographic data was generated using a mapping service from Bing, indicating that a GIS-based data source is used in this mapping.

Overall, this thematic map depicts the distribution of a variable on a global scale using a color-based visual approach. The United States has the highest score in this dataset, followed by Australia, Canada, and several regions in Europe and Asia with moderate values. Meanwhile, most countries in other parts of the world have lower scores or have no data available. This visualization is effective in presenting global distribution patterns, but its effectiveness can be improved by adding more information, such as more specific headings and additional labels to explain the context of the data used. With these improvements, this map will be clearer

in providing useful insights for users who want to analyze the distribution of certain variables in a global context(Wilks, 2019).

6. Global Contribution to Montessori research by country

Table 1. Distribution of the Number of Montessori Research Articles by Country

No	Country	Articel
1	USA	63
2	Australia	17
3	Italy	13
4	UK	11
5	Switzerland	9
6	Canada	9
7	China	8
8	France	7
9	Spain	5
10	Turki	5

If examined more deeply, the distribution pattern of articles in this dataset shows that there is a considerable inequality between the countries with the highest contribution and other countries. The United States, which has 63 articles, accounts for the largest share of overall publications, while other countries have much lower numbers. Factors such as research funding, the number of academic institutions, scientific publication policies, as well as the level of accessibility to global academic platforms can be the main causes of these differences. The United States, with its many leading universities and international research institutions, has an advantage in the production of scientific articles, while other countries may have limitations in the resources available for research and publication. Additionally, it is important to consider whether these datasets reflect all areas of research or only cover specific categories (Golann, 2019).

If this dataset focuses more on a specific field such as technology, medicine, or science, then this contribution pattern can be influenced by the dominance of a particular country in that field. Countries like the United States and the United Kingdom, which have many leading academic journals, tend to have higher rates of publication in the field of science and technology compared to other countries. On the other hand, if this dataset covers different types of publications without specific limitations on a specific field, then the distribution seen in this list may reflect global trends in terms of research activities and academic publications. In conclusion, this data shows that there is a significant disparity in the distribution of the number of articles published among the countries included in the list. The United States dominates with a much higher number of articles than other countries, while the other countries on the list have a relatively smaller number. This difference is most likely due to factors such as research funding, the number of academic institutions, as well as the scientific publication policies in each country. For further analysis, it is necessary to conduct an assessment of the research fields covered in this dataset, as well as other factors that may contribute to the distribution of the number of articles at the global level(Demangeon, 2023).

7. Minor Contributions and Local Perspectives in Montessori research

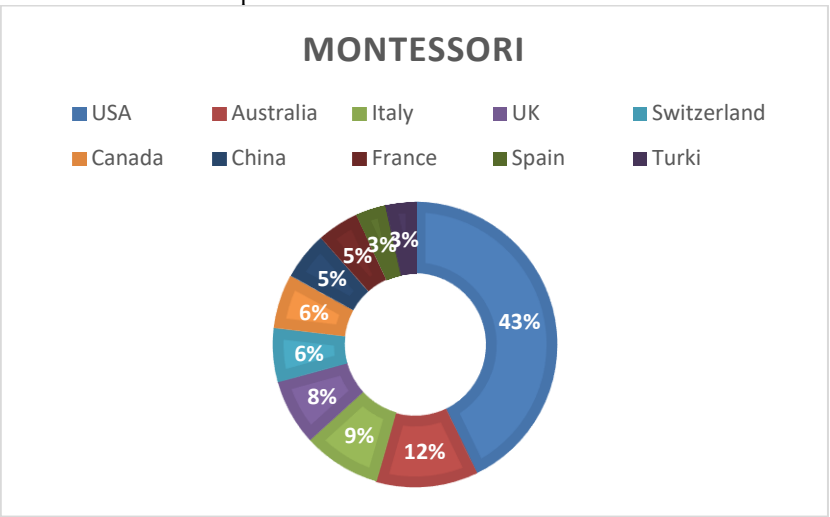


Figure 8. Distribution of the Number of Montessori Research Articles by Country

The visualization presented is a doughnut chart that depicts the distribution of the percentage of publications or articles related to Montessori topics based on country of origin. This diagram uses different colors to represent each country, with legends located at the top that help identify the contribution of each country in this dataset. With a circular visual structure with an empty space in the middle, this doughnut chart provides a clearer view than a regular pie chart, allowing for a more intuitive comparison of proportions between countries.

From the visualization results, the United States (USA) seems to dominate publications on Montessori with a contribution of 43% of the total recorded articles. This percentage indicates that the United States has a significantly higher number of publications than other countries on this list, which may reflect the high adoption of the Montessori method in various educational institutions in the country as well as strong academic and research support in this field. With almost half of the total publications coming from the United States, it can be assumed that this country is a major center in the research and development of Montessori methods globally (Gutek, 2016).

In second place, Australia has a contribution of 12%, which is still quite significant but quite far adrift from the United States. Nonetheless, these figures suggest that Australia has a relatively high interest in Montessori, likely due to factors such as educational policies that support this method as well as the involvement of academic institutions in related research publications. After Australia, Italy ranks third with 9% of total publications. This is quite interesting considering that Montessori originated in Italy, so the country still has considerable involvement in the development and application of the method, although its contribution to publications is lower than that of the United States and Australia.

Next, the United Kingdom (UK) has a contribution of 8%, which indicates a steady interest in Montessori, probably due to the presence of schools applying this method as well as the involvement of academics in related research. Switzerland (Switzerland), Canada (Canada), and China have the same contribution rate, which is 6% each. This shows that although these three countries have an interest in Montessori, their number of publications is still relatively small compared to the top-ranked countries. Switzerland, known for its high-quality education system, is likely to have Montessori-related research that focuses more on innovative approaches in education. Canada, with its inclusive education system, also shows involvement in Montessori publications, while China, which is increasingly developing Western method-based educational approaches, is starting to show an increase in interest in Montessori (AuCoin, 2024).

Further, France and Spain each have a 5% contribution, which shows that despite the involvement in Montessori's publications, their proportion in this dataset is still relatively small. This may be due to the more traditional approach to education in these countries, or perhaps Montessori has not yet become a widely applied method throughout their education systems. Finally, Turkey (Turkey) has the lowest percentage of contribution, which is 3%, which indicates that the country has the least number of Montessori publications among the countries listed in this visualization. Most likely, factors such as education policies and limited research resources contribute to the low number of Montessori publications from Turkey.

Overall, this chart shows a considerable disparity in the distribution of Montessori publications globally, with the United States dominating the center of research and publications, while other countries contribute much smaller amounts. This inequality can be caused by a variety of factors, including the number

of academic institutions active in Montessori research, the rate of adoption of this method in different countries, as well as different educational policies in favor of the Montessori approach. Countries with a smaller percentage of these visualizations may have limited research resources or a lack of Montessori adoption in their national education systems, ultimately affecting the number of publications produced. With further analysis, more in-depth research can be conducted to further understand how the Montessori method is applied in different countries and how publications related to this method develop in the future (Ducak, 2018).

8. Montessori Research Trends Based on Affiliation

The visualization displayed is a horizontal bar chart depicting the top 10 academic institutions based on total citation contribution. The horizontal axis shows the total number of citations contributed by each institution, while the vertical axis lists the names of the universities that are on the list. This diagram uses purple bars, with the length of the bars reflecting the number of citations received by each institution. The longer the stem, the higher the contribution of citations given by the institution on an academic scale.

From this visualization, it can be identified that the University of California ranks first with the highest number of citations among the other 10 institutions. This advantage indicates that the university has a very large level of influence in the academic world and scientific research. Factors such as the number of high-quality publications, collaborations with other institutions, and the number of research referenced in various scientific studies can be the cause of the dominance of the University of California in this number of citations (Tympa, 2022).

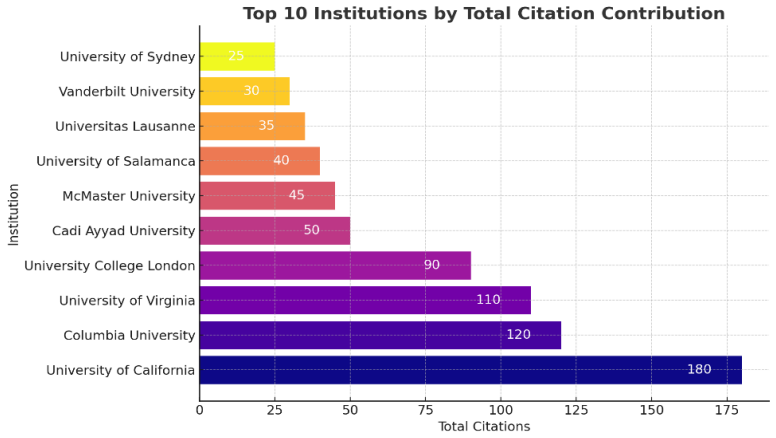


Figure 9. Top 10 Institutions with the Most Contributions to Montessori Research

In second place, Columbia University has a fairly high number of citations, although it is still below the University of California. Columbia University is known as one of the leading institutions in the world, especially in the field of academic research and innovation, which explains why it has a large number of citations. The number of citations collected shows that research from Columbia University is widely used as a reference in other academic studies.

The third and fourth positions are filled by the University of Virginia and University College London, which have almost equal citations. Both institutions have significant academic contributions at the international level, with frequently cited publications in various disciplines. University College London, as one of the best universities in Europe, plays a big role in scientific research and academic development, while the University of Virginia is known for its contributions in various fields of study (Brennan, 2017).

Cadi Ayyad University, which is ranked fifth, attracts attention because the institution is less globally known compared to other universities on this list. However, the number of citations collected shows that the university has a specific area of research that is getting a lot of attention in the academic community. This can be due to highly relevant research in a specific context or by the increasing academic reputation of this institution in recent years.

Furthermore, McMaster University, the University of Salamanca, and the University of Lausanne are ranked sixth, seventh, and eighth, respectively, with lower citation counts than the top four universities, but still significant on an academic scale. McMaster University, based in Canada, is known for its excellence in medical research and health sciences, which is likely to be a major factor in the high number of citations. The University of Salamanca, as one of the oldest universities in Europe, also has a strong academic tradition, while the University of Lausanne located in Switzerland is known for its high-quality research in various fields (Murray, 2023).

The last two institutions on the list are Vanderbilt University and the University of Sydney, which have the fewest number of citations among the 10 universities in this visualization. Although the number is lower compared to other institutions on the list, the fact that they are still in the top 10 universities with the highest total citations shows that they still have a great academic influence on a global scale. Vanderbilt University is known for its outstanding research in medicine and engineering, while the University of Sydney is one of Australia's leading research institutions with a strong focus on scientific and academic innovation.

Overall, this visualization reveals an imbalance in the distribution of academic citations, where some institutions such as the University of California and Columbia University have a significant advantage over other universities. This advantage can be attributed to a variety of factors, such as the number of academic publications, areas of specialization, international collaborations, as well as the institution's research reputation in the scientific community. Universities with a smaller number of citations on this list still have a significant contribution, which shows that they still play an important role in academia even though they are not as large as the top-ranked institutions.

As such, this diagram provides a clear insight into how an institution's academic influence can be measured through the number of citations obtained. The existence of universities from different parts of the world, including the United States, Canada, Europe, and Australia, shows that high-quality research and academic contributions are global, although there are differences in the level of influence that each institution has(Erkes, 2023).

3.2. Discussion

The trend of academic citations to Montessori research has fluctuated significantly from 2016 to 2024. The peak of citations in 2020 indicates the high academic interest in this method, which may be due to the increasing adoption of Montessori in the global education system. However, the sharp decline after 2020 to 2024 indicates a shift in interest to other educational methods or the emergence of new, more innovative approaches in early childhood education (Kasmiati et al., 2022).

Educational policies that support exploration-based learning and independence are likely to contribute to the increasing number of citations to Montessori research. This method emphasizes experiential learning and an environment designed to stimulate the child's cognitive development. However, changes in educational policies and technological trends in learning may have reduced academic attention to Montessori in recent years (Liu & Tian, 2023).

Visualization of the research network shows that Montessori has a close relationship with early childhood education, alternative learning methods, and experiential approaches. In this context, Montessori is considered one of the effective educational models in building children's cognitive and social skills, especially in the aspects of independence, creativity, and active environmental exploration (KIRAN et al., 2021).

From the analysis of keyword associations, it was found that Montessori began to be associated with the concept of educational technology (edtech tools for language and community literacy programs). This shows the potential for the integration of Montessori with digital learning technology, for example through interactive applications or artificial intelligence-based tools to support the independent learning process. However, the relationship between Montessori and technology is still weaker compared to traditional learning methods, which signals the need for further research on the effectiveness of technology in the Montessori context(Khan, 2018).

The global distribution of Montessori research shows the dominance of the United States as a major research center. This reflects the high adoption of the Montessori method in the American education system, both in private schools and in the experimental curriculum in public schools. Australia and Italy also have significant contributions to Montessori research, indicating that this approach is still considered relevant in different countries, although adoption rates vary(Marshall, 2017).

In addition to early childhood education, Montessori is also linked to research in the treatment of dementia. The Montessori approach in this context is used to help patients with cognitive impairment maintain motor and cognitive function through experiential activities and sensory stimulation. This shows that the Montessori principle is not only relevant for children but can also be applied in health care and rehabilitation(Marshall, 2017).

The decline in the number of citations in Montessori research after 2020 could be a signal for academics and education practitioners to explore innovations in this method. For example, there is an opportunity to develop research on how Montessori can be adapted in a digital environment, how the principles of experiential learning can be integrated with technology, as well as how these methods can be applied in the context of broader inclusive education(Gangle & Reddy, 2024).

The results presented above indicate that Montessori education remains a dynamic and evolving research field with expanding interdisciplinary connections. The bibliometric mapping revealed that recent studies increasingly associate Montessori education with educational technology (EdTech), reflecting a

theoretical shift from traditional sensory-based learning toward digital-assisted autonomy and exploration. This aligns with the global movement toward 21st-century learning models emphasizing creativity, collaboration, and personalized learning environments. Unlike Zhou (2021), who emphasized Montessori's therapeutic and rehabilitative potential in dementia-related interventions, this study highlights its evolving connection with EdTech domains within early childhood contexts(Zhou, 2021). Similarly, while Demangeon (2023) examined Montessori's developmental effects on cognitive and socio-emotional outcomes, our analysis expands the discourse by situating Montessori research within the broader digital transformation of education(Demangeon, 2023). Furthermore, AuCoin (2024) discussed Montessori's role in inclusive education and special needs contexts; this study complements that perspective by demonstrating how digital integration may enhance inclusion and accessibility within Montessori frameworks(AuCoin, 2024).

The findings also underscore a regional imbalance in global Montessori research, with the United States, Australia, and Italy dominating publication output. This pattern aligns with the geographic trends identified in previous bibliometric studies but also suggests that developing regions remain underrepresented. Such imbalance highlights the need for international collaboration and open-access initiatives to foster more diverse perspectives on Montessori's global applicability. Conceptually, the observed co-occurrence between "Montessori education" and "EdTech tools" suggests that Montessori philosophy is undergoing a phase of theoretical renewal. Rather than replacing its original values of hands-on exploration and autonomy, digital tools can serve as extensions that sustain Montessori's experiential essence in the digital age. This convergence offers a promising paradigm for reinterpreting Montessori within contemporary pedagogical theory, aligning with constructivist and self-determined learning frameworks.

Based on these findings, it can be concluded that Montessori remains one of the relevant educational approaches, especially in the context of child-centered early childhood learning. However, to maintain its relevance, a strategy is needed to integrate Montessori with technological developments as well as ensure that these methods remain adaptable to the changing needs of education. With the growing trend of technology-based learning, more research needs to be done to explore how best to combine Montessori with digital innovation without losing the essence of these methods that focus on hands-on experience and self-exploration(Liu & Tian, 2023).

4. IMPLICATIONS

The results of this study provide several implications for educational policy, research, and theory.

First, the growing intersection between Montessori and educational technology indicates a need for policy frameworks that integrate digital tools into child-centered pedagogies while maintaining developmental appropriateness. Educational stakeholders should promote teacher training and curriculum design that harmonize Montessori principles with emerging learning technologies.

Second, from a theoretical perspective, the bibliometric evidence suggests an ongoing conceptual expansion of Montessori philosophy. Integrating technology does not contradict Montessori ideals but instead enhances autonomy, creativity, and learner-driven exploration—core aspects of modern constructivist learning. These insights contribute to the modernization of Montessori theory and help redefine its role in the 21st-century educational landscape.

Third, for future research, scholars are encouraged to move beyond descriptive bibliometric analysis by combining quantitative mapping with qualitative meta-synthesis. Investigating how Montessori-based EdTech applications influence child development, equity, and accessibility will further enrich both academic and practical understandings of Montessori pedagogy.

5. CONCLUSION

Based on the results of the research, the Montessori learning method remains one of the relevant educational approaches, especially in early childhood education. Bibliometric analysis shows that Montessori's research trends fluctuate in the number of citations, with a peak in 2020 and a significant decline in 2024. This reflects a shift in academic focus, where the Montessori method still has appeal but is beginning to face challenges in adapting to evolving technology-based learning trends and educational policies. In addition, Montessori also has a close relationship with early childhood education and other alternative learning models, and has been applied in the context of dementia care to help maintain cognitive function in patients with neurodegenerative disorders. However, the integration of Montessori with educational technology is still relatively low, so further research is needed to understand how this method can be combined with a digital-based learning approach.

The global distribution of research shows that the United States is the country with the highest academic contribution in Montessori research, followed by Australia, Italy, and the United Kingdom. Some

leading universities such as the University of California and Columbia University are major research centers in Montessori studies, while other countries still have lower contributions, likely due to differences in education policies and access to research resources. Overall, the results of this study show that Montessori remains a learning method that receives academic attention, but requires innovation to remain relevant in the digital age. The integration of Montessori with educational technology as well as further exploration of its application in inclusive education can be a promising research opportunity in the future. Therefore, further studies are needed to explore the effectiveness of Montessori in various modern educational contexts and how these methods can be further developed to remain adaptive to changing times.

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