Bibliometric and visualized analysis of global research on technology in anatomy education from 1987 to 2021

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SUMMARY

While anatomy has been taught by means of traditional methods for centuries, today anatomy education methods are developing with various digital educational resources. Therefore, determining the trends of publications on the use of technology in anatomy education can provide a roadmap for future studies on this topic. This study aims to conduct a bibliometric analysis of the documents about technology in anatomy education. Using the bibliometric analysis method, 437 documents between 1987 and 2021 were included in the study. Publications in journals indexed in Web of Science were reviewed in terms of the country, journal, citation, year, author, keywords, co-authorship, co-occurrence, and co-citation. The H-index value of the publications was 47, and the total number of citations was 8501. The publications highlight an exponential increase in the last few years, as well as the prominence of a particular journal and countries such as the USA, England or Australia. Wilson TD was the most prolific author in the field. According to the co-occurrence analysis, it is observed that the terms "gross anatomy education", and "medical education" are frequently used by the authors. In the last few years, 3D printing, virtual reality, augmented reality and social media were selected in anatomy education. This study identified the main research hotspots related to the use of technology in anatomy education. The findings can also help provide new directions and ideas for future research.

Key words: Anatomy education – Bibliometric study – Technology

INTRODUCTION

Anatomy is an important branch of basic medical sciences. It is also of great importance, as it includes the scientific and terminological foundations of medicine and other health disciplines (Moxham and Plaisant, 2014). It is possible to encounter anatomy education at almost all levels of the health education system (Estai and Bunt, 2016; Schaefer et al., 2019; Zargaran et al., 2020). In order to teach anatomy effectively, many researchers, especially anatomy educators, have been

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developing various theories and contributing to the literature by introducing new evidence-based applications for many years (Scott, 1993; Singh et al., 2019). In the Web of Science (WoS) alone, there are 4356 documents between 1975 and2019 that contain the keyword "anatomy education" (Petekkaya et al,. 2021).

Many alternative education methods are used in the presentation of anatomy education. Methods such as face-to-face learning, books, atlas, dissection, prosection, plastination, video, online resources, social media, 3D models, augmented reality and virtual reality are among the methods used to teach anatomy effectively (Iwanaga et al., 2021). Comparative research on the advantages and disadvantages between traditional methods and newer and more technological methods tends to increase. Anatomy teaching methods and resources used to help provide educational material have evolved significantly in recent years (Hulme and Strkalj, 2017). Today, more innovative and interactive teaching strategies and techniques which sare student-centred rather than cadaver-based are becoming popular. These techniques are problem-based, self- or team-based learning, as well as computer-assisted learning, videos, simulations and 3D images in anatomy education (Singh et al., 2019; Turney, 2007). Due to the rapid progress of technology and the increasing need for e-learning, it is important to explore the potential of technology in anatomy education. All technologically realized innovations provide medical students with accessible and standardized anatomy teaching (Zargaran et al., 2020).

The first and most important basis for acquiring adequate knowledge and skills in anatomy is for students to concentrate and engage in learning anatomy (Kumar and Singh, 2020). At this point, studies show that educational approaches made using active and engaging learning strategies in anatomy education can improve student participation and interaction are highlighted (Eleazer and Scopa, 2018; Singh et al., 2019). In recent years, with the increasing ease of access to innovations such as 3-D printers, virtual reality and augmented reality, innovative anatomy education models have been developed. In anatomy laboratories, materials consisting of 2D plastic and atlas models are replaced by 3D virtual reality models that provide a deeper understanding of anatomy with today's technology (Falah et al., 2014). However, there is still uncertainty about the various materials and techniques used for anatomy education and the methods to provide optimal teaching (Zargaran et al., 2020).

Bibliometric analysis provide a different perspective in reflecting developments in various fields of scientific research (Petekkaya et al., 2021). This analysis is a useful method to objectively measure the current status and international scientific impact of a particular topic (Van Raan, 2003). At the same time, it succinctly and intelligibly presents to researchers and readers the general trends in their field of research. Visualization of Similarities viewer (VOSviewer) is a specially designed software tool that creates and visualizes bibliometric maps, thereby demonstrating the structural and dynamic aspects of scientific research areas (Mas-Tur et al., 2021). The accumulated knowledge of most scientists during the historical development of anatomy has led to a detailed anatomy database (Bahsi and Bahsi, 2019). Advances in anatomy education are the topic of many research articles, reviews, scientific meetings (Estai and Bunt, 2016; Iwanaga et al., 2021; Singh et al., 2019). For this reason, bibliometric, scientometric and altmetric analyses related to this current issue may also be useful (Petekkaya et al., 2021). Currently, there is a lack of research on the current situation, trends, hotspots and evaluation of the future appearance regarding the innovations brought by technology in anatomy education. With the innovations offered by technological developments, new evidence-based approaches to learning and teaching are being designed for students in the field of medicine and health sciences. Studies on anatomy education and technology are increasing in order to reveal effective learning methods.

This study aims to conduct a bibliometric analysis of documents related to anatomy education and technology using the WoS database. Until 2021, we present the trends of current publications on the subject in areas such as authors, keywords and countries to relevant researchers.

MATERIALS AND METHODS

Study design

This bibliometric study was conducted using documents published in indexed in the Web of Science (https://www.webofscience.com/). The datasets collected via WoS were obtained on December 20, 2021. All bibliometric analyses were completed by conducting them through the files downloaded on this date.

Data search and collection

In this study, data were collected through the Web of Science Core Collection database. The science of anatomy can potentially be covered by many journals in the fields of medicine, health, biology and biomedicine. Therefore, data collection was not attributed to the scope of any particular journal, and interdisciplinary research cutting across multiple fields and extending to related areas were also included in the analyses. All document types (article, proceeding paper, book chapter, etc.), countries, languages, data categories were included without going to any exclusion. We selected the words to search as TS = (technology OR virtual reality OR augmented reality OR 3D OR video OR social media OR internet) AND anatomy education. The first publication in the WoS database is obtained in 1987. A total of 438 documents were obtained by December 20, 2021, without restricted time parameters. Since the publication date of a document is 2022, a total of 437 documents were included in the research between 1987 and 2021. In addition, the authors checked for duplication in the documents. The accuracy of data such as titles, countries, journals, or authors were confirmed by the researchers, and the analyses were performed.

Data analysis and visualization

The datasets were downloaded from the database in "plain text file" format and Microsoft Excel program was used for descriptive results. Bibliometric analysis were performed, and network visualization maps were created using the VoSviewer package program (Van Eck and Waltman, 2010). The analyses were made on the basis of the number of publications and citations by year, the most prolific authors and journals, frequently used keywords, bibliographic coupling including co-citations of the authors, and co-authorship (Mas-Tur et al., 2021).

Bibliometric Analysis

With bibliometric analysis, it is possible to profile the relevant publications on a particular scientific research topic. Qualitative and quantitative changes of the subject can be determined, and trends within a discipline can be determined. This analysis consists of the application of some kind of statistical methods (De Bakker et al., 2005). Mas-tur et al. (2021) reported that analyses by using this method can rely on a variety of calculations (number of citations or number of publications by author, institution or country, keyword occurrence or co-occurrence, or co-authorship). Whether it is regarding a publication, author collaborations, a journal, or popularity on a topic, researchers can benefit from such systematic methods of revealing the influence of literature and scientific trends. Thus, bibliometric studies provide an opportunity to evaluate national and international cooperation on leading issues (De Bakker et al., 2005; Duque Oliva et al., 2006).

Visualization of Similarities viewer (VOSviewer)

VOSviewer is a software tool for creating and visualizing bibliometric networks such as journals, researchers or publications (LIUPost, 2021). VOSviewer uses the VOS mapping method. Depending on the matching method, images with citation, bibliographic matching, co-citation, or co-authoring relationships can be created. In this study, VOSviewer's network visualization and overlay visualization map type method were applied (Hebebci, 2021).

The VOSviewer clustering algorithm uses the smart local moving algorithm. This algorithm works based on clustering topics, marking and classifying each cluster with a different colour. A cluster consists of closely related nodes. Each node in a network is assigned to a cluster. The number of clusters is determined by a resolution parameter. The higher its value, the greater the number of clusters. VOSviewer uses colours to indicate the cluster to which a node is assigned.

Items are indicated by a label and, by default, a circle. The size of the circles and the size of the number of font occurrences of the label, and the colours represent the clusters. The distance between the two circles reveals the similarity and relationship between them (Van Eck and Waltman, 2010; Van Eck and Waltman, 2014).

In order to empirically determine the matches with the highest frequency in the data set examined in this study, some threshold values were determined for the terms that should be included in the cluster numbers (such as minimum 2 documents for network map including country, at least twenty citations for author co-authorship and co-citation analyses, author keywords used at least ten times, etc.).

Table 1. Top 20 most cited documents in Web of Science.

Authors	Article Title	Citations*	Total link strength**
Sugand et al. (2010)[b]	The Anatomy of Anatomy: A Review for Its Modernization[1]	484	132
McMenamin et al. (2014)[a]	The Production of Anatomical Teaching Resources Using Three-Dimensional (3D) Printing Technology[1]	294	61
Nicholson et al. (2006)[a]	Can virtual reality improve anatomy education? A randomised controlled study of a computer-generated three-dimensional anatomical ear model[2]	236	18
Estai and Bunt (2016)[b]	Best teaching practices in anatomy education: A critical review[3]	226	117
Moro et al. (2017)[a]	The Effectiveness of Virtual and Augmented Reality in Health Sciences and Medical Anatomy[1]	200	72
Preece et al. (2013)[a]	"Let's Get Physical": Advantages of a physical model over 3D computer models and textbooks in learning imaging anatomy[1]	197	58
Lim et al. (2016)[a]	Use of 3D printed models in medical education: A randomized control trial comparing 3D prints versus cadaveric materials for learning external cardiac anatomy[1]	173	29
Jaffar (2012)[a]	YouTube: An emerging tool in anatomy education[1]	158	16
Petersson et al. (2009)[a]	Web-Based Interactive 3D Visualization as a Tool for Improved Anatomy Learning[1]	146	33
Pereira et. ak (2007)[a]	Effectiveness of using blended learning strategies for teaching and learning human anatomy[2]	135	41
Barry et al. (2016)[a]	Anatomy Education for the YouTube Generation[1]	121	39
Yammine and Violato (2015)[a]	A meta-analysis of the educational effectiveness of three-dimensional visualization technologies in teaching anatomy[1]	117	108
Ghosh (2017)[b]	Cadaveric Dissection as an Educational Tool for Anatomical Sciences in the 21st Century[1]	116	140
Khor et al. (2016)[b]	Augmented and virtual reality in surgery-the digital surgical environment: applications, limitations and legal pitfalls[4]	114	10
Khot et al. (2013)	The relative effectiveness of computer-based and traditional resources for education in anatomy[1]	110	64
Kucuk et al. (2016)[a]	Learning Anatomy via Mobile Augmented Reality: Effects on Achievement and Cognitive Load[1]	106	66
Trelease (2016)[b]	From Chalkboard, Slides, and Paper to e-Learning: How Computing Technologies Have Transformed Anatomical Sciences Education[1]	103	160
Davis et al. (2014)[a]	Human Anatomy: Let the Students Tell Us How to Teach[1]	96	100
Codd and Choudhury (2011)[a]	Virtual Reality Anatomy: Is it Comparable with Traditional Methods in the Teaching of Human Forearm Musculoskeletal Anatomy?[1]	93	76
McBrid and Drake (2018)[a]	National survey on anatomical sciences in medical education[1]	90	20

Document Type: [a] Article; [b] Review.
Journal: [1] Anatomical Sciences Education; [2] Medical Education; [3] Annals of Anatomy; [4] Annals of Translational Medicine.
* Number of citations in the Web of Science database.
** Total link strength calculated by selecting a minimum number of 2 citations in VoSviewer.

Research ethics

The study protocol was approved by the Clinical Research Ethics Committee of the university (Number: 2021/491).

RESULTS

Overview of Publications on Anatomy education and technology

This study included 437 documents in total. It was determined that the majority of the documents were published in journals within the scope of Science Citation Index Expanded (366, 83.75%). According to Web of Science Categories, the top 5 categories were listed as follows: Education Scientific Disciplines (262, 59.95%), Anatomy Morphology (57, 13.04%), Radiology Nuclear Medicine Medical Imaging (24, 5.49%), Imaging Science Photographic Technology (21, 4.81%), and Surgery (21, 4.81%). The H-index of the documents was 47, the total number of citations was 8501 (6279 without self-citations). The majority of document types were articles (326; 74.6%). The first 20 documents with the most citations are shown in Table 1. The network map containing these documents (having minimum of 90 citations) was presented in Fig. 1. The documents with the highest number of citations and total link strength, respectively, included: "The Anatomy of Anatomy: A Review for Its Modernization" and "From Chalkboard, Slides, and Paper to e-Learning: How Computing Technologies Have Transformed Anatomical Sciences Education".

Publication Year

In the WoS database, the years 1987, 1994, 1999, 2000, 2005 and 2006 included a document. The years 2003 and 2004 included two documents. The majority of documents were published in the last 3 years: 2021 (78; 17.85%), 2020 (70, 16.02%) and 2019 (62; 14.19%). Top 3 citing years were as follows: 2021 (2025; 23.82%), 2020 (1934, 22.75%) and 2019 (1321; 15.54%) (Fig. 2).

Publication Countries

It was determined that a total of 60 countries contributed to the literature on anatomy education and technology. The first 10 of these are listed in Table 2. The United States was the country with the highest production with 125 (28.60%) documents followed by UK and Australia with 61 (13.96%) and 53 (12.13%), respectively. The forty countries with more than two publications linked to other countries and six clusters are shown in Fig. 3. The United States (35577) and England (25157) were the countries with the highest total link strength.

Publication Authors and Journals

There were a total of 1556 authors in documents on anatomy education and technology. The average number of documents per author was 0.28. Wilson TD was the author with the highest production, with 13 (2.98%) documents followed by Seo JH and Chytas D, with 9 (2.59%) and 8 (1.83%), respectively. The network map of the co-authorship analysis with authors with a minimum of 20

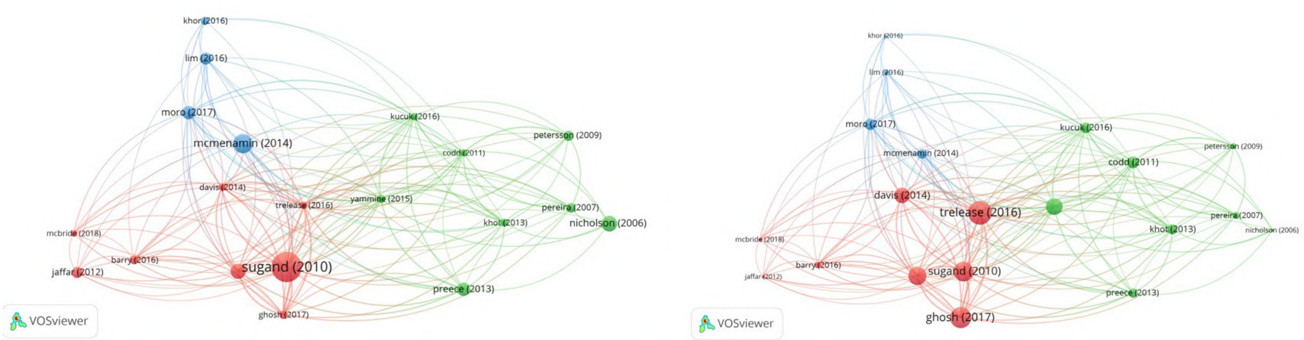

Fig. 1.- Network maps by citation and total link strength of the top 20 publications. 20 publications in 3 clusters. On the left, as the number of citations increases, the size of the circle increases. On the right, the total link strength increases as the size of the circles increases.

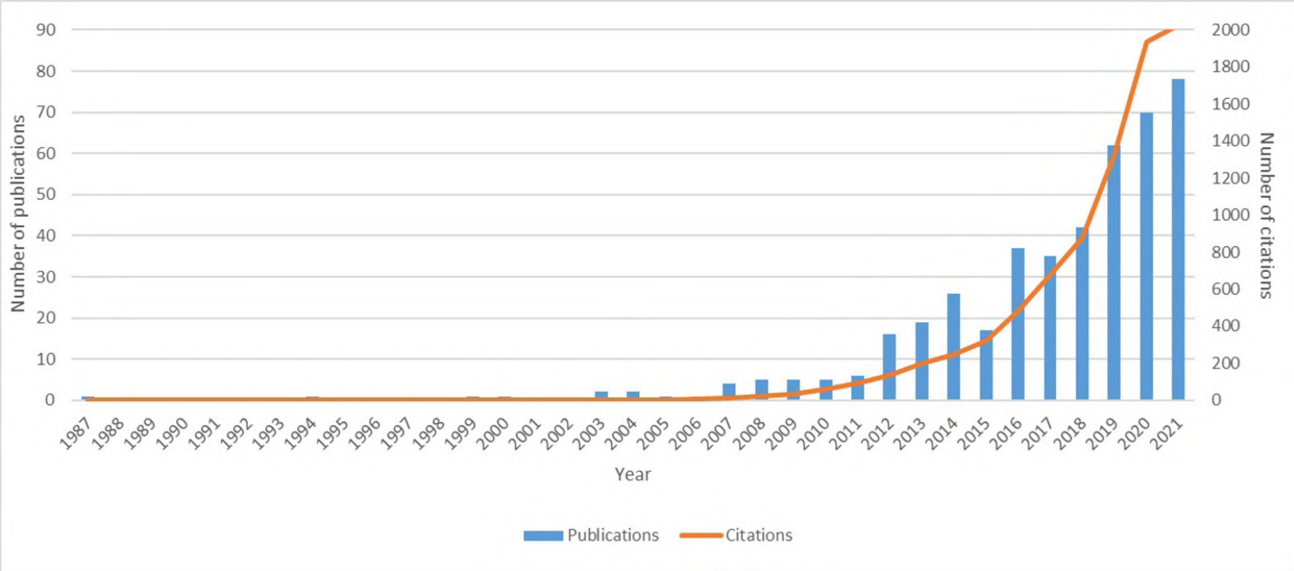

Fig. 2.- Change in the number of publications and citations of documents on "anatomy education and technology" in WoS by year.

Table 2. Top 10 countries of documents on anatomy education and technology.

Rank	Country	Frequency	% of 437	Citations / Documents (up 2021)	H-Index	Total link strength*
1	United States	125	28.60	17.66	25	35577
2	England	61	13.96	28.87	20	25157
3	Australia	53	12.13	29.72	17	19859
4	Canada	42	9.61	27.95	18	19455
5	Germany	22	5.03	18.50	11	7059
6	China	17	3.89	9.94	6	4122
7	Turkey	17	3.89	9.82	6	4288
8	Netherlands	16	3.66	10.44	9	9297
9	Scotland	14	3.20	8.57	5	4260
10	Ireland	13	2.98	18.23	6	3856

* Minimum number of documents of country: 2

citations are shown in Fig. 4A. Accordingly, 31 authors who met the threshold were distributed in 6 different clusters.

Co-citation analysis was also performed to reveal the most cited authors. When the minimum number of citations for an author was set to 20, 104 authors met this threshold and 3 clusters were distributed. Drake RL, Trelease RB, and Mayer RE were the authors with the highest total link strength, with 2776, 2157, and 1849, respectively (Fig. 4B).

The top ten journals with the highest number of documents are shown in Table 3. Anatomical Sciences Education (208, 47.6%) was the journal with the most publications.

Author keywords

Co-occurrence of keywords in 437 documents on anatomy education and technology was sent to VOSviewer for analysis and visualization, and 1190 keywords were formed. Twenty-seven keywords used at least ten times by the authors are in Table 4; the co-occurrence overlay and network visualization maps of these keywords are presented in Figures 4C and 4D, respectively. In the last few years, "COVID-19", "social media",

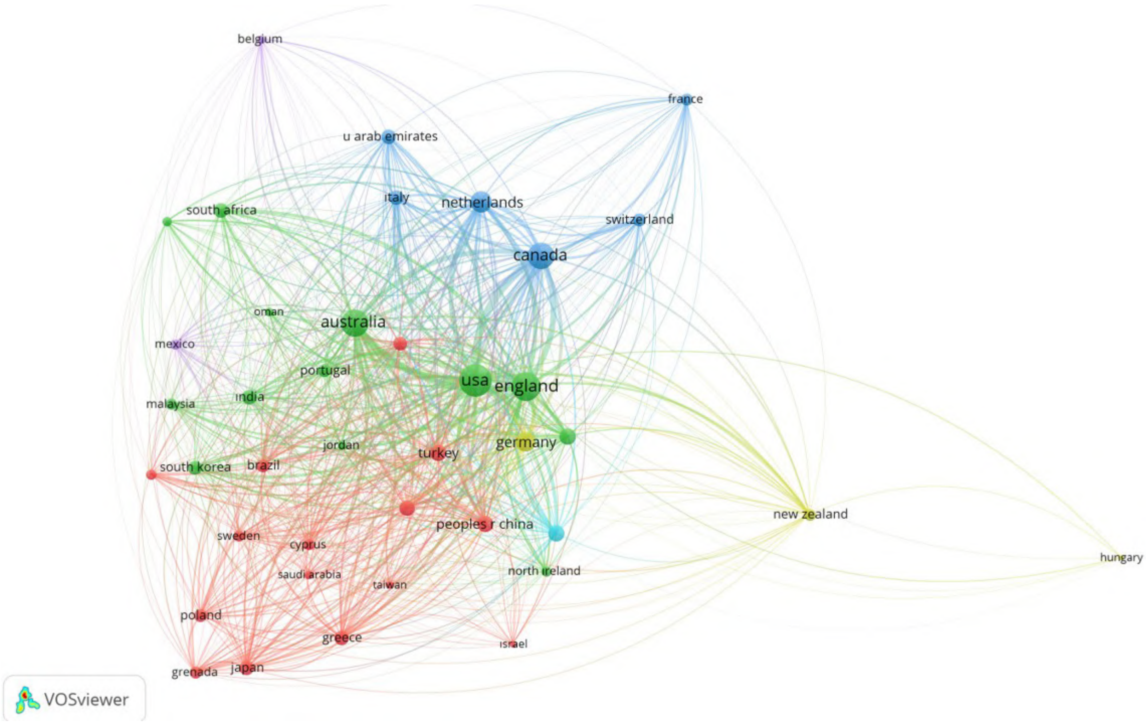

Fig. 3.- Network map with 40 countries in 6 clusters by setting the threshold to minimum 2 documents. As the size of the circles increases, the total number of links increases. More connections between different nodes indicate more cooperation between different countries.

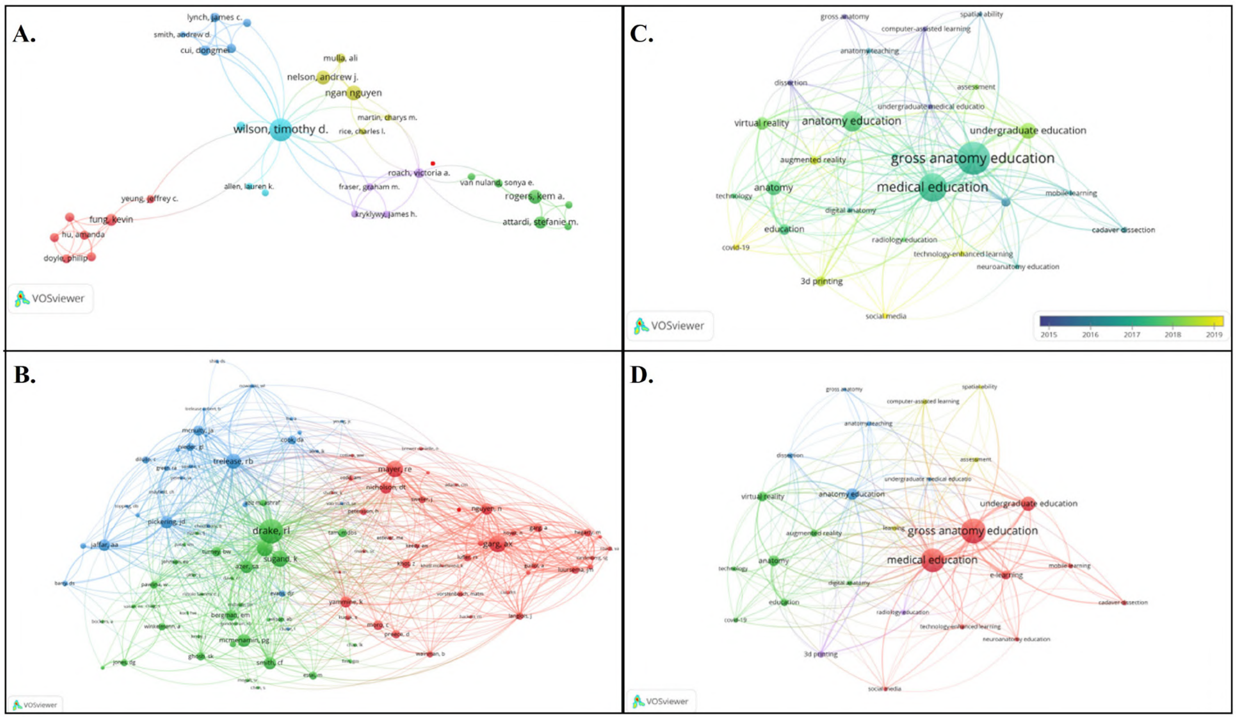

Fig 4.- A and B include maps of author co-authorship and co-citation analysis with VOSviewer. The size of each circle indicates the citations of articles produced by the author. The distance between any two circles indicates the relationship of co-authoring links, and the thickness of the link line indicates the strength of the link. **A.** Author co-authorship analysis. 442 authors met minimum of twenty citations threshold criteria and 31 of them are connected. Red cluster (7 items); green cluster (6 items); blue cluster (5 items); yellow cluster (5 items); purple cluster (4 items); turquoise cluster (4 items). **B.** Author co-cited analysis. 104 authors met minimum of twenty citations threshold criteria and are connected. Red cluster (39 items); green cluster (36 items); blue cluster (29 items). **C.** VOSviewer co-occurrence overlay visualization mapping of most frequent author keywords (minimum of 10 occurrences) in Anatomy education and Technology research from 1987 to 2021. Keywords in blue appeared earlier than that in yellow. **D.** VOSviewer co-occurrence network visualization mapping of most frequent author keywords (minimum of 10 occurrences) in Anatomy education and Technology. Twenty seven keywords were collected in 5 clusters. The large circles represent keywords with high link strength.

Table 3. Journals with publication titles on the topic.

Rank	Journals	Frequency	% of 437
1	Anatomical Sciences Education	208	47.6
2	Advances in Experimental Medicine and Biology	18	4.11
3	Clinical Anatomy	15	3.43
4	Faseb Journal	13	2.98
5	Medical Sciences Educator	11	2.52
6	International Journal of Morphology	9	2.06
7	Journal of Anatomy	8	1.83
8	Surgical and Radiologic Anatomy	7	1.60
9	Annals of Anatomy	6	1.37
10	BMC Medical Education	6	1.37

Table 4. Author keywords used at least ten times

Rank	Keywords	Occurrences	Total link strength
1	Gross anatomy education	176	322
2	Medical education	143	301
3	Anatomy education	88	103
4	Undergraduate education	60	141
5	Anatomy	54	92
6	Virtual reality	44	81
7	Education	34	56
8	3d printing	32	52
9	E-learning	27	74
10	Augmented reality	24	52
11	Cadaver dissection	14	29
12	Anatomy teaching	13	26
13	Dissection	13	33
14	Social media	13	25
15	Assessment	12	32
16	COVID-19	12	28
17	Technology	12	28
18	Technology-enhanced learning	12	30
19	Computer-assisted learning	11	31
20	Gross anatomy	11	16
21	Learning	11	31
22	Mobile learning	11	30
23	Neuroanatomy education	11	28
24	Radiology education	11	33
25	Undergraduate medical education	11	21
26	Digital anatomy	10	30
27	Spatial ability	10	21

"technology-enhanced learning"," undergraduate education", "3d printing" and "augmented reality" were the frequently used keywords by the authors (Fig. 4C). In Fig. 4D, these keywords that appeared more than ten times are included and classified into five clusters in the map: cluster 1 (gross anatomy education, medical education, undergraduate education, e-learning, cadaver dissection, social media, technology-enhanced learning, mobile learning and neuroanatomy education, in red); cluster 2 (anatomy, virtual reality, education, augmented reality, COVID-19, technology and digital anatomy, in green); cluster 3 (anatomy education, anatomy teaching, dissection, gross anatomy and undergraduate medical education, in blue); cluster 4 (assessment, computer-assisted learning, learning and spatial ability, in yellow), cluster 5 (3d printing and radiology education, in purple).

DISCUSSION

The rapid growth of the scientific community in recent years has made it necessary to show the research habits, trends and effects of a topic through scientific data in many respects (Ji et al., 2021). In this study, anatomy education and technology studies were analysed based on bibliometric and visualization methods to reveal the current state of technology use in anatomy education worldwide. The top publications, the researchers, publishers, countries and keywords were presented in order to examine the best teaching practices in the field of anatomy and to show the change of these practices with the developing technology.

The inclusion of modern and alternative approaches in the education process is an indispensable element of the education sector (Kurt et al., 2013). A number of developments were observed in the teaching resources used in anatomy education in the world at the beginning of the 21st century. The methods of teaching and learning anatomy have been extended with new tools and supports (Duparc et al., 2019). In this study, it was clearly observed that the popularity of publications related to technology in anatomy education has increased in recent years. These results suggest that anatomy education continues to be improved with technology-based materials. In fact, it was confirmed in our study that about half of the publications on the topic were published in the last three years and the number of citations made in these years constituted approximately 60% of all years. The increasing need for online education during the pandemic may also have had an impact on the increase in publications. The COVID-19 pandemic, which caused the interruption of face-to-face education in all forms of education, has also had tremendous effects on anatomy education (Iwanaga et al., 2021). In this process, as technology allows for students, educators added educational dissection videos to distance learning, students were encouraged to watch videos from social media such as YouTube, and universities acquired digital resources that support online learning (Franchi, 2020; Pather et al., 2020). The fact that the keywords used by the authors in our study in recent years are words such as COVID-19 and social media supports this situation.

Many years ago, many famous anatomists and practitioners in history, such as Vesalius, travelled along Europe's largest universities and contributed to the exchange of anatomical knowledge (Duparc et al., 2019). Today, information exchange can be monitored between authors, institutions and countries through simple software. A previous study reported the most influential countries in the world in the field of anatomy education as the United States, England and Australia, respectively. In this previous study, it was stated that these three countries have 70% of anatomy education publications (Kurt et al., 2013). The results in our study were similar to the findings of this previous study. Moreover, our study showed that these productive countries often cooperate with different countries. It can be predicted that these countries will come to the fore more than other countries in shaping the future of anatomy education. Another study, examining the publications of countries in the field of educational technology, reported the ten most productive countries as the United States, England, Taiwan, Australia, Netherlands, Canada, Turkey, Greece, Singapore and Germany, respectively (Hsu et al., 2013). As a matter of fact, as seen in the previous study, it is seen that the leading countries in the field of educational technologies were among the most effective and productive countries in our study (United States, England, Australia, Netherlands, Canada, Turkey and Germany). Advances in educational technologies of countries may have also affected publications about technology in anatomy education. We also emphasize that due to the educational policies and practices of each country or related industry developments, technology in terms of anatomy education between countries can be applied to different research programs and the current study results have a general perspective.

One of the most interesting publications on anatomy education is "*The Anatomy of Anatomy: A Review for Its Modernization*" (Sugand et al., 2010). Since its publication, it has been cited many times by other researchers. Despite frequent citations from this study, it was not in the first place in the current study in terms of total link strength. This indicates that the high number of citations may not always contain high links to other studies. A time effect occurring in terms of citation and link data may also have affected the findings. It might be more helpful to look at the download number when some kind of time effect maths added. Respectively by Trelease (2016) and Ghosh (2017), "*From Chalkboard, Slides, and Paper to e-Learning: How Computing Technologies Have Transformed Anatomical Sciences Education*" and "*Cadaveric Dissection as an Educational Tool for Anatomical Sciences in the 21st Century*" showed higher links with other work (Ghosh, 2017; Trelease, 2016). These 3 publications were published in Anatomical Sciences Education, which is one of the respected journals in the field of anatomy, as well as about half of the publications on anatomy education and technology in the current study. The main explanation for this situation can be explained by the content of the journal, the compatibility relationship between the publication, the author and the journal. Researchers will follow a significant part of the publications that will shape the future about anatomy education, which probably includes technological materials, through these current journals.

The publications on technology in anatomy education have increased due to the use of digital technologies in the field of education as in every field and the limitation of face-to-face education due to pandemic conditions. However, educators should pay attention to the use of technology in anatomy education. It is too early to accept that technology will be useful in anatomy education. Randomized controlled studies are still needed to show which method or methods are effective (Singh et al., 2019). Quality and bias-free studies can enable anatomy educators to understand which technology to use and when to use them. It may be beneficial to match such emerging and developing digital technologies with the learning characteristics of individuals in anatomy education (Pringle and Rea, 2018).

The author keywords are an important part of the literature and can be used to reflect research points in a particular field (Qin et al., 2020). At this point, in a previous study investigating digital technologies in anatomy education by creating various keywords, it was determined that 3D virtual reality models were the most common and effective digital technology used, followed by internet-based resources and computer-assisted learning (Pringle and Rea, 2018). In the recent past, videos, computer aided teaching methods, multimedia media resources, plastic anatomical models and the use of plastination were frequently used in the past in terms of anatomy education (Estai and Bunt, 2016; Hulme and Strkalj, 2017; Ogunranti, 1987). In our study, besides the keywords containing education, keywords such as virtual reality, 3D printing and E-learning were the keywords at the forefront of technology. The keywords suggest that the technologies of anatomy education were becoming increasingly widespread and important.

In our study, it was seen that the authors who focus on anatomy education continue to use keywords such as "technological" and "cadaver dissection" or just "dissection". This indicates that an effective anatomy learning and teaching methodologies are still discussed in the literature. Although new trends in anatomical education are introduced, not all universities or training centres can meet these approaches. A curriculum plan that includes different combinations of anatomy teaching approaches is highly institution-specific. The cost of any method to be chosen may be much more important at this point. In a recent study, dissection, plastinated specimens, simulation, virtual dissection tables, plastic models and computer-aided teaching/learning methods were ranked from expensive to economical, respectively (Chumbley et al., 2020). In fact, it is a fact that, besides the high cost of using cadavers, there are many disadvantages such as cadaver supply, transportation, storage, short-term usability and psychological stress (Sahin and Cavus, 2019). At this point, perhaps computers will be preferred more by students and educators because they are advantageous in terms of both time and cost.

Contrary to studies stating that cadaver-based approaches are losing their effectiveness in anatomy education today (Singh et al., 2019; Turney, 2007), one of the keywords frequently used in our study is “cadaver dissection”. Our findings were in line with a previous study. The top-ten keywords featured in our current study reflect the link between technology and anatomy teaching. Immediately after these came “cadaver dissection”. This situation still points to the importance of traditional cadaver-based methods. Kurt et al. (2013) reported similar findings. Although the use of all these new and technologically developed methods has reduced both the time required for education and the cost of education, traditional cadaver teaching continues to be the preferred learning resource for medical students today. In addition, teaching based on prosection and plastination is more suitable for students of dentistry, pharmacy and related health sciences (Estai and Bunt, 2016). Anatomy knowledge is necessary in all invasive or non-invasive evaluation and treatment applications, especially in human surgical interventions (Turney, 2007). Therefore, it requires the best design of the anatomy curriculum in medical education. In our study, the keywords “cadaver dissection” and “dissection” had links with medical anatomy education in particular. These results suggest that the technological methods researched in anatomy education reflect the increasing search for alternatives due to the problems experienced with cadavers all over the world. As a matter of fact, recent research has emphasized that technological interventions and modern teaching methods should be preferred as an adjunct to or complementary to cadaver teaching in standardized medical curriculum (Kurt et al., 2013, Kumar and Singh, 2020; Zargaran et al., 2020).

The present study has some limitations. Since the study included results from only one database, publications related to the topic in other databases could not be evaluated. In addition, bibliometric indicators are limited to assessing the impact of research within the scientific community, and newer studies are disadvantaged here due to limited interaction. On the other hand, this study reveals the relationships between previous studies on anatomy education and technology, and provides an opportunity to identify common relationships in themes such as authors, countries, keywords of some frequently cited research and compilation publications. It also adds a different perspective to researchers by presenting a bibliometric methodology about studies on anatomy education and technology (Pringle and Rea, 2018; Zargaran et al., 2020) and the general trends of publications in recent years. It has been found that the publications on technology in anatomy have increased, especially the anatomy curriculum in medical faculties, and 3D printing, virtual reality, augmented reality and social media content are included. Reviewing this study while planning new studies on this specific topic may provide convenience to researchers, especially in terms of quickly evaluating cooperation between authors, publications and countries. For all these reasons, we think that the results of this study contain information that will guide researchers who are interested in anatomy education.

ETHICS APPROVAL

The study protocol was approved by the Clinical Research Ethics Committee of the university (Number: 2021/491).

AVAILABILITY OF DATA AND MATERIAL

The datasets used and/or analysed during the current study are available at the following URL: https://www.webofscience.com/wos/woscc/summary/536c467b-47e5-498d-ad8f-9fbffa51e612-1a1923e0/times-cited-descending/1

CONTRIBUTIONS

YEK and EA contributed to the study conception and design. Material preparation, data collection and analysis were performed by YEK. The first draft of the manuscript was written by YEK, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

REFERENCES

BAHŞI I, BAHŞI (2019) "Teşrih-ül Ebdan ve Tercümânı Kıbale-i Feylesûfan": the first illustrated anatomy handwritten textbook in Ottoman-Turkish medicine. *Surg Radiol Anat,* 41(10): 1135-1146.

CHUMBLEY SD, DEVARAJ VS, MATTİCK K (2021) An approach to economic evaluation in undergraduate anatomy education. *Anat Sci Educ*, 14(2): 171-183.

DE BAKKER FG, GROENEWEGEN P, DEN HOND F (2005) A bibliometric analysis of 30 years of research and theory on corporate social responsibility and corporate social performance. *Bus Soc*, 44(3): 283-317.

DUPARC F, GRIGNON B, KACHLIK D (2019) History in anatomy education. *Surg Radiol Anat*, 41(10): 1101-1102.

DUQUE OLIVA EJ, CERVERA TAULET A, RODRÍGUEZ ROMERO C (2006) A bibliometric analysis of models measuring the concept of perceived quality inproviding internet service. *Innovar*, 16(28): 223-243.

ELEAZER CD, SCOPA KELSO R (2018) Influence of study approaches and course design on academic success in the undergraduate anatomy laboratory. *Anat Sci Educ,* 11(5): 496-509.

ESTAI M, BUNT S (2016) Best teaching practices in anatomy education: A critical review. *Ann Anat,* 208: 151-157.

FALAH J, KHAN S, ALFALAH T, ALFALAH SF, CHAN W, HARRISON DK, CHARISSIS V (2014) Virtual Reality medical training system for anatomy education. *Science and Information Conference*, IEEE, 752-758.

FRANCHI T (2020) The impact of the Covid-19 pandemic on current anatomy education and future careers: a student's perspective. *Anat Sci Educ,* 13(3): 312-315.

GHOSH SK (2017) Cadaveric dissection as an educational tool for anatomical sciences in the 21st century. *Anat Sci Educ,* 10(3): 286-299.

HEBEBCI MT (2021) The bibliometric analysis of studies on distance education. *Int J Technol Educ*, 4(4): 796-817.

HSU YC, HUNG JL, CHING YH (2013) Trends of educational technology research: More than a decade of international research in six SSCI-indexed refereed journals. *Educ Technol Res Dev,* 61(4): 685-705.

HULME A, STRKALJ G (2017) Videos in anatomy education: history, present usage and future prospects. *Int J Morphol*, 35(4): 1540-1546.

IWANAGA J, LOUKAS M, DUMONT AS, TUBBS RS (2021) A review of anatomy education during and after the COVID-19 pandemic: Revisiting traditional and modern methods to achieve future innovation. *Clin Anat*, 34(1): 108-114.

JI P, JIN J, KE ZT, LI W (2022) Co-citation and co-authorship networks of statisticians. *J Bus Econ Stat,* 40(2): 469-485.

KUMAR R, R SINGH (2020) Model pedagogy of human anatomy in medical education. *Surg Radiol Anat,* 42(3): 355-365.

KURT E, YURDAKUL SE, ATAÇ A (2013) An overview of the technologies used for anatomy education in terms of medical history. *Procedia Soc Behav Sci,* 103: 109-115.

LIUPOST (2021) Bibliometrics: Tools and Software. Available at: https://liu.cwp.libguides.com/c.php?g=225325&p=4966525.

MAS-TUR A, ROIG-TIERNO N, SARIN S, HAON C, SEGO T, BELKHOUJA M, PORTER A, MERIGÓ JM (2021) Co-citation, bibliographic coupling and leading authors, institutions and countries in the 50 years of Technological Forecasting and Social Change. *Technol Forecast Soc Change,* 165: 120487.

MOXHAM BJ, O PLAISANT (2014) The history of the teaching of gross anatomy - how we got to where we are. *Eur J Anat,* 18: 219-244.

OGUNRANTI J (1987) Video technology in integrated anatomy education. *J EducTelev,* 13(1): 63-67.

PATHER N, BLYTH P, CHAPMAN JA, DAYAL MR, FLACK NAMS, FOGG QA, GREEN RA, HULME AK, JOHNSON IP, MEYER AJ, MORLEY JW, SHORTLAND PJ, ŠTRKALJ G, ŠTRKALJ M, VALTER K, WEBB AL, WOODLEY SJ, LAZARUS MD (2020) Forced disruption of anatomy education in Australia and New Zealand: an acute response to the Covid-19 pandemic. *Anat Sci Educ,* 13(3): 284-300.

PETEKKAYA E, KARADAĞ M, DOKUR M (2021) Bibliometric and altmetric analysis of publications examining education methods in realm of anatomy. *Eur Res J,* 7(4): 391-408.

PRINGLE Z, P REA (2018) Do digital technologies enhance anatomical education? *Practice Evidence Scholarship Teach Learn Higher Educ,* 13(1): 2-27.

QIN F, DU J, GAO J, LIU G, SONG Y, YANG A, WANG H, DING Y, WANG Q (2020) Bibliometric profile of global microplastics research from 2004 to 2019. *Int J Environ Res Public Health,* 17(16): 5639.

SAHIN T, CAVUS N (2019) Education in the digital age: technological trends in anatomy education. *Folklor/Edebiyat,* 25(97): 31-46.

SCHAEFER AF, WILSON AB, BARGER JB, AZIM HM, BROKAW JJ, BROOKS WS (2019) What does a modern anatomist look like? Current trends in the training of anatomy educators. *Anat Sci Educ*, 12(3): 225-235.

SCOTT T (1993) How we teach anatomy efficiently and effectively. *MedTeach,* 15(1): 67-75.

SINGH K, BHARATHA A, SA B, ADAMS OP, MAJUMDER, MAA (2019) Teaching anatomy using an active and engaging learning strategy. *BMC Med Educ,* 19(1): 1-8.

SUGAND K, ABRAHAMS P, KHURANA A (2010) The anatomy of anatomy: a review for its modernization. *Anat Sci Educ,* 3(2): 83-93.

TRELEASE RB (2016) From chalkboard, slides, and paper to e learning: How computing technologies have transformed anatomical sciences education. *Anat Sci Educ,* 9(6): 583-602.

TURNEY BW (2007) Anatomy in a modern medical curriculum. *Ann R Coll Surg Engl,* 89(2): 104-107.

VAN ECK NJ, WALTMAN L (2010) Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics,* 84(2): 523-538.

VAN ECK NJ, WALTMAN L (2014) Visualizing Bibliometric Networks. In: Ding Y, Rousseau R, Wolfram D (eds). *Measuring scholarly impact: Methods and practice*. Springer, Cham, pp 285-320.

VAN RAAN A (2003) The use of bibliometric analysis in research performance assessment and monitoring of interdisciplinary scientific developments. *TATuP-Zeitschrift Technikfolgenabschätzung Theorie Praxis,* 12(1): 20-29.

ZARGARAN A, TURKI MA, BHASKAR J, SPIERS HVM, ZARGARAN D (2020) The role of technology in anatomy teaching: striking the right balance. *Adv Med Educ Pract,* 11: 259-266.