

Scientometric Mapping of the Flipped Classroom in Dental Education: Geospatial Dynamics, Emergent Patterns, and Networking

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ABSTRACT

Aim: To perform a scientometric mapping of the flipped classroom (FC) in dental education through an analysis of geospatial dynamics, emerging patterns, and collaborative networks.

Materials and methods: A comprehensive search of the Web of Science database (Core Collection) was conducted on September 1, 2024, using specific terms related to innovative teaching methodologies and dental education. Articles published between January 2005 and September 2024, indexed in Web of Science, and published in English were included. The collected data included article title, authors, year of publication, journal, keywords, and number of citations. Data analysis was conducted using CiteSpace and Bibliometrix to identify publication patterns, emerging trends, and collaborative networks.

Results: Between 2005 and 2024, 306 documents from 94 sources were analyzed, with an annual growth rate of 20.2%. The average age of the documents was 6.19 years, with an average of 12.47 citations per document and 7,469 references. In total, 701 authors' keywords were identified. A total of 1,183 authors participated, of whom 19 published single-authored papers, resulting in 20 single-authored papers. The average number of coauthors per paper was 4.39, with 18.63% international coauthorships. The main clusters identified were "Flipped Classroom," "COVID-19," and "Curriculum Reform." The years 2019 and 2020 contained the highest number of co-citations, highlighting authors such as Gianoni-Capenakas and Iyer. The three-dimensional structure of the landscape view graph revealed densely connected areas, indicating consolidated research themes.

Conclusion: The results of this study have demonstrated a significant evolution in educational methodologies in dentistry, with an increasing focus on the FC and other educational technologies. The high concentration of publications in key journals and the predominance of authors with a single publication underline the importance of fostering collaborative networks and the dissemination of innovative practices. These findings require alignment with the conclusion mentioned in the main manuscript, as the overall conclusion is very broad and needs to be more specific to reflect the detailed results of the study.

Clinical significance: This study mapping the FC in dental education is clinically significant because it has a chance to influence the very nature of teaching methodologies. The study treats geospatial dynamics, emerging patterns, and collaborative networks and has highlighted the further incursion of innovative educational practices. The findings show that continued research and collaboration are needed to further optimize and develop these methodologies for the benefit of both educators and learners in the field of dentistry.

Keywords: Dental education, Dental training, Flipped classroom, Scientometrics.

The Journal of Contemporary Dental Practice (2024): 10.5005/jp-journals-10024-3800

INTRODUCTION

The flipped classroom (FC) approach is considered a particularly suitable methodology for health professionals because it addresses academic performance from different perspectives compared to traditional teaching methods. However, its effectiveness can be increased by implementing a questionnaire at the beginning of each session.¹ The determining factor is not the style of classroom instruction but the number of opportunities offered for the development of students' individual learning processes. Therefore, the use of this teaching system is crucial for the learning outcomes as a whole.²

First, he highlights how tutorials facilitate students' application of knowledge in real clinical settings, which is crucial for their professional development and competence. In addition, it highlights how academic training is more engaging and inspiring for students, which can lead to better learning outcomes and increased motivation. These points are significant because they provide evidence that innovative teaching methods, such as tutorials, can

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How to cite this article: Espinoza-Carhuancho F, Taquia-Faustino A, Quispe-Tasayco L, *et al.* Scientometric Mapping of the Flipped Classroom in Dental Education: Geospatial Dynamics, Emergent Patterns, and Networking. *J Contemp Dent Pract* 2024;25(12):1172–1178.

Source of support: Nil

Conflict of interest: None

improve both practical skills and the overall educational experience of dental students.³ The FC strategy in a tele-simulation course demonstrated better student comprehension and greater efficiency in questionnaire problem-solving. The management of medical emergencies in dental clinics can be learned remotely using Zoom, which is a suitable FC tele-simulation platform for dentists.⁴

The positive attitudes of the students toward the inverted class evidenced the applicability and necessity of this methodology in health science education. A favorable attitude toward e-learning and the generational characteristics of the students was observed.⁵ However, the combination of a physical classroom with virtual courses represents a new teaching modality for dental training, expanding the concept of learning by integrating the inverted classroom with practical experience.⁶

The FC model facilitated the development of problem-solving and critical thinking skills during the time allotted in class.⁷ In addition, formative evaluation of students and dental schools suggests that continuing education has a significant and positive effect on student learning.⁸ The FC model allowed students to view pre-recorded lectures prior to each class, which encouraged more interactive activities, such as group work, discussions, and problem-solving, providing a more personalized knowledge experience.⁹ The well-structured traditional and FC learning methodologies provide immediate knowledge after the application of the learning methods.¹⁰ Unlike the theoretical classroom, which only involves interaction between teacher and student, the FC enhances both individual performance and group interaction, achieving a better mastery of dental knowledge.¹¹ In conclusion, the inverted classroom experience provided dental students with positive experiences.¹²

This study addresses several gaps in the existing research on the FC in dental education. Although FC has been shown to improve academic performance and student engagement, there is a lack of studies exploring its specific impact on clinical competence and its effectiveness in different educational settings. Furthermore, this study adds unique value to the literature by using scientometric mapping to analyze geospatial dynamics, emerging patterns, and collaborative networks in dental education. By identifying and visualizing these trends, the study provides a deeper understanding of how educational methodologies are evolving and how they can be optimized to improve learning outcomes in dentistry. FC in dental education faces several specific challenges and limitations. Scarcity of resources, such as limited access to appropriate technology and educational materials may hinder its effective implementation. In addition, resistance to change on the part of some faculty and students may be a significant obstacle, as they are accustomed to traditional teaching methods.⁷⁻¹²

The objective was to evaluate a scientometric mapping of the FC in dental education using geospatial dynamics, emergent patterns, and collaborative networks.

MATERIALS AND METHODS

The Type of Study

This was a descriptive scientometric study that focused on analyzing the evolution and trends in dental education by using innovative methodologies such as the inverted classroom.

Search Strategy

A comprehensive search was conducted in the Web of Science database (Core Collection) on September 1, 2024. The search terms

used were: TS = ("Flipped classroom" OR "inverted classroom" OR "blended learning" OR "active learning" OR "experiential learning" OR "problem-based learning" OR "project-based learning" OR "inverted classroom" OR "reverse classroom" OR "flipped learning" OR "inverted learning" OR "reverse instruction" OR "flipped education" OR "backward classroom" OR "upside-down classroom") and TS = ("dental teaching" OR "dental education" OR "dental instruction" OR "dental training" OR "dentistry teaching" OR "dentistry education" OR "oral health education" OR "dental pedagogy" OR "dentistry instruction").

The selection of the period 2005–2024 for this study is justified for several reasons. First, this interval of almost two decades allows for an analysis of the evolution and long-term trends in dental education, providing a more complete and detailed view of changes in educational methodologies. In addition, this period includes the introduction and adoption of innovative educational technologies, such as the FC, and encompasses significant events such as the COVID-19 pandemic, which spurred the use of online and blended learning methods. By choosing this time frame, the study captures a wide range of developments and adaptations in dental education, providing a comprehensive and up-to-date perspective.

Selection Criteria

In this study, articles addressing dental education and using innovative teaching methodologies, published between January 2005 and September 2024, and indexed in the Web of Science database (Core Collection), were included. Editorials, notes, and commentaries were excluded, as these papers do not provide empirical data or comprehensive reviews, limiting their value for scientometric analysis. This rigorous selection ensures that only studies with a solid evidence base are considered, allowing for a more accurate and relevant analysis of trends and patterns in dental education. To ensure the transparency and reproducibility of the study, the search results were selected using a PRISMA flowchart, which details each stage of the selection process, from the identification of articles to their final inclusion. However, restricting the study to the Web of Science (Core Collection) database limits the breadth of the analysis. Other important databases, such as Scopus or PubMed, should be included, as they would provide a more holistic view of the literature, allowing a more complete and diverse evaluation of educational methodologies in dentistry.

Data Collection

Data analysis was conducted using two main tools: CiteSpace and Bibliometrix. CiteSpace was used to perform citation network analysis and detect emerging patterns in the literature. Specific steps included generating co-citation networks to identify the most influential articles and authors in the field, clustering analysis to group articles into thematic clusters, temporal visualization to identify periods of high citation activity and the most prominent authors in those periods, and citation burst detection to identify references with significant increases in the number of citations during specific periods. On the other hand, Bibliometrix was used to perform a detailed bibliometric analysis, including a descriptive analysis of metrics such as the number of publications per year, the average age of documents, and the average number of citations per document; keyword analysis to understand thematic trends; co-authorship analysis to identify collaborations between authors and the proportion of international co-authorships; and the application of Bradford and Lotka's laws to evaluate the distribution of publications and author productivity. These analyses made

it possible to identify publication patterns, emerging trends, and collaborative networks in dental education, providing a comprehensive view of the evolution and impact of innovative teaching methodologies in the field.

Although CiteSpace and Bibliometrix are appropriate tools for scientometric analysis, a brief justification of their selection over other alternatives would strengthen the methodological rationale. CiteSpace was chosen for its ability to perform citation network analysis and detect emerging patterns in literature, while Bibliometrix was selected for its ability to perform detailed and descriptive bibliometric analysis. These complementary tools allow for a comprehensive understanding of collaborative trends and networks in dental education, providing a solid foundation for scientometric analysis.

Data Analysis

The collected data were analyzed using scientometric analysis tools to identify publication patterns, emerging trends, and collaborative networks. Pie charts, time-zone visualization, and three-dimensional landscape views were used to visually represent connections and thematic evolution in dental education. In addition, Bradford and Lotka’s laws were applied to evaluate the distribution of publications and author productivity. In addition, graphics were designed using the R Studio version 4.2.3 and CiteSpace 6.3 R2.

RESULTS

Between 2005 and 2024, 306 documents from 94 sources were analyzed, representing an annual growth of 20.2%. The average age of the documents was 6.19 years, with an average of 12.47 citations per document and 7,469 references. In total, 701 authors’ keywords were identified. A total of 1,183 authors participated, of whom 19 published single-authored papers, resulting in 20 single-authored papers. The average number of coauthors per paper was 4.39, with 18.63% of international coauthorships. There were 262 published articles, 9 early access articles, 1 proceedings article, 5 editorial materials, 1 letter, 1 meeting abstract, 23 reviews, and 4 early access reviews (Table 1).

When analyzing the pie chart clustering, it was evident that the main clusters corresponded to #0 FC, #1 COVID-19, and #2

curriculum reform, among others. The most representative authors within each cluster were Qutieshat AS for cluster #0, Iyer P for cluster #1, and Bassir SH for cluster #2 (Fig. 1).

When analyzing the time zone visualization graph, it was evident that 2019 and 2020 concentrated the highest co-citation, with the largest nodes. In 2019, the most representative author was Gianoni-Capenakas, while in 2020, the most prominent authors were Quteshhat, Iyer, and Quinn. These findings indicate intense research activity and the high influence of these authors in their respective years (Fig. 2).

Table 1: Main characteristics

Description	Results
Timespan	2005–2024
Sources	94
Documents	306
Annual growth (%)	20.2
Document average age	6.1
Average citations per doc	12.4
References	7,469
Author’s keywords	701
Authors	1183
Authors of single-authored docs	19
Single-authored docs	20
Co-authors per doc	4.39
International co-authorships (%)	18.6
Article	262
Article; early access	9
Article; proceedings paper	1
Editorial material	5
Letter	1
Meeting abstract	1
Review	23
Review; early access	4

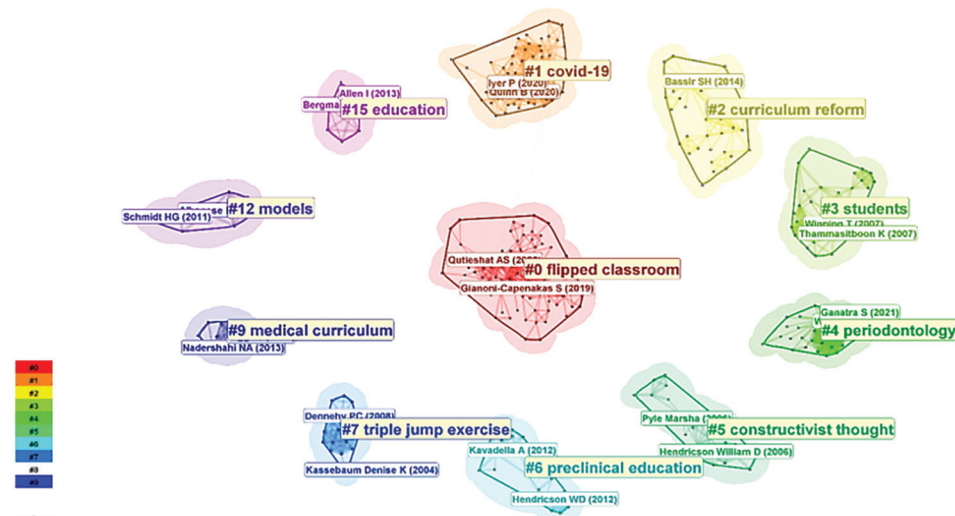


Fig. 1: Circular clustering view

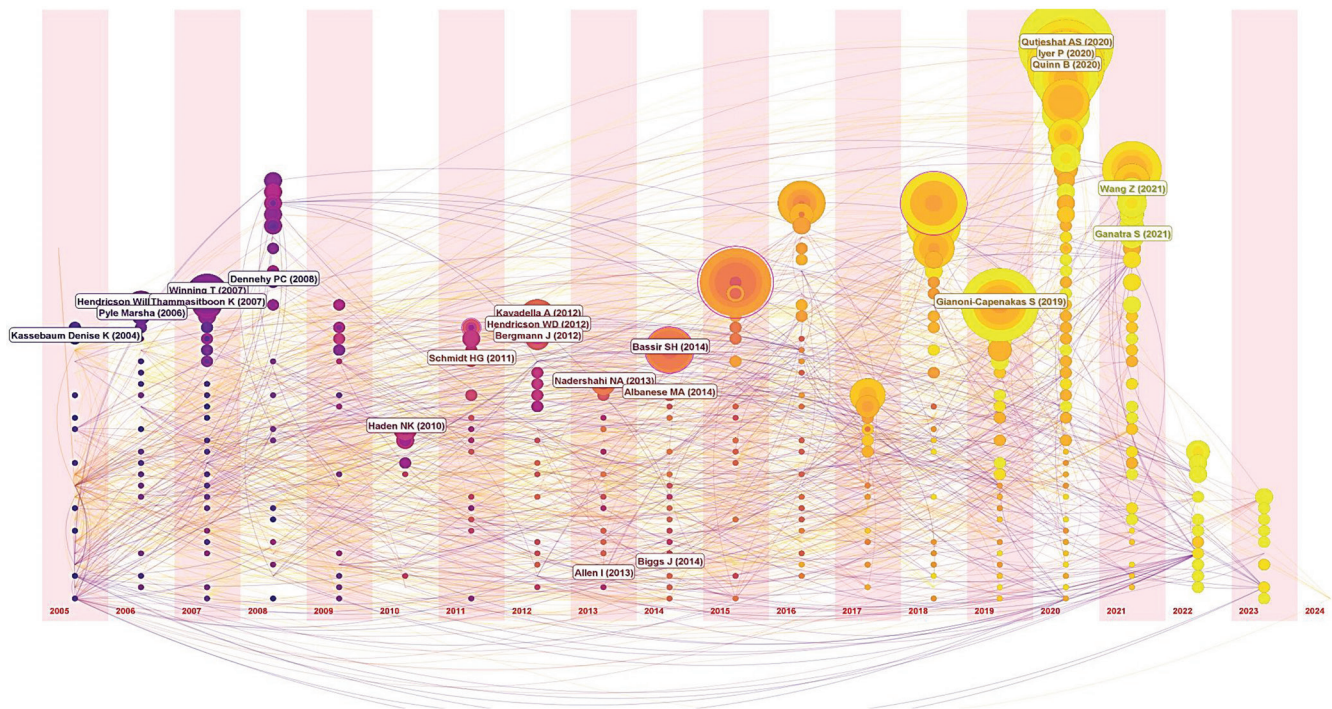


Fig. 2: Timezone view



Fig. 3: Top 10 references with the strongest citations bursts

When analyzing the top references with the strongest citation bursts graph in CiteSpace, several references that experienced a significant increase in the number of citations during specific periods were identified. For example, the reference by Park showed a remarkable citation burst with an intensity of 5.65, indicating that this work had a considerable impact on the scientific community since its publication. The increased citation count can be attributed to the relevance of the study in a specific field. Another noteworthy reference is Iyer, which presented a citation burst with an intensity of 4.46 in the same year. This pattern suggests that Iyer’s work has been pivotal to subsequent research, especially in the context of the COVID-19 pandemic, reflecting his rapid adoption and significant influence. Similarly, Quinn reported a citation burst with an intensity of 4.46 in 2020. The coincidence in year and burst intensity with

the Iyer reference indicates that both papers have been crucial in the development of pandemic-related research, highlighting their relevance and the interest generated in the scientific community (Fig. 3).

The dual map overlay graph shows the citation relationships among the different scientific fields. It was observed that cluster 9 (dentistry, dermatology, surgery) has multiple connections to other clusters. Specifically, this cluster frequently cites journals in clusters 5 (health, nursing, medicine), 14 (dermatology, dentistry, surgery), and 7 (psychology, education, social). This suggests a strong interdependence between these fields, where advances in dentistry, dermatology, and surgery are significantly influencing research in health, nursing, medicine, psychology, education, and social sciences. The connection between clusters 9 and 7 indicates

personalized models, and blended teaching were demonstrated. These models contribute to the formation of a new generation of exceptional talent in health sciences.¹⁴

Study trends in the FC can be identified by examining how topics evolve and the purpose of other concepts. It is highlighted that the top three topics whose magnitude of study has increased over time are “attitude and achievement”, “active learning strategies”, and “nursing education”.¹⁵ Highlighting the importance of repeating the inverted classroom analysis with more specific and indigenous sub-themes. This allows us to determine trends in different time periods and compare current and future scenarios to observe how trends of increase or decrease in topics have changed, thus better understanding the changes in this field of study.¹⁵ Simulation tools and online learning platforms, such as Zoom and Moodle, have enabled greater student interaction and participation, facilitating active and autonomous learning. These technologies have not only improved the accessibility and flexibility of learning but have also provided innovative resources that enrich the educational experience, proving to be fundamental for the effective implementation of the FC model in dental education.

On the other hand, a literature review evaluated the overall effect of the FC on students in terms of learning outcomes. Comparisons were made with traditional virtual classrooms, and the results were found to be significantly favorable for the FC.¹⁶ In contrast, in the bibliometric analysis, publications from 2010 to 2019 were included, collecting 126 articles related to the FC, which were evaluated and reviewed. According to the content analysis, 79 articles were specifically selected for their focus on education and the inverted classroom.¹⁷ According to our research, it can be inferred that the collected articles span from 2005 to 2021, totaling 306 documents. However, the inverted classroom presented interesting concepts that were applied in the literature review, thus benefiting dentist training. Thus, concepts were investigated to establish the research parameters of the bibliometric analysis. For example, studies have shown that students who participate in the FC tend to perform better on tests and show higher skill retention rates compared to traditional methods. These quantitative data provide a strong basis for claims about the effectiveness of the FC, underscoring its ability to improve academic performance and knowledge retention in dental education. Besides, workshops and training sessions could be organized for teachers, focusing on the benefits and techniques of FC. In addition, gradual implementation of FC, starting with specific modules before expanding across the curriculum, could facilitate adaptation. It is also crucial to provide adequate technological resources and ongoing support to ensure a smooth and effective transition to this innovative approach.

In terms of limitations, research on the FC in dental education is an emerging field that has gained interest recently because of its potential to improve learning. Although few studies on this topic are available, they are gaining relevance and providing more detailed explanations. Current information is limited, which makes it difficult to obtain accurate and realistic data. Therefore, there is a need to generate new articles on the FC in dental education to address the current paucity of information and provide greater emphasis on explaining these issues. The available articles and studies were obtained from repositories such as PubMed and Scopus, which contain old and scarce information, highlighting the need to improve the information by combining these two topics

and providing criteria and opinions for future research. For example, more diverse databases such as Scopus and PubMed could be used to obtain a more comprehensive view of the literature. In addition, conducting longitudinal studies would allow assessment of the long-term impact of the FC on dental education. These strategies would provide more robust data and a deeper understanding of innovative educational methodologies in this field.

Our study conforms to reporting and measurement of Items for Bibliometric or Scientometric Studies in Health Sciences (RAMIBS) and has had a significant impact on the nature and typification of bibliometric and scientometric research. Key points include analysis of co-citations, social networks, spatial distribution, citations, and the number of publications, providing a consistent and clear structure for research on the identified topic.¹⁸ The RAMIBS analysis helped to properly organize the topic of the FC in dental education, providing a better understanding and order for future publications on the topic. The time frame from 2005 to 2024 was selected for the study in order to analyze the progress and effects of innovative teaching methods in dental education, especially the FC approach. This almost 2-decade time span will provide a time series analysis of the dynamism of geography, emerging trends, and collaborative networks. Such an intuitive and fine-grained view of long-lasting trends and significant changes in education practices within the discipline of dentistry will be explored at great length to give substantial insight into how the methodology was developed and applied over time.

The advantages and relevance of this research are based on its ability to provide a coherent and well-supported commentary to the reader. However, since the topic has been under-researched, the lack of criteria has limited the study. The inverted classroom is essential for determining concepts in educational processes and promoting learning for both teachers and students, complementing dental concepts and improving learning and knowledge retention. These innovations allow the application of a better structure for conducting classes, benefiting both students and teachers with a better understanding of the class being taught. However, the accuracy of the FC approach in dental education can be gradually advanced to determine if it is a teaching method that can provide better academic results.

CONCLUSION

In conclusion, the scientometric analysis of the FC in dental education revealed a significant evolution in educational methodologies between 2005 and 2024, with an annual growth of 20.2% in scientific production. The integration of educational technologies, such as FC and e-learning, has been fundamental, especially in the context of the coronavirus pandemic. The main clusters identified, such as “FC”, “COVID-19”, and “Curriculum Reform”, highlight the continuous adaptation of dental education to new methodologies. The high concentration of publications in key journals, such as the *Journal of Dental Education*, and the predominance of authors with only one publication, according to Bradford and Lotka’s laws, underline the importance of fostering collaborative networks and the dissemination of innovative practices. These findings suggest that the implementation of the FC approach and other educational technologies can significantly improve dental education, promote more active and participatory learning, and facilitate international collaboration and innovation in the educational curriculum.

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