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Bibliometric and altmetric analysis of publications examining education methods in realm of anatomy

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ABSTRACT

Objectives: This study aimed to investigate the significance of publications examining the effectiveness of education methods in the field of anatomy with the method of bibliometric and altmetric analysis, as well as online attention levels.

Methods: To search all publications, "Anatomy education" was entered as a search term on the Web of Science database. The topics, journal impact factors, publication years and research centers of the first 100 articles with the highest numbers of citations were examined, and their analysis was conducted with the "Altmetric it on website: http: almetric.com".

Results: Four thousand, three hundred fifty-six articles published in the period of 1975-2019 containing the key phrase "Anatomy education" were found on Web of Science. The study with the highest number of citations was the study published by McLachlan *et al*. titled "Teaching anatomy without cadavers, 2004". It was observed that the study titled "The production of anatomical teaching resources using three-dimensional (3D) printing technology, 2014" was the article with the highest rate of sharing on Twitter with the highest altmetric attention score (AAS) value. The AAS rates varied between 130 and 0.

Conclusions: Bibliometric and altmetric analysis provides significant but different points of view regarding the effects of an article in the world of science. The altmetrics score may provide contributions in determining the direction of studies regarding the high-level interests and perceptions of the public on dynamic science and the field of medicine.

Keywords: Bibliometric, altmetrics, analysis, anatomy, educational methods

It is important to assess the effectiveness of medical education in today's conditions with evidence-based analyses, because these assessments have the potential of directing practices of developing curricula. While anatomy education is the building block of medicine, it is seen by students as a difficult to learn subject at the beginning of medical education [1]. The rapid development of technology has allowed development of various methods that present the practical ways of learning anatomy today. The practices of anatomy education have been enriched by cadaver dissection coming from traditional medical education, followed by plastic modellings of body parts and highly diverse online electronic sources that provide information gathering methods today, interactive three-dimensional (3D) visualization technologies and

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"multimodal" approaches such as radiological imaging [2]. Especially 3D mobile applications that include virtual anatomy animations supported by videos, YouTube videos and animations obtained from other social sharing sites, colorful 3D images and problem-focused learning have taken their place as the current methods used in anatomy education [3, 4]. With the initiatives of anatomy educators to preserve traditional basic training methods such as dissection, there has been a face off between some clinical field educators that have transitioned to virtual simulative applications and conventional educators [2].

In this context, a process that gives rise to a necessity of updating the curriculum with various education and instruction methods has emerged. In addition to these methods, sharing of anatomy information via social networks today has started to be used by students as a learning method. For this reason, investigating the usage of existing anatomy learning methods and social platforms today for medical instruction purposes and shedding light on anatomy education have become a current need. For this purpose, we aimed to investigate publications that examine existing anatomy learning methods that are prevalently used by using metric methods. Especially bibliometric analysis (index criteria) is used in several fields to define the most significant studies [5]. This analysis method uses citation ranking to define the output with the largest intellectual effect in ranking articles.

The number of citations made to published articles is a reference in measuring the influence of the journal they are published in and assessing the capability of authors, and it is based on bibliometrics, which investigates such associations. Other important indicators that show the effect and quality of a journal are the journal impact factor (IF) which is based on citations and the h-index value provided by Web of Science (WoS), Scopus, Google Academics and Scimago Journal & Country Rank (SJCR) [6, 7]. IF is a significant bibliometric indicator that needs to be used carefully as it is known to be a value in which several criteria play a role on the final value. JCR calculates the citations and publications of the last two years and returns the value of IF every September [12]. It is clearly seen that although it allows the evaluation of large data sets, keeping track of changes in citation databases over time and evaluating journal IF that vary from year to year creates measurement and technical problems for bibliometric analysis.

Altmetrics, which is a new web-based metric analysis method, has started to be used as a current method in assessing the impact analyses of publications on social media platforms [14]. This method that conducts an analysis as the Altmetric Attention Score (AAS) and Altmetric feedback was designed to make it easier to define how much and what type of interest a certain research output receives [15]. AAS is calculated by an automated algorithm created by the company Altmetric based on the weighted quantity of the online interest received by a research output. This algorithm that is used under the name of Altmetric Explorer (Altmetric, London, the United Kingdom) Score is a web-based application that can use some research output resources to present the online activities of publications and the most relevant discussion forms in a current sense [15]. While making calculations, three main factors are used to determine the weights: volume, sources and authors. The role of social media platforms in the publicity, dissemination and presentation of the medical literature was increased substantially in the last few years [17]. Altmetrics are advantageous in that they can reflect significant non-academic effects and are visible before even academic citations occur, but they also have some disadvantages. At the beginning of these disadvantages, we can say that it is still not clear which general conclusion to draw from the altmetric analysis. In addition, data sparseness is an important disadvantage that makes altmetric analysis insufficient alone.

In this context, this study aimed to determine the relationship between bibliometric analysis on the number of citations of articles and journal IF values and Altmetric analysis (highest AAS and IF) which determine the social media usage score of studies in determining the quantitative impacts of methods in the field of anatomy in the world of medicine.

METHODS

In this study, WoS Core Collection database was used for bibliometric citation analysis and PubMed was used for other article information. PubMed data was used to see the total number of authors of the article and the type of article (eg Review etc.) and to evaluate the altmetric score on the "altmetric it / alt-

metric.com" website. The WoS database was accessed (date of access: 15 January 2020) to determine the publications between 1975 and 2019 that contained the key phrase "Anatomy Education". As the WoS article database includes articles that have been published since 1975 on February 15, 2020, our access date, earlier articles could not be reached. As a result, 4356 articles related to the subject were obtained, and among these results, the 100 articles that received the most citations (T100) were subjected to bibliometric and altmetric score analysis. After writing "Anatomy education" in the "topic" criterion in WoS, there were articles outside the scope of anatomy education among the articles exhibited. For this reason, during the creation of the T100 article list, the Pubmed MESH terms were first examined to evaluate whether the studies were covered by the term "Anatomy education". In addition, the abstracts of the articles were read independently and carefully by the article researchers and the compatible articles with the subject of anatomy education were determined. The full texts of the articles, whose article summary was not clear enough, were also examined and carefully evaluated in such a way that bias was not allowed. At the end of these evaluations, articles that fall within the scope of "Anatomy education" are included in the study list, while other articles were excluded from the study as they are outside the scope of "Anatomy education". Subsequent articles were included within the scope to complement 100 in place of the articles that were omitted. For the studies published in the relevant field, name of the journal of publication, journal IF (2019 Journal Citation Reports (Clarivate Analytics)), year of publication, topic of article, type of article and sub-types were determined.

The AASs were obtained from the Altmetric.com website (https://www.altmetric.com/products/free-tools/bookmarklet/) by using the "Altmetric it" function. Each color in altmetric feedback represents a different source from the social media sharing network [18]. As Altmetric Explorer is a licensed application, Altmetric it was used instead. In the color spectrum of feedback, blue represents Twitter, dark blue represents Facebook, yellow represent blogs, red represents news stories, orange represents patents, pink represents Google, and brown represents Wikipedia (Fig. 1). The study included original research articles, review articles, conference manuscripts and letters to the editor. Additionally, PubMed was utilized to obtain additional data for the study. This study did not need to be approved by an ethics committee, because it only conducted bibliometric and altmetric analyses on classical studies that have been published.

Statistical Analysis

To determine the relationships between the number of citations of the selected T100 anatomy education articles and AAS and between IF and AAS, descriptive statistics was revealed and evaluated, and Spearman's correlation analyses were carried out in SPSS package software.

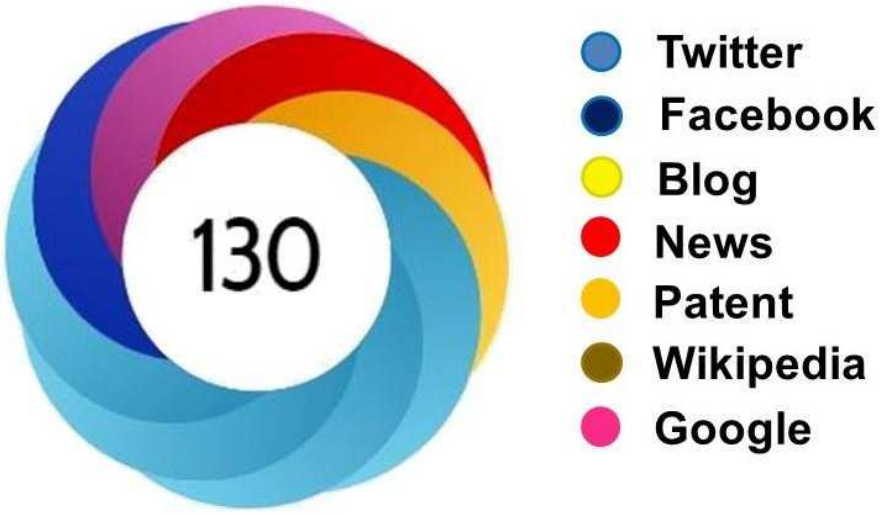

Fig. 1. Example of altmetric feedback scoring sources.

RESULTS

In the search for publications in the period of 1975-2019 on WoS containing the key phrase "Anatomy education", 4356 articles were found. The T100 list on anatomy education shown in the literature was examined (Supplementary Table 1). In the list, the publications' numbers of citations, journals of publication, the highest numbers of publications based on years and AAS values were shown.

Sixty-eight of the T100 articles in this study were published in journals with an IF value of at least 2. According to Clarivate Analytics (2017), the average IF of 10 journals (Table 1) out of 26 journals in which at least two T100 articles were published was found, was 2.987, and the average h-index value was 80. The number of citations of the studies varied between 29 and 268. The study with the highest number of citations was published by McLachlan *et al*. [Suppl. Table 1 Rank 1] with the title "Teaching anatomy without cadavers, 2004". The one with the lowest number of citations was published by Baskaran *et al*. [Suppl. Table 1 Rank 100] with the title "Current applications and future perspectives of the use of 3D printing in anatomical training and neurosurgery".

Considering the publication years of the articles, it was determined that the time that passed since the article in the first place showed a change in favor of citations. Concerning the numbers of citations based on years, it was determined that the T100 publications almost did not receive any citations in 1998 and 1999, their numbers of citations continued to increase in the following years, and the highest number of citations was in 2019 (Fig. 2). Considering the distribution of the publications on the topic of anatomy education based on years, while there was no publication in the years 1997 and 1998 among the articles, the lowest number of publications were in 1996 and 2003 by one article each, while the highest numbers of publications were in 2007 and 2016 (Fig. 3).

The journal with the highest number of publications in this field was "Anatomical Sciences Education" with 39 publications, which was followed by "Clinical Anatomy" in the second place with 19 and "Medical Education" in the third place with 13 publications. On the field of anatomy education, the Journals Anatomical Record, ANZ Journal of Surgery, Computers Education and Surgical and Radiologic Anatomy had 2 publications each (Table 1).

Among the T100 articles with the highest numbers of citations, 86 were research articles, 6 were reviews, 5 were verbal presentations, and 3 were letters to the editor. The highest number of original articles published in the relevant field was 34 for the period of 2006-2010, the highest number of reviews was 4 for 2011-2015, and the highest number of verbal presentations was 2 for 2011-2015 (Table 2).

Considering the countries of publication of these articles, the United States of America (USA) had the first place with 37 publications, while the United Kingdom was in the second place with 18 publications, and Australia was in the third place with 15,

Table 1. Journals where the T100 articles with most citations were published

Rank	Journals	Amount	IF	H Index	Q Category
1	Anatomical Sciences Education	39	4.027	38	Q1
2	Clinical Anatomy	19	1.813	62	Q2
3	Medical Education	13	4.619	120	Q1
4	Annals of Anatomy	3	2.241	45	Q2
5	Medical Teacher	3	2.706	91	Q1
6	Academic Radiology	2	2.110	87	Q1
7	Anatomical Record	2	1.329	84	Q2
8	Anz Journal of Surgery	2	1.605	69	Q3
9	Computers Education	2	5.627	149	Q1
10	Surgical and Radiologic Anatomy	2	1.039	52	Q2

*Journals with 2 or more publications are listed.

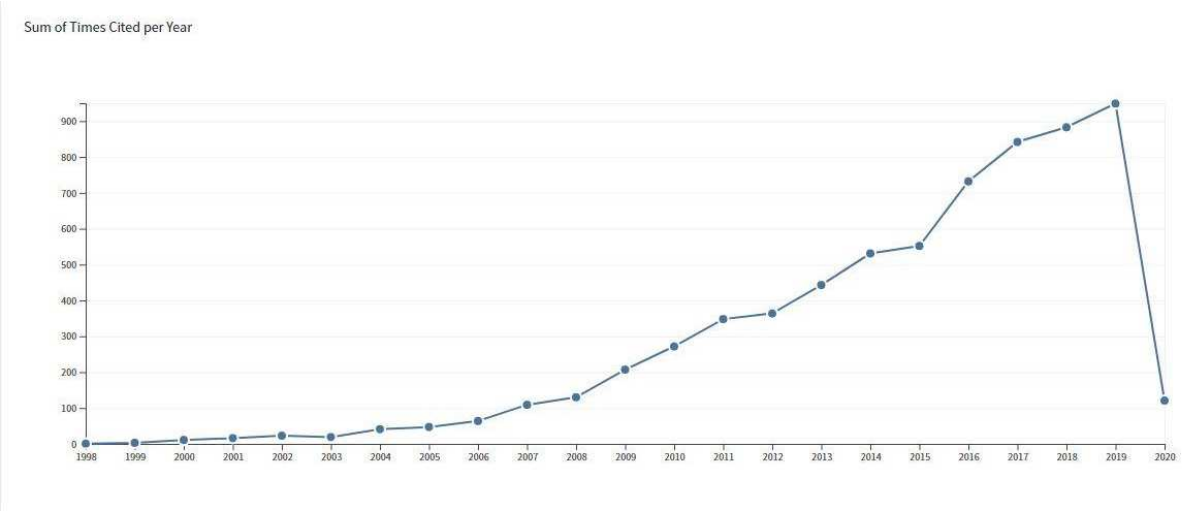

Fig. 2. Number of citations of publications in the field of anatomy education by years.

whereas 70% of the T100 articles were found to have been published by these three countries. The years with most publications for the USA and UK were 2006-2010, while Australia published more in the period of 2011-2015 in comparison to the other years (Table 2). From Turkey, only the article by Küçük. *et al*. [Suppl. Table 1 Rank 84] titled "Learning anatomy via mobile augmented reality: effects on achievement and cognitive load, 2016" was in this list.

When the types of research centers where the publications were made were examined, it was seen that these centers mostly operate in the fields of Education and educational research, Anatomy morphology and Health sciences. The highest number (68) and ratio (48.83%) of the articles were in the field of education research, which naturally included studies on education. As seen in Table 3, it was observed that the number higher than 100 in the T100 list was caused by separate assessment of multidisciplinary studies and other fields.

The AAS values varied between 0 and 130. The article "The production of anatomical teaching resources using three-dimensional (3D) printing technology, 2014" (score 130) had the highest AAS score and most shares on Twitter. It was determined that it gained a fast scoring with social media shares although it was published on a close date. The T100 anatomy education articles' AAS, total number of citations, citations based on years, IF and h-index values are shown in Table 4. Accordingly, for the T100 articles ranked based on their total number of citations, the mean ASS was 5.29 ± 40.44, and the mean total num-

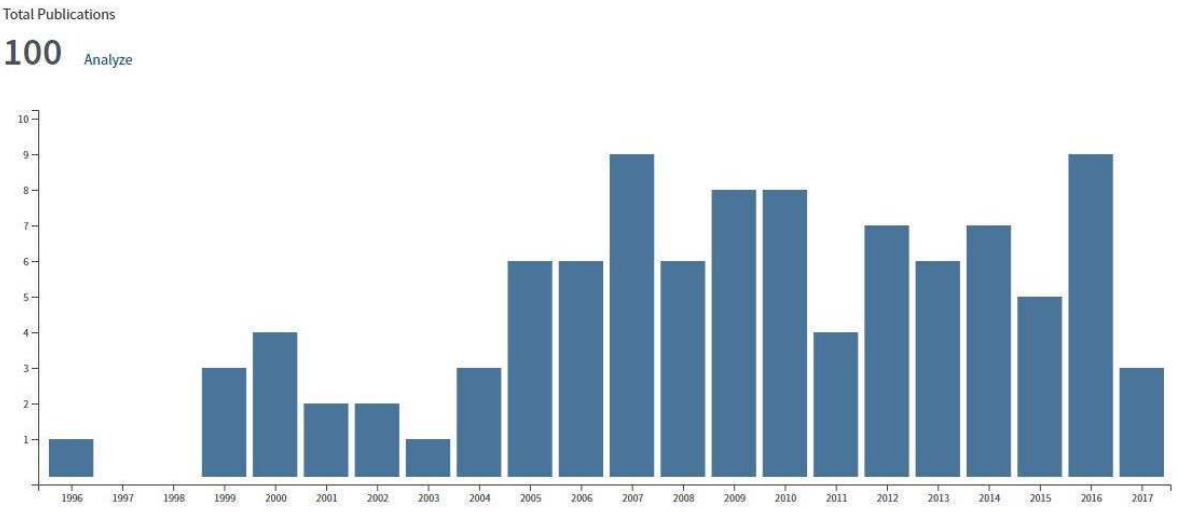

Fig. 3. Distribution of publications in the field of anatomy education by years.

Table 2. Distribution of types of study and countries of the T100 articles with most citations based on years

		Years										
		< 2000		2001-2005		2006-2010		2011-2015		2016-2020		
		n	%	n	%	n	%	n	%	n	%	Sum
Study Type	Original article	8	88.90	12	92.30	34	91.90	21	75.00	11	84.60	86
	Review	0	0.00	0	0.00	1	2.70	4	14.30	1	7.70	6
	Oral presentation	1	11.10	0	0.00	1	2.70	2	7.10	1	7.70	5
	Letter to the editor	0	0.00	1	7.70	1	2.70	1	3.60	0	0.00	3
Countries	Germany	1	11.10	0	0.00	4	10.80	0	0.00	0	0.00	5
	USA	7	77.80	5	38.50	13	35.10	7	25.00	5	38.50	37
	Australia	1	11.10	1	7.70	4	10.80	5	17.90	4	30.80	15
	United Arab Emirates	0	0.00	0	0.00	0	0.00	3	10.70	0	0.00	3
	France	0	0.00	0	0.00	1	2.70	1	3.60	0	0.00	2
	England	0	0.00	5	38.50	6	16.20	5	17.90	2	15.40	18
	Ireland	0	0.00	0	0.00	0	0.00	0	0.00	2	15.40	2
	Spain	0	0.00	0	0.00	3	8.10	2	7.10	0	0.00	5
	Sweden	0	0.00	0	0.00	2	5.40	1	3.60	0	0.00	3
	Italy	0	0.00	1	7.70	0	0.00	1	3.60	0	0.00	2
	Canada	0	0.00	1	7.70	4	10.80	3	10.70	0	0.00	8
	Sum	9	100.0	13	100.0	37	100.0	28	100.0	13	100.0	

Table 3. Research centers where the T100 articles with most citations were conducted.

Rank	Research type	n	%
1	Educational Research	63	48.83
2	Morphological Anatomy	27	20.93
3	Health Sciences	18	13.95
4	Surgery	6	4.65
5	Radiological Nuclear Medicine	5	3.87
6	Computer Science	3	2.32
7	Neuroscience, Neurology	2	1.55
8	Acoustic	1	0.78
9	General Internal Medicine	1	0.78
10	Science Technology Other Subjects	1	0.78
11	Social Sciences Other Subjects	1	0.78
12	Veterinary Sciences	1	0.78
	Sum	129	100

Table 4. Number of citations, AAS and IF of the journals published the T100 anatomy education articles

	Mean ± SD	P25	Median	P75
Altmetric score	5.29 ± 40.44	0.00	0.00	3.00
Total citations	66.84 ± 1.23	39.50	48.50	87.50
Number of citations per year	6.33 ± 35.73	3.33	5.47	7.86
IF	3.31 ± 15.70	1.81	4.03	4.03
H Index	65.75 ± 3.87	38.00	54.00	84.00

ber of citations was 66.84 ± 1.23. The mean number of citations per year was 6.33 ± 35.73, the mean IF was 3.31 ± 15.70, and finally, the mean h-index was 65.75 ± 3.87 (Table 4).

Correlation analyses were conducted to determine the relationship between AAS and the number of citations based on years and h-index. While there was a positive moderate relationship between AAS and number of citations based on years (r = 0.428), AAS and h-index had a negative weak relationship (r = -0.358). Likewise, there was a positive weak relationship between IF and h-index and number of citations based on years. There was no significant relationship between total number of citations and AAS (Table 5).
The variation of the instruction methods used in anatomy education was determined (Table 6). A broad scale of anatomy learning methods was determined to include current methods in the form of virtual and augmented reality applications, mobile technology applications in the form of ultrasonography, virtual simulators, laparoscopy and other radiological imaging methods, clinical anatomy instruction methods, outputs obtained by 3D printer technology, plastination, web-based interactive 3D visualization, enriched multimedia e-book applications, close peer, problem-focused instruction, clay models, and YouTube and social media sharing. Comparisons of education with and without cadavers had a significant place. While there was also an education method in the form of integrated multimodal-multidisciplinary and blended instruction method examinations, this method involved comparison of several models.

DISCUSSION

For the purpose of determining the effectiveness of methods that are used in the field of anatomy education, determining the online interest value and social media sharing scores of articles published on this topic and received the highest numbers of citations is highly

Table 5. Correlation analysis of the relationship between AAS and number of citations by year and h-index

		Total citations *	Number of citations per year	H Index	IF
Altmetric scoring	r	-0.051	0.428	-0.358	**0.002**
	p value	0.616	**< 0.001**	**< 0.001**	0.983
Total citations *	r		0.555	0.266	0.166
	p value		**< 0.001**	**0.009**	0.106
Number of citations per year	r			-0.192	0.277
	p value			0.060	**0.006**
H Index	r				0.123
	p value				0.231

r = Spearman's correlation coefficient

Table 6. The most prevalent instruction modalities that are currently used in anatomy education

Rank	Anatomy education methods	Classification	Amount
1	Teaching with cadaver and dissection	I	14
2	Teaching with virtual reality, mobile augmented reality and mobile technology	II	18
3	3D computer modeling and digital animated teaching	III	10
4	Anatomy teaching in clinical applications (Through Ultrasound imaging, Laparoscope imaging, Surgical simulators, Other radiological imaging techniques)	IV	12
5	Computer assisted teaching	V	10
6	Integrated multimodal-multidisciplinary and blended teaching	VI	11
7	Teaching with Youtube	VII	7
8	Teaching with 3D printer technology	VIII	4
9	Other:	IX	14
	Problem-based teaching (3)		
	Near peer teaching (3)		
	Teaching with clay models (1)		
	Teaching with plastination (2)		
	Anatomy teaching with social media (1)		
	Teaching with enriched multimedia Ebook application (1)		
	Teaching with web-based interactive 3D visualization (3)		

important in terms of determining trends towards the future. There are numerous studies and discussions carried out on suitable methods in obtaining academic information. Measuring the value and impact of studies and determining the trending topics are a significant criterion in determining the direction of studies. Considering that studies covering the comparative examinations of current practices used in anatomy education were conducted mostly in the period of 2007-2016, it was thought that this situation may be related to the date where especially virtual reality applications started to enter education. Virtual reality studies started to be carried out in 2006, and virtual reality became included in the education process as a technology-integrated instrument [19].

AAS assessment in our study revealed that the articles shared via social networks were rather on looking for answers to the question of "how to learn anatomy", and the effects of current practices such as "the contribution of 3D applications on anatomy education" were investigated. As Marsland and Lazarus [20] in 2018 stated in their work, information sharing via social media is more popular with students due to the continuous existence of technology throughout the lives of young people, and that it is an international academic platform for sharing knowledge and education research experiences among academicians. This situation showed that youths focused on studies on learning methods involving current techniques rather than conventional ones. When studies on learning with YouTube videos, which is another method used in anatomy education, is examined by bibliometric analysis, it was stated that YouTube videos would display low educational value in the case that they are not checked by member of academia [21-23]. In their study on the learning levels of students with anatomy education videos uploaded on YouTube, Jaffar [24] in 2012 emphasized that videos could be useful, but their effect on examination performance is weak, and students prefer to learn surface anatomy by cadavers and

models. This idea was supported by the findings that YouTube videos and three-dimensional virtual reality videos have lower value in terms of education then dissections [25]. On the other hand, Winkellman [26] in 2007 reported that anatomy teaching with living beings and medical imaging methods is dominant over cadaver teaching. They added that these methods, which are especially advantageous for visual learners, are more compatible with clinical examination [26]. However, teaching about the 3D structure of the human body using 2D images is highly complicated. It is especially more difficult to perform volumetric examinations on the organs and structures that are desired to be imaged. For this reason, anatomic applications created in 3D are seen as an important method in making it easier to access structures by three-dimensional imaging.

Besides, teaching with cadavers should not be underestimated by relying solely on social media posts. Wilson *et al*. [27] in 2018 advocated the idea that the anatomical knowledge obtained by teaching with cadaver dissection remains in mind for a longer term in the temporal course in their studies where anatomy teaching methods were examined using meta-analysis method. However, they still recommended the examination and dissection of cadavers in the post-graduation surgical training of cadaver training.

When the social media sharing frequency of the article with the highest AAS (130) in our study, "The production of anatomical teaching resources using three dimensional (3D) printing technology," is examined, it was determined that it was shared via Twitter 30 times, Facebook 7 times, Google users 6 times, blogs 4 times and other networks 10 times. The highest number of shares made for the article with the second highest AAS, "Human cadaver vs. multimedia simulation: a study of student learning in anatomy," was again on Twitter. These findings confirm the comments of previous studies concluded that students and academicians have increased their interest in teaching styles with increased visual aspects. Regardless, as reported by Marsland and Lazarus [20], MD discussions around the anatomy teaching on twitter shows the need to develop potential educational resources to eliminate the difficulty in teaching and learning difficult areas in anatomy education.

It is highly important to comprehend basic anatomy in terms of being able to make the connections between anatomy knowledge and the clinic and integrate knowledge in surgical practices. For this reason, developing effective methods to teach anatomy is very important for medical practices. Since the Renaissance, cadaver dissection is still considered to be the most ideal and universal method for this purpose, and thus, it continues to be used as the building block of anatomy education [1, 28]. Moreover, considering the increasing prevalence of robotic surgeries, it may be stated that application of cadaver surgery and virtual simulations together could be more ideal. Students are no longer satisfied with looking at the pictures of a textbook or observing from the corner of a crown surrounding a cadaver [29]. Therefore, it was thought that in could be sufficient in meeting educational needs for educators to plan a modern anatomy education that will integrate "new and old" approaches for these searches of students and put these plans into practice.

Altmetric scoring assesses an interest shown in a publication from a different perspective. While a relationship is expected between bibliometric and altmetric assessment, such a relationship could not be found in the analyses that were conducted. An interesting finding in our study was that the articles with the highest IF values did not receive more interest than the ones with low IF values. For example, journals like Computers Education, Medical Education and Anatomical Sciences Education that are included in the high-IF journal list or contributed to a large number of articles in the field of anatomy education were observed to be not in the highest rating in terms of Altmetric scoring. While it was expected for the relationship between altmetric scoring and number of citations based on years to be stronger, it was determined that this relationship was moderate. Due to the contribution of the public in addition to the scientific world to the scores of articles shared on social networks, it was considered that the main factor determining the direction is the attractiveness of the topic. eBizMBA Inc. [30] in 2020 listed the most popular social websites worldwide as Facebook, YouTube, Instagram and Twitter and stated Facebook as the most popular among these. The popular social networks in the list followed as WhatsApp, Pinterest, Reddit, Ask.fm, Tumblr, Flickr, SnapChat, VK, LinkedIn, Tagged and

Meetup.

Although eBizMBA stated that Facebook is the most popular social network for sharing, it was seen that literature sharing was carried out more on Twitter. Marsland and Lazarus [20] in 2018 reported that an online community has formed on Twitter regarding literature sharing, but the impact of Twitter has not been completely demonstrated in anatomy instruction. They showed that Twitter could only be an instrument that strengthens the collaboration and communication of students with academicians, and social platforms may only have a useful impact under the appropriate guidance of academicians. Facebook is the most popular social media site visited daily by university students in integrating social media technologies into education. In their study that examined the usage activity of Facebook for the purpose of education in the field of anatomy, Jaffar [21] in 2014 reported that it has a natural potential in increasing learning in students, and it may be accepted as an instruction tool supportive of conventional education.

AASs are observed to provide new points of view in collecting scientific information. However, as the Altmetric system has started to collect data since the end of 2011, this method is only sensitive for later news. It may be considered that new articles may receive more AAS in time and lead to some incomplete interpretations. For this reason, by using bibliometric analysis, the weak aspect of the method was strengthened. Another important issue that should not be overlooked in AASs is social media policies of journals. Managers of some journals can develop planning digital scientific marketing practices for such social media metrics, which can influence the social media visibility of the journal and hence the journal's publications. This can be an important study topic that needs careful consideration. Even so it may be stated that AAS may be an indicator of the perceptions of the public on the dynamic field of science and medicine, and it will make it easier to determine the direction of studies in line with the high levels of interest by the public in time. It may also be considered as a catalyst that encourages reading scientific articles on a topic that is considered valuable by the public.

CONCLUSION

In this study, articles that examined instruction resources and strategies that are used in the discipline of anatomy were evaluated with analysis methods that allow looking from a broad perspective. The necessity of planning an anatomy education that comprehensively integrates conventional and modern approaches and the necessity of presenting these in practice were determined by the analyses. It may be stated that there is no strong evidence yet to suggest that social networks are strong anatomy instruction instruments. While the interest received by a scientific study in the literature is usually measured by the number of citations it receives, the interest received by it in the public is measured with parameters such as the number of news stories published on it and the speed of being shared on social platforms. Consequently, for being able to more comprehensively assess scientific research outputs, we recommend assessment of AAS and conventional metrics in combination.

Authors' Contribution

Study Conception: EP; Study Design: MD; Supervision: EP, MD; Funding: EP; Materials: EP, MD; Data Collection and/or Processing: EP, MD; Statistical Analysis and/or Data Interpretation: MK; Literature Review: MK, EP, MD; Manuscript Preparation: EP, MD, MK and Critical Review: EP, MD, MK.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

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Supplementary Table 1. Details of the T100 list on anatomy education

Rank	Article Title	Journal	Volume	Year	First Author	TCited*	Average Citations per Year**	Altmetric Score
1	Teaching anatomy without cadavers	Medical Education	38	2004	McLachlan, JC	268	15.76	7

Supplementary Table 1. Cotinued.

Rank	Article Title	Journal	Volume	Year	First Author	TCited*	Average Citations per Year**	Altmetric Score
2	The production of anatomical teaching resources using three dimensional (3D) printing technology	Anatomical Sciences Education	7	2014	McMenamin, PG	174	24.86	130
3	Anatomical dissection as a teaching method in medical school: a review of the evidence	Medical Education	41	2007	Winkelmann, A	174	12.43	4
4	Can virtual reality improve anatomy education? A randomised controlled study of a computer-generated three-dimensional anatomical ear model	Medical Education	40	2006	Nicholson, DT	148	11.47	1
5	Do we need dissection in an integrated problem-based learning medical course? Perceptions of first- and second-year students	Surgical and Radiologic Anatomy	29	2007	Azer, SA	148	10.57	3
6	A pilot study of comprehensive ultrasound education at the Wayne state university school of medicine - A pioneer year review	Journal of Ultrasound in Medicine	27	2008	Rao, S	143	11.00	3
7	"Let's Get Physical": Advantages of a physical model over 3D computer models and textbooks in learning imaging anatomy	Anatomical Sciences Education	6	2013	Preece, D	129	16.13	5
8	The dissection course - necessary and indispensable for teaching anatomy to medical students	Annals of Anatomy-Anatomischer Anzeiger	190	2008	Korf, HW	129	9.92	0
9	Near-peer teaching in anatomy: an ppproach for deeper learning	Anatomical Sciences Education	2	2009	Evans, DJR	125	10.42	4
10	Web-based interactive 3D visualization as a tool for improved anatomy learning	Anatomical Sciences Education	2	2009	Petersson, H	121	10.08	0
11	Mortui vivos decent? The evolving purpose of human dissection in medical education	Academic Medicine	75	2000	Dyer, GSM	121	5.76	0
12	Survey of clinicians' attitudes to the anatomical teaching and knowledge of medical students	Clinical Anatomy	18	2005	Waterston, SW	118	7.38	0
13	Perceptions of dissection by students in one medical school: beyond learning about anatomy. A qualitative study	Medical Education	39	2005	Lempp, HK	114	7.13	0
14	Does problem-based learning lead to deficiencies in basic science knowledge? An empirical case on anatomy	Medical Education	37	2003	Prince, KJAH	114	6.33	0
15	Reciprocal peer teaching: Students teaching students in the gross anatomy laboratory	Clinical Anatomy	18	2005	Krych, AJ	109	6.81	0

Supplementary Table 1. Continued.

Rank	Article Title	Journal	Volume	Year	First Author	TCited*	Average Citations per Year**	Altmetric Score
16	Effectiveness of using blended learning strategies for teaching and learning human anatomy	Medical Education	41	2007	Pereira, JA	108	7.71	0
17	The relationships between learning outcomes and methods of teaching anatomy as perceived by professional anatomists	Clinical Anatomy	21	2008	Patel, K	105	8.08	0
18	Integrating professionalism in early medical education: the theory and application of reflective practice in the anatomy curriculum	Clinical Anatomy	19	2006	Lachman, N	105	7.00	1
19	The gross anatomy course: an analysis of its importance	Anatomical Sciences Education	3	2010	Boeckers, A	99	9.00	0
20	Modernization of an anatomy class: from conceptualization to implementation. A case for integrated multimodal-multidisciplinary teaching	Anatomical Sciences Education	5	2012	Johnson, EO	97	10.78	2
21	YouTube: an emerging tool in anatomy education	Anatomical Sciences Education	5	2012	Jaffar, AA	96	10.67	15
22	Medical students' learning of anatomy: memorisation, understanding and visualisation	Medical Education	41	2007	Pandey, P	94	6.71	
23	Evaluation of computer-aided instruction in a gross anatomy course: a six-year study	Anatomical Sciences Education	2	2009	McNulty, JA	92	7.67	
24	Use of 3D printed models in medical education: a randomized control trial comparing 3D prints versus cadaveric materials for learning external cardiac anatomy	Anatomical Sciences Education	15	2016	Lim, KHA	89	17.80	12
25	A novel three-dimensional tool for teaching	Human Neuroanatomy.	3	2010	Estevez, ME	88	8.00	7
26	Virtual reality and brain anatomy: a randomised trial of e-learning instructional designs	Medical Education	41	2007	Levinson, AJ	87	6.21	0
27	Teaching anatomy: cadavers vs. computers?	Annals of Anatomy-Anatomischer Anzeiger	188	2006	Biasutto, SN	87	5.80	0
28	Using multimedia and Web3D to enhance anatomy teaching.	Computers & Education	49	2007	Brenton, H	84	6.00	0
29	Best teaching practices in anatomy education: a critical review.	Annals of Anatomy-Anatomischer Anzeiger	208	2016	Estai, M	83	16.60	0

Supplementary Table 1. Continued.

Rank	Article Title	Journal	Volume	Year	First Author	TCited*	Average Citations per Year**	Altmetric Score
30	Computer-aided learning: an overvalued educational resource?	Medical Education	33	1999	Devitt, P	76	3.45	0
31	Restructuring a basic science course for core competencies: an example from anatomy teaching	Medical Teacher	31	2009	Gregory, JK	75	6.25	0
32	Teaching and learning gross anatomy: dissection, prosection, or "both of the above?"	Clinical Anatomy	12	1999	Dinsmore, CE	73	3.32	0
33	Anatomical dissection: Why are we cutting it out? Dissection in undergraduate teaching.	ANZ Journal of Surgery	31	2002	Parker, LM	71	3.74	2
34	Ultrasound anatomy: a practical teaching system in human gross anatomy	Medical Edication	30	1996	Teichgraber, UKM	71	2.84	0
35	The relative effectiveness of computer-based and traditional resources for education in anatomy	Anatomical Sciences Education	6	2013	Khot, Z	69	8.63	3
36	Integration of ultrasound in the education programme in anatomy	Medical Edication	11	2005	Tshibwabwa, ET	69	4.31	0
37	Importance of dissection in learning anatomy: personal dissection versus peer teaching	Clinical Anatomy	15	2002	Johnson, JH	67	3.53	0
38	Dissection as a modulator of emotional attitudes and reactions of future health professionals	Medical Edication	42	2008	Arraez, A	66	5.08	0
39	Advanced 3D visualization in student-centred medical education	Medical Teacher	30	2008	Silen, C	62	4.77	0
40	The role of three-dimensional information in health care and medical education: the implications for anatomy and dissection	Clinical Anatomy	13	2000	Marks, SC	62	2.95	0
41	Complementing anatomy education using three-dimensional anatomy mobile soware applications on tablet computers	Clinical Anatomy	27	2014	Lewis, TL	60	8.57	7
42	Medical students' approaches to learning anatomy: students' experiences and relations to the learning environment.	Clinical Anatomy	23	2010	Smith, CF	55	5.00	1
43	Anatomy education for the YouTube generation	Anatomical Sciences Education	9	2016	Barry, DS	54	10.80	15
44	Evaluation of a surgical simulator for learning clinical anatomy	Medical Education	38	2004	Hariri, S	53	3.12	0

Supplementary Table 1. Continued.

Rank	Article Title	Journal	Volume	Year	First Author	TCited*	Average Citations per Year**	Altmetric Score
45	Ultrasound and cadaveric prosections as methods for teaching cardiac anatomy: a comparative study	Anatomical Sciences Education.	5	2012	Griksaitis, MJ	52	5.78	3
46	Mirracle: an augmented reality magic mirror system for anatomy education	İEE Virtual Reality Conference	…	2012	Blum, T	52	5.78	0
47	The value of teaching sectional anatomy to improve CT scan interpretation	Clinical Anatomy.	14	2001	De Barros, N	52	2.60	0
48	From Chalkboard, slides, and paper to e-learning: how computing technologies have transformed anatomical sciences education	Anatomical Sciences Education.	9	2016	Trelease, RB	49	9.80	5
49	Back to the future: teaching anatomy by whole-body dissection	Medical Journal of Australia.	193	2010	Ramsey, G	49	4.45	0
50	Learning of cross-sectional amatomy using clay Models	Anatomical Sciences Education	2	2009	Oh, CS	49	4.08	1
51	Can "YouTube" help students in learning surface anatomy?	Surgical and Radiologic Anatomy	34	2012;	Azer, SA	48	5.33	3
52	Computer visualizations: factors that influence spatial anatomy comprehension	Anatomical Sciences Education	5	2012	Ngan, N	48	5.33	0
53	A meta-analysis of the educational effectiveness of three-dimensional visualization technologies in teaching anatomy	Anatomical Sciences Education	8	2015	Yammine, K	46	7.67	0
54	The application of 3D printing in anatomy education	Medical Education Online	20	2015	AbouHashem, Y	46	7.67	6
55	Virtual reality anatomy: is it comparable with traditional methods in the teaching of human forearm musculoskeletal anatomy?	Anatomical Sciences Education	4	2011	Codd, AM	46	4.60	7
56	Problem-based learning: is anatomy a casualty?	Plastic and Reconstrictive Surgery	3	2005	Hinduja, K	46	2.88	0
57	Progress and perspectives in computational neuroanatomy	Anatomical Record	257	1999	Ascoli, GA	46	2.09	3
58	Experimental evidence for improved neuroimaging interpretation using three-dimensional graphic models	Anatomical Sciences Education	5	2012	Ruisoto, P	45	5.00	0
59	How useful is plastination in learning anatomy?	Journal of Veterinary Medical Edcuation	34	2007;	Latorre, RM	45	3.21	3
60	Using QuickTime virtual reality objects in computer-assisted instruction of gross anatomy: Yorick - the VR skull	Clinical Anatomy	13	2000	Nieder, GL	45	2.14	0

Supplementary Table 1. Continued.

Rank	Article Title	Journal	Volume	Year	First Author	TCited*	Average Citations per Year**	Altmetric Score
61	Tendons, ligaments, and capsule of the rotator cuff. Gross and microscopic anatomy	Anatomical Sciences Education	7	2014	Clark JM	44	6.29	0
62	Building the dody: active learning laboratories that emphasize practical aspects of anatomy and integration with radiology	Anatomical Sciences Education	3	2010	Zumwalt, AC	44	4.00	0
63	The effectiveness of virtual and augmented reality in health sciences and medical anatomy	Anatomical Sciences Education.	10	2017;	Moro, C	43	10.75	34
64	Teaching anatomy in the XXI century: new aspects and pitfalls	Scientific World Journal	---	2013	Papa, V	43	5.38	1
65	Teaching anatomy with surgeons' tools: use of the laparoscope in clinical anatomy	Clinical Anatomy	14	2001	Fitzpatrick, CM	43	2.15	0
66	Social media and anatomy education: using Twitter to enhance the student learning experience in anatomy	Anatomical Sciences Education	9	2016	Hennessy, CM	42	8.40	47
67	The impact of alternating dissection on student performance in a medical anatomy course: are dissection videos an elective substitute for actual dissection?	Clinical Anatomy	20	2007	Granger, NA	42	3.00	1
68	Virtual anatomy: an anatomist's playground	Clinical Anatomy	19	2006	Spitzer, VM	42	2.80	0
69	Building virtual models by postprocessing radiology images: a guide for anatomy faculty	Anatomical Sciences Education.	3	2010	Tam, M	40	3.64	0
70	Virtual temporal bone: an interactive 3-dimensional learning aid for cranial base surgery	Neurosurgery	64	2009	Kockro, RA	40	3.33	3
71	The poor, the black, and the marginalized as the source of cadavers in United States anatomical education	Clinical Anatomy	20	2007	Halperin, EC	40	2.86	22
72	Teaching methods in anatomy courses in North American medical schools: the role of radiology	Academis Radiology	13	2006	Ganske, I	40	2.67	0
73	Anatomy instruction in medical schools: connecting the past and the future	Advances in Health Sciences Education	11	2006	Leung, KK	40	2.67	0
74	Evaluation of computer-aided instruction in the medical gross anatomy curriculum	Clinical Anatomy	17	2004	McNulty, JA	40	2.35	0

Supplementary Table 1. Continued.

Rank	Article Title	Journal	Volume	Year	First Author	TCited*	Average Citations per Year**	Altmetric Score
75	Animated PowerPoint as a tool to teach anatomy	Conference: Annual Meeting of the AAA held at the EB	261	2000	Carmichael, SW	40	1.90	0
76	Effectiveness of three-dimensional digital animation in teaching human anatomy in an authentic classroom context	Anatomical Sciences Education	3	2014	Hoyek, N	39	5.57	3
77	Undergraduate perspectives on the teaching and learning of anatomy	Anz Journal of Surgery	79	2009	Mitchell, R	39	3.25	0
78	Direct manipulation is better than passive viewing for learning anatomy in a three-dimensional virtual reality environment	Computers & Education	247	2017	Jang, S	38	9.50	10
79	How useful is YouTube in learning heart anatomy?	Anatomical Sciences Education	7	2014	Raikos, A	38	5.43	35
80	Cadaveric dissection as an educational tool for anatomical sciences in the 21st century	Anatomical Sciences Education	10	2017	Ghosh, SK	37	9.25	7
81	A change in paradigm: giving back identity to donors in the anatomy laboratory	Clinical Anatomy	26	2013	Talarico, EF	37	4.63	0
82	A head in virtual reality: development of a dynamic head and neck model	Anatomical Sciences Education	2	2009	Nguyen, N	37	3.08	0
83	Transforming clinical imaging data for virtual reality learning objects.	Anatomical Sciences Education	1	2008	Trelease, RB	37	2.85	0
84	Learning anatomy via mobile augmented reality: effects on achievement and cognitive load	Anatomical Sciences Education	9	2016	Küçük, S	36	7.20	1
85	Perceptions of a mobile technology on learning strategies in the anatomy laboratory	Anatomical Sciences Education	6	2013	Mayfield, CH	36	4.50	1
86	Use of plastinated prosections for teaching anatomy-The view of medical students on the value of this learning resource	Clinical Anatomy	24	2011	Fruhstorfer, BH	36	3.60	1
87	Explorable three-dimensional digital model of the female pelvis, pelvic contents, and perineum for anatomical education	Anatomical Sciences Education	3	2010	Sergovich, A	36	3.27	0
88	Developing medical students as teachers: an anatomy-based student-as-teacher program with emphasis on core teaching competencies	Anatomical Sciences Education	6	2013	Erie, AJ	35	4.38	34

Supplementary Table 1. Continued.

Rank	Article Title	Journal	Volume	Year	First Author	TCited*	Average Citations per Year**	Altmetric Score
89	Human cadavers vs. multimedia simulation: a study of student learning in anatomy	Anatomical Sciences Education	7	2014	Saltarelli, AJ	34	4.86	52
90	An enriched multimedia eBook application to facilitate learning of anatomy	Anatomical Sciences Education	7	2014	Stirling, A	34	4.86	14
91	Enhancement of temporal bone anatomy learning with computer 3D rendered imaging sowares	Medical Teacher	332	2010	Venail, F	34	3.09	0
92	How spatial abilities and dynamic visualizations interplay when learning functional anatomy with 3D anatomical models	Anatomical Sciences Education	8	2015	Berney, S	33	5.50	3
93	ARBOOK: Development and assessment of a tool based on augmented reality for anatomy	Journal of Science Education and Technology	24	2015	Ferrer, TJ	33	5.50	1
94	Fabrication and assessment of 3D printed anatomical models of the lower limb for anatomical teaching and femoral vessel access training in medicine	Anatomical Sciences Education	9	2016	O'Reilly, MK	32	6.40	2
95	Virtual cerebral Ventricular system: an MR-based three-dimensional computer model	Anatomical Sciences Education	4	2011	Adams, CM	32	3.20	0
96	Using 3D modeling techniques to enhance teaching of difficult anatomical concepts	Academic Radiology	23	2016	Pujol, S	31	6.20	2
97	Utilising mobile-augmented reality for learning human anatomy	Conference: 7th World Conference on Educational Sciences Location: Athens, GREECE		2015	Jamali, SS	31	5.17	0
98	A "Second Life" for gross anatomy: applications for multiuser virtual environments in teaching the anatomical sciences	Anatomical Sciences Education	4	2011	Richardson, A	31	3.10	0
99	Comparison of computer-based and paper-based imagery strategies in learning anatomy	Clinical Anatomy	18	2005	Khalil, MK	30	1.88	0
100	Current applications and future perspectives of the use of 3D printing in anatomical training and neurosurgery	Frontiers in Neuroanatomy	24	2016	Baskaran, V	29	5.80	2

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