Top 10 Most-Cited Articles Concerning Blended Learning for Introductory Algorithms and Programming:
A Bibliometric Analysis and Overview

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Abstract—Blended learning, also known as mixed-mode instruction, combines in-person and online instruction. Blended learning is widely used in school and university subjects. This research aims to determine how blended learning has been applied to algorithms and programming courses over the last 20 years. This study analyzes the quality and quantity of scientific publications using bibliometric techniques and then provides an overview of how blended learning is used and its impact. For this analysis and review, this study conducted a bibliometric analysis of articles published in the last 20 years (2000–2021) and then presented the 10 most cited articles. We established the following criteria for articles: 1) sourced from the Scopus database, 2) concerned about blended learning in algorithms and programming, and 3) publication is limited to articles published in indexed international journals and proceedings. The VOSviewer and MS-Excel applications help with data presentation in this method. We collected 240 articles that met these criteria from the Scopus database, which contained 297 articles published between 2000 and 2021. The most-cited article received 52 citations, while the least received only 3. The top 10 most cited articles are from the following countries: 1) Norway, 2) Serbia, and 3) Saudi Arabia. We divided the articles into categories based on the Sustainable Development Goals (SDGs). The findings of this study can be used as a reference for state-of-the-art and novelty, as well as for the dissemination of scientific references related to the use of blended learning for introductory algorithms and programming.

Keywords—blended learning, programming, bibliometric, most-cited

1   Introduction

The excessive papers published in journals in internet databases have led to an overabundance of information, making it difficult for practitioners and researchers to

quickly find relevant references to their topics of interest [1]. From bibliometric analysis, we can see trends and patterns of scientific development in disciplines [2]. This information will be used to conduct further research so that re-examining does not occur. Therefore, it is very necessary to filter papers concerned with a research topic. So this helps make it easier for practitioners and researchers to access articles that are useful in their research fields efficiently. In addition, bibliometrics can also be used to assess the productivity of authors, institutions, and even a country.

The two primary goals of the bibliometric analysis are (1) research performance evaluation of individual and institutional research and publication trends and (2) mapping, which seeks to expose the structure and development of a studied topic [3]. Each uses a distinct method. We employ precise quantitative calculations such as the overall number of citations, the average number of citations, and the collaboration index to evaluate research performance. [4] Like mapping analysis, keyword analysis can examine the relationship between one topic and another in a specific field [5].

This study was undertaken following one of the primary goals of bibliometric analysis. We can determine the current state of knowledge and the direction of future research. In addition, we may follow the citation chain from one paper to the next. Bibliometric analysis can help us decide which publications are influential, who the influential authors on the issue are, the progression of a topic (based on citations between papers), previously covered topics, and even identify potential collaborators whom we will invite to be co-authors [6].

2 Methodology

This study includes quantitative research. This study examines the trends in blended learning research on the introduction of algorithms and programming over the last 20 years using bibliometric studies from the Scopus database. Before that, we established several criteria for collecting article data: 1) Publications are sourced solely from the Scopus database; 2) there is concern about blended learning in algorithms and programming; and 3) publications are limited to indexed international journal articles and proceedings. On October 24th, 2021, the investigation began with an online search. Visualization software VOSviewer and MS-Excel were used for data analysis. The VOSviewer tool was used to create and visualize a structure map of the researchers' and co-authors' source coupling networks [6], [7]. Figure 1 shows a more detailed research procedure:
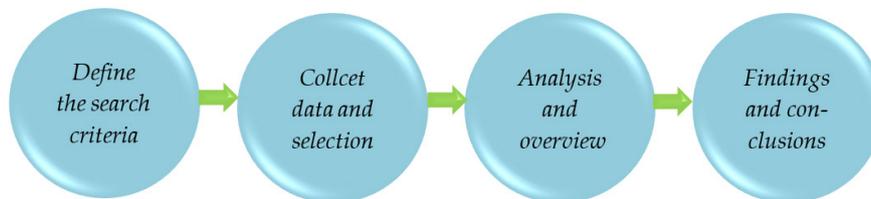

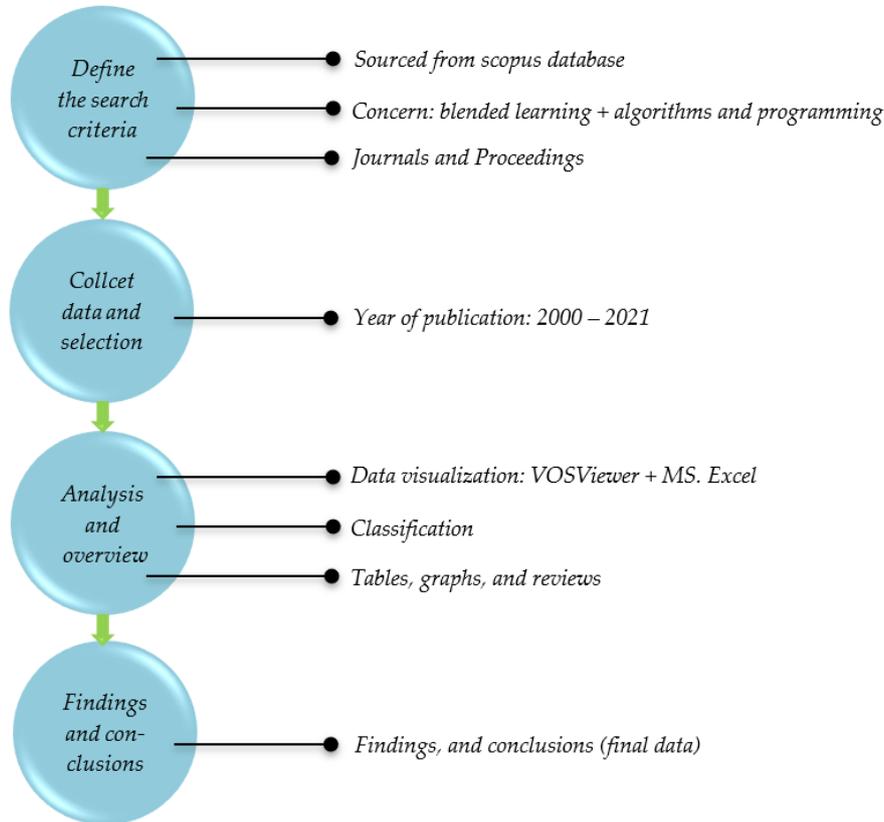**Fig. 1.** Bibliometric analysis procedures

Fig. 2. Detailed procedure of bibliometric analysis (cont.)

3 Results and discussion

3.1 Data selection

By using Publish or Perish (Pop) with keywords "BLENDED LEARNING" and "PROGRAMMING", we found 319 articles. Then, we selected based on the range of publication years (2000-2021). As a result of this selection, we found 297 articles concerning blended learning for introductory algorithms and programming from 2000-2021. Finally, we re-selected by only taking articles published in international journals and proceedings indexed by Scopus. We collected 240 articles that met these criteria. Now, let's look at Figure 3 below.

Based on the data in Figure 4, it can be seen that as many as 240 articles met the criteria (journals and proceedings only). The bars and graphs show increased publications in 2010, from 1 article in 2009 to 10 articles in 2010. Article data for the last 2 years includes as many as 37 articles in 2020 and 36 articles in 2021. So, it can be

interpreted that research on blended learning in algorithms and programming courses has increased significantly every year. The articles consist of 56% published in Scopus-indexed journals and 44% published in Scopus-indexed proceedings.

Fig. 3. Article publication data from 2000 - 2021

Fig. 4. Article publication data from 2000 – 2021 (journals and proceedings only)
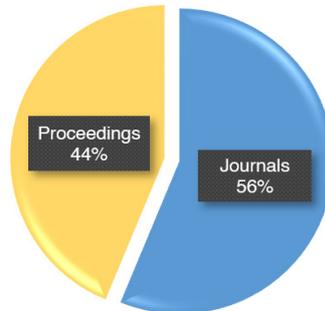
Fig. 5. Distribution of articles by document type

It can be said that these results do not reach hundreds in a year or are relatively few. We only need to underline that these data have very specific selection criteria and focus, which only discuss the study of "blended learning" for "programming." If we exclude the keyword "programming," we will get very different results because blended learning has been widely applied in various courses at universities around the world.

3.2 Classification of articles by SDGs

According to the Sustainable Development Goals (SDGs). The 240 articles are classified as follows (See Figure 6):
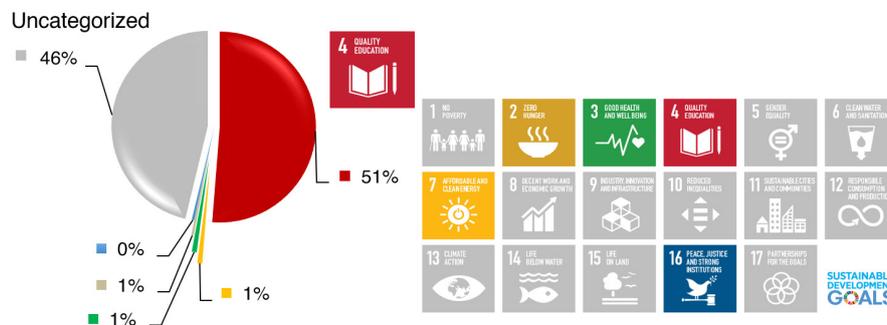

Fig. 6. Classification of articles by SGDs

In Figure 6, it can be seen that the dominance of articles on blended learning did contribute to improving the quality of education based on the SGDs, namely 51% of the number of articles that had an impact on 04, "Quality Education".

3.3 Co-authorship analysis

Co-authorship analysis aims to see the relationship between one article and another and see collaboration between researchers. Figure 7 shows that 7 researchers own the

widest network: *Fraga, Francisco J; Goya, Denise Hideko; Josko, João Marcelo Borovina; Kobayashi, Guiou; Pimentel, Edson Pinheiro; Savegnago, Heitor Rodrigues; and Zampirolli, Francisco A.*
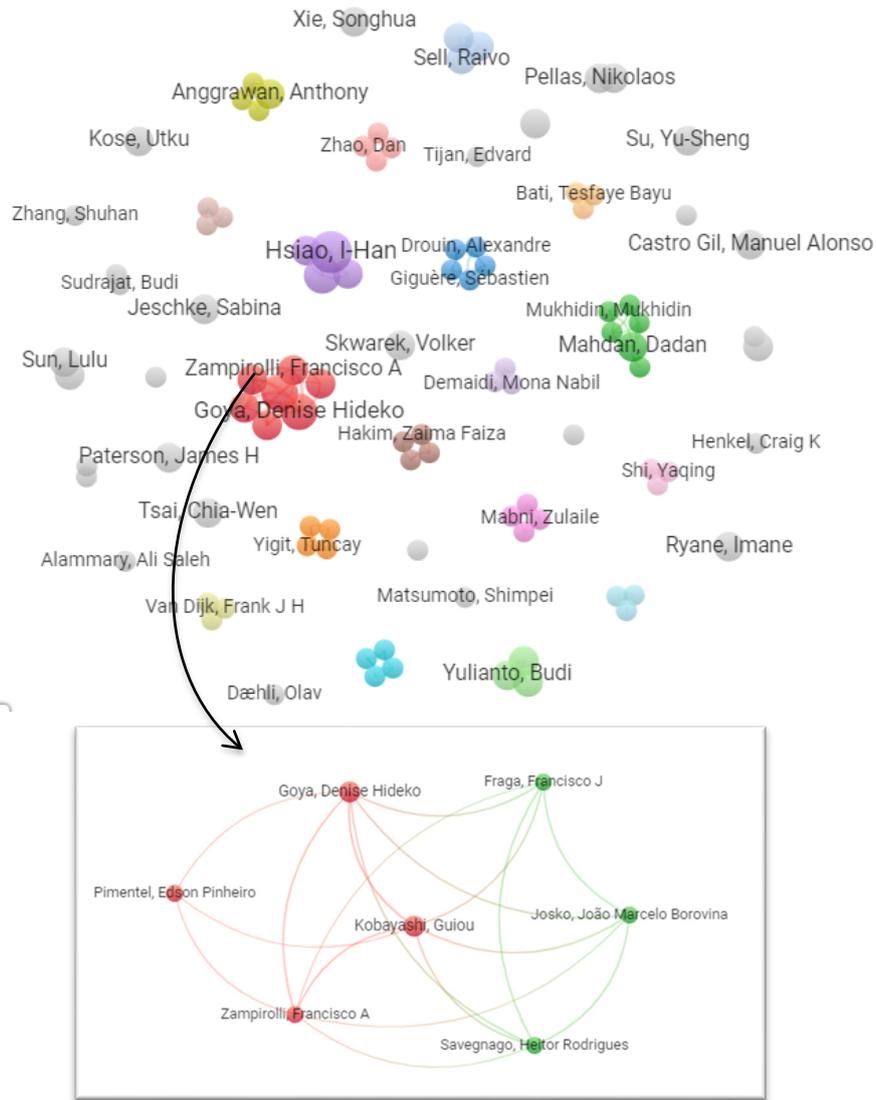

Fig. 7. Co-authorship analysis: the most extensive network

3.4   Top 25 most-cited articles

In Table 1, there are 25 articles concerned with blended learning in algorithms and programming courses with the highest number of citations. S. Hadjerrouit (52) is from

Norway, followed by S. DJenic (43) from Serbia, followed by A. Alammary (41) from Saudi Arabia, and followed by J. Galvez (41) from Spain. Meanwhile, the lowest quote was obtained by Y. Murai (3) from Canada. The article with the most citations (52) was published in 2008, CPY (3.71), and the lowest citation (3) in 2020, CPY (1.50). Meanwhile, based on CPY, the highest CPY (13.67) was published in 2019 by A. Alammary, and the lowest CPY (0.45) was published in 2011 by Mohorovicic.

Table 1. Top 25 most-cited articles

No	Authors	Cited	Year	CPY	Type	Country
1	S. Hadjerrouit	52*	2008	3.71	Article	Norway
2	S. Djenic	43	2011	3.91	Article	Serbia
3	A. Alammary	41	2019	13.67*	Article	Saudi Arabia
4	J. Gálvez	41	2009	3.15	Article	Spain
5	J. van Niekerk	37	2016	6.17	Article	South Africa
6	O. Deperlioglu	37	2013	4.11	Article	Turkey
7	T.B. Bati	26	2014	3.25	Article	Ethiopia
8	A. El-Zein	19	2009	1.46	Article	Australia
9	F. Lazarinis	13	2019	4.33	Article	Greece
10	W. Farag	13	2012	1.30	Proceedings	United States
11	F.A. Zampirolli	11	2018	2.75	Article	Brazil
12	S. Thamarai Selvi	11	2012	1.10	Proceedings	India
13	A. Al-Azawei	10	2016	1.67	Article	Iraq
14	M. Yağci	9	2016	1.50	Article	Turkey

No	Authors	Cited	Year	CPY	Type	Country
15	V. Del Fatto	9	2016	1.50	Article	Italy
16	K. Georgouli	9	2010	0.75	Proceedings	Greece
17	F.L. Wang	9	2008	0.64	Proceedings	Hong Kong
18	M. Demaidi	8	2019	2.67	Article	Palestine
19	E. Albrecht	8	2018	2.00	Proceedings	Germany
20	A. Anggrawan	7	2018	1.75	Proceedings	Indonesia
21	C. Huda	6	2018	1.50	Proceedings	Indonesia
22	S. Mohorovičič	5	2011	0.45	Article	Croatia
23	Y. Shi	4	2019	1.33	Proceedings	China
24	V. Gupta	3	2020	1.50	Proceedings	India
25	Y. Murai	3	2020	1.50	Article	Canada

Note: CPY = Cites Per Year; * = the highest

3.5   Top 10 authors: most-cited articles

The top 10 authors with the most citations are S. Hadjerrouit, S. Djenic, A. Alammary, J. Gálvez, J. van Niekerk, O. Deperlioglu, T.B. Bati, A. El-Zein, F. Lazarinis, and W. Farag. All of them come from different countries. However, apart from the top 10 authors, it is known from Table 1 or Figure 9 that 3 countries have 2 articles: Greece, India, and Indonesia (2).

Table 2. Top 10 authors: most-cited articles

| Author	Year	Title	Publisher
S. Hadjerrouit	2008	[8]	Informatics in Education
S. Djenic	2011	[9]	IEEE Transactions on Education
A. Alammary	2019	[10]	PLoS ONE
J. Gálvez	2009	[11]	Knowledge-Based Systems
J. van Niekerk	2016	[12]	Computers and Education
O. Deperlioglu	2013	[13]	Computer Applications in Engineering Education
T.B. Bati	2014	[14]	Computer Science Education
A. El-Zein	2009	[15]	Advances in Engineering Education
F. Lazarinis	2019	[16]	Education and Information Technologies
W. Farag	2012	[17]	Informatics in Education
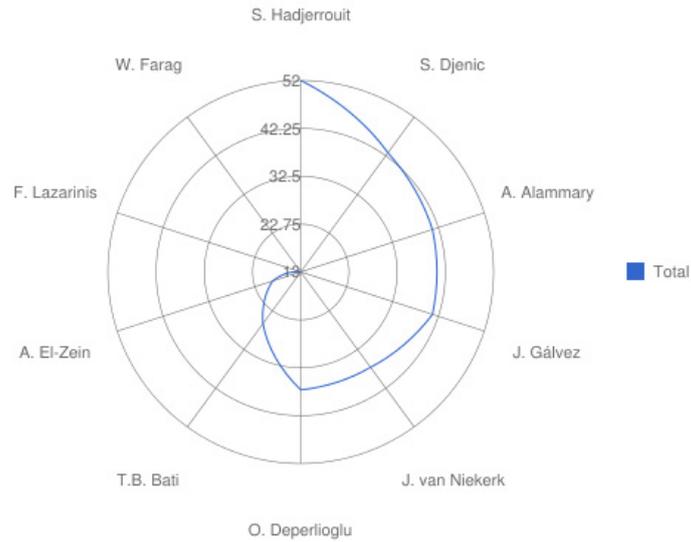
Fig. 8. Top 10 authors: most-cited articles

Fig. 9. Top 10 authors: most-cited articles by countries

3.6 Blended learning for algorithm and programming teaching

We have reviewed 10 articles written by the top 10 authors and sorted them by year.

Table 3. Top 10 most-articles: overview

Author	Year	Overview
S. Hadjerrouit	2008	*It is concluded that combining face-to-face learning with information technology cannot provide effective and efficient learning solutions if appropriate learning theories and pedagogical strategies are not used. This research presents a blended learning model for Java programming. Blended learning relies heavily on online resources. Lectures and self-paced online resources are used to deliver course content. Students work on coding exercises individually or in small groups in labs. Online collaborative activities have been added for students to discuss their programming solutions.*
J. Gálvez	2009	*OOPS (Object-Oriented Programming System) learning tools and a testing system used (SIETTE). OOPS is a problem-solving technique that allows students to complete Object Oriented Programming exercises. Web-based scoring system for learning strategies that assess students formatively..*
A. El-Zein	2009	*A WebCT-based Self-Practice Online Tool (SPOT) was used to support student programming learning.*
S. Djenic	2011	*Applied programming learning through the use of the Internet and multimedia in an integrated learning environment. Students practice coding in the lab. Additional practical exercises and knowledge assessments were given regularly via the Internet.*
W. Farag	2012	*Programming integrated learning environment was used. Blended learning has the potential to improve learning outcomes significantly.*

Author	Year	Overview
O. Deperlioglu	2013	*Blending can improve learning and flexibility by integrating face-to-face and online learning. The use of the blended e-learning model in data structures and algorithms was explained in this study. LMS is the technology used. Students practice coding both in-person and online. Class time is spent explaining complex concepts and answering questions from students.*
T.B. Bati	2014	*This study contributes to theory by presenting a design of a blended learning solution for large class programming instruction based on constructivist learning theory and free and open source technologies. Theories and practices from education, blended learning, and computer science education were used to design the course and blended learning environment. The emphasis was on the problematic area of large-class programming instruction. Most lecture time is spent on content delivery, live coding, and problem-solving. Online resources are being added to allow students to study at their own pace.*
J. van Niekerk	2016	*Some pedagogical principles must still be followed when developing e-learning content. This study found that e-learning material that adheres to brain-compatible education principles shows promise in teaching students fundamental programming logic.*
A. Alammary	2019	*The following models were identified: flipped model, mixed model, flex model, supplemental model, and online-practicing model. Their classification has been made based on whether the content delivery and practical activities take place face-to-face or online. All of these models appear to have the potential to improve the learning experience of novice programmers. As a result, a monitoring strategy should be implemented to ensure that students complete the online work. In labs, pair programming with questions from the online resource is used.*
F. Lazarinis	2019	*In a blended learning approach, the course was designed as a Moodle course that was realized in discrete runs with manageable groups. The educational materials included learning objects with specific objectives, video content, and try-out activities. The activity was implemented with additional face-to-face support to increase active participation and improve completion rates.*

3.7 Discussion

Based on the data presented, it is clear that the trend of using blended learning in algorithm and programming learning has increased significantly. Although the data does not detail blended learning, we have an overview of the 10 authors who have received the most citations on the subject. Then, from the articles, we discovered an exciting summary by Alammary (2019), who identified 5 blended models used in algorithms and programming courses, as shown in Table. 3. Incorporating digital technology and online components into learning can give students more autonomy in managing their learning, better access to learning resources, and more flexibility in planning and managing their studies. Blended learning approaches have also improved students' satisfaction and learning outcomes. This is because they have understood the learning flow from the start. Various learning models have advantages, disadvantages, and challenges. However, a good learning model must include the following components: (1)

syntax, (2) social system, (3) reaction principle, (4) support system, and (5) instructional impact and nurturing effect.

4   Conclusions

Education has a significant impact on a nation's quality of life. Education will determine where this country goes in the future and whether it becomes a great country that is civilized, intelligent, and ready to adapt to changing times. Implementing blended learning is nothing more than the goal of improving the learning process, which impacts the quality of education itself. As we discussed earlier, all the analyzed data contributed to Sustainable Development Goal 4, namely education quality. According to the analysis and summary, the 10 most cited authors are from 10 countries: Norway, Serbia, Saudi Arabia, Spain, South Africa, Turkey, Ethiopia, Australia, Greece, and the United States. The Scopus database contained most citations with publication dates ranging from 2000 to 2021; S. Hadjerrouit in 2008. We must decide which learning media to use during the learning process when using blended learning. Web-based LMS, multimedia, e-books, smart devices, the Internet, and other technologies are widely used to support blended programming. Online assessments must support the blended learning approach, and lecturers must monitor students' online activities either regularly or automatically through the technology used to ensure students do not neglect their work while studying online. Finally, the blended learning model's implementation must consider student characteristics, pedagogical strategies, supporting resources, facility conditions, and infrastructure.

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