Analysis of Academic Databases for Literature Review in the Computer Science Education Field

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***Abstract*—Literature review is a fundamental part of a research process, and systematic protocols for this activity have been used for a long time, mainly in the field of health. Specifically in the Computer Science Education area, the use of systematic literature review has grown. One of the steps in a systematic literature review (SLR) is the selection of academic databases in which to search for articles. There are several databases with academic documents that may be relevant to SLR, for example: Google Scholar, which indexes different types of documents, such as articles, dissertations, theses, and others; Scopus and Web of Science are large databases that index articles from different conferences and journals. ACM Digital Library and IEEE Xplore are also important sources of information in the field of Computer Education. These tools have different characteristics, some charge a fee, others have only information about the title and authors and do not have access to the full article, others have advanced features, with many filters. In this context, this article presents the following research questions: RQ1) What metadata can be extracted automatically from the databases?; RQ2) What kind of visualization tools are available?; RQ3) Do the documents returned by the databases cover the research topic?; RQ4) Do the databases have papers from the main CSE venues?; and RQ5) How many databases are required to perform a literature review in CSE? To answer these questions we used five academic databases: Google Scholar, Scopus, Web of Science, ACM Digital Library, and IEEE xplore. Regarding the results, Scopus and Web of Science have the best visualization of the documents and a robust query engine, however those academic databases are not free. ACM Digital library, IEEE Xplore, Scopus and Web of Science allow the automatic download of the papers' metadata (author, title, abstract, affiliation and others). Specifically in the field of Computer Science Education, the ACM Digital Library and the IEEE Xplore have important papers from conferences (SIGCSE and FIE) and journals (ACM Transaction on Education and IEEE Transaction on Education). In this full paper, the results will be presented to help researchers to choose the most appropriate academic databases based on their requirements and available options.**

***Index Terms*—Literature Review, Academic Database, Computer Science Education**

I. Introduction

A literature review is an important step in a research process. With the growing amount of available academic documents such as conference papers, journals, books, theses, and dissertations, a literature review that encompasses the main works in a research area has become a significant challenge. Increasingly, literature review processes have been defined with protocols that specify which activities to carry out or avoid. Examples of these protocols can be found in [1]–[6]. Specifically within Engineering and Computing Education, different types of literature reviews are observed, as can be seen in [7]–[9].

One of the activities in a literature review process is the selection of academic databases in which to search for relevant articles in the research topic. The databases are often related to the area of knowledge; those in the medical area are often different from the ones in the areas of Engineering and Computer Science. In addition to the field-specific bases, there are those that index documents from any area of knowledge, such as Google Scholar, Scopus, and Web of Science.

According to [10], researchers select electronic data sources based on personal preferences or previous experience. However, such an ad-hoc approach can lead to inefficient or inaccurate searches. It is important to build an evidence-based understanding of how sources are chosen. The selection of sources should be a detailed step in the literature review process.

Previous studies addressed literature reviews in the context of a specific domain such as software engineering [1], [5], [14], health [12], engineering education [8], pair programming [7] or the use of bloom's taxonomy in computer science education [13]. Our work focuses on the aspects that influence database choices in the context of computer science education.

In the literature, it is possible to find different articles that analyze academic databases, as in [15]–[19]. However, none of these works specifically analyzed the area of Engineering and Computing Education; hence, the differential of our paper is to analyze these databases from the perspective of this area.

This paper aims to analyze five academic databases (Scopus, Web of Science, ACM Library Digital, IEEE Xplore, and Google Scholar) in the context of the Computer Science Education (CSE) domain. We intend to identify the advantages and disadvantages of these five databases for the purposes of a CSE literature review.

The rest of this paper is organized as follows. Section II provides a theoretical reference where a brief description of each investigated academic database is presented. Section III analyzes approaches carried out in other works. Section IV presents the results of this research and Section V discusses them. Section VI explains the limitations of this work and Section VII concludes.

II. Theoretical Reference

Choosing academic databases for the selection of relevant articles in a literature review process involves several factors, such as access to the database, the area of knowledge of the research, among others. There are general databases, such as Google Scholar, Scopus and Web of Science, and specific databases for knowledge areas, for example, PubMed for the Health area, and for the Engineering and Computer Science Education area, ACM Digital Library and IEEE Xplore. Google Scholar, Web of Science and Scopus are query engines which index the papers, IEEE Xplore and ACM Digital Library have a query engine and also store the full documents. In our paper, all these data sources are referred to as academic databases, and they are used to identify the relevant papers. Each academic database is described below.

A. Scopus

The Scopus [22] database gathers documents from several trusted digital repositories, indexes content from more than 24,600 active titles and 5,000 publishers, which are rigorously examined and selected by an independent review board that makes use of a rich architecture of underlying metadata to connect people, ideas and institutions [23].

The Scopus query engine offers many features: it is possible to use operators and many extra filters to direct the search in a specific way, including search by year, research area, document type, country, conference and others. In addition, there are thirteen refinement options after starting the search. It is possible to extract more than 30 types of data (metadata) from a single document in different formats (for example, mendeley, excel, csv, and ris). However, it is possible to download only 2,000 metadata items; to extract a larger amount, it is necessary to complete a registration requesting that these data be forwarded by email. It is possible to have a global view of the documents accessed through a graphical interface that maps the documents searched. For example, the database also provides a graph by author, institution, country, institution that financed the research, and the area of knowledge where the research topic was most published.

B. Web of Science

Web of Science (WoS), according to [24] [25], is a publisher-independent global citation database, considered one of the most trusted in the world. It is possible to choose the repository in which the search will be carried out. Initially, there is the central repository of WoS itself and five other options. The search engine is divided into basic, advanced, by author, and by cited reference search. Some logical operators make the search feasible and, after the search, it is possible to refine the results through many filters.

Regarding metadata, it is possible to extract various types of information from the paper in different file formats. On Web of Science, it is possible to view the documents searched through different visualizations, for example by year, author, country, and document type.

C. IEEE Xplore

Concerning the Engineering and Computing area, IEEE Xplore [26] is a digital library that has resources to access scientific and technical content published by IEEE (Institute of Electrical and Electronics Engineers) and its publishing partners. This database provides web access to more than four million full-text documents from some of the world's most cited publications in electrical engineering, computer science, and electronics [26] [27].

IEEE Xplore has a basic and advanced search facility and many types of filters after the initial search and logical operators in the advanced search. Metadata of the papers includes information such as abstract, title, authors' names, affiliations, and other data. It is possible to download the metadata to different format files. Regarding access, with IEEE Xplore, it is possible to search the database, and download the metadata for each document. However, to access the full document is necessary to pay a subscription.

D. ACM Digital Library

The fourth platform analyzed was ACM Digital Library, a collection of complete texts from all of its publications, including journals, conference proceedings, technical magazines, newsletters, and books [28], it is a comprehensive bibliographic database dedicated exclusively to the field of computing [28] [20].

ACM Digital Library has basic and advanced search facilities. It is possible to read the abstracts of the articles, but when the metadata is downloaded, the information is summarized, bringing only basic data from the documents, such as: article name, year, abstract, and type of publication. Similarly to IEEE Xplore, it is possible to access information about the papers without paying and have access to the papers' metadata. Some open access papers may be downloaded in full.

E. Google Scholar

Google Scholar, a repository of Google, is a free platform widely used in research. According to information from the repository, the documents delivered to the researcher have the following sources: the most accessed websites, blogs, and magazines on the topic searched on the internet [29]–[31].

Google Scholar has basic and advanced search facilities; however, it is not complete like the other data repositories. The basic search is defined by year, relevance, and language. Visualization is simple, without charts. It is not possible to download the papers' metadata, however there are external tools to download these metadata.

III. Methodology

This section presents the methodology applied to analyze the databases. The method applied in this research consisted of the following steps: the definition of the databases to be investigated, the definition of the research questions, the definition of the search process for the articles, analysis process, and discussion of the results.

In the first step, defining the databases for the Computer Science Education area, ACM Digital Library and IEEE xplore databases are very important, as they are repositories of the main conferences in the area, such as ACM SIGCSE, ACM SIGiTE, IEEE FIE, among others, as well as several journals: IEEE Transaction on Education, ACM Transactions on Computing Education, etc. For open databases from all areas, Google Scholar was selected for this research, and also the Scopus and Web of Science indexing bases, which have important tools for index analysis in all academic areas.

For the definition phase of the research questions, five were chosen to assist researchers to select the database that best suits their research. The research questions were:

- RQ1: What metadata can be extracted automatically from the databases?
- RQ2: What kind of visualization tools are available?
- RQ3: Do the documents returned by the databases cover the research topic?
- RQ4: Do the databases have papers from the main CSE venues?
- RQ5: How many databases are required to perform a literature review in CSE?

To answer RQ3 the process was: definition of the search string, definition of the criteria for selecting the documents, and execution of the search in each database. The researchers involved in this research defined a search string comprehensively, since the investigation will be carried out in the area of Computer Science Education. The chosen search string was "computer science education". This string returned a high number of papers on the analyzed topic. For a comparison of the databases, similar search criteria were defined for all platforms:

- C1: Documents published between 2015 and 2019. The objective was a closed search interval of five years for all indexed bases investigated;
- C2: After some tests, searching academic databases by publication date, number of citations and others, we chose to use the relevance option for the selection of the papers. It was found that all five databases have the option of displaying results by relevance. As each database has its own relevance algorithm, this criterion provides us with the most relevant articles from each database;
- C3: Retrieve the first 100 articles in each database. As many articles were published in the different databases, the researchers in this article decided to limit the analysis to 500 articles (100 from each database). For empirical analysis, in tests carried out, the number of 500 articles already presented the answers to the research questions in this article.

To answer RQ4, based on Lunn *et. al.* [33] and Masapanta-Carrión and Velázquez-Iturbide [13], Randolph *et. al.* [34], Google Scholar h5-index, and Clarivate' Journal Citation Reports (JCR) 2020, we selected 10 venues. We then analyzed each database looking for the indexation of those venues. For the definition of the venues, we gathered all the venues mentioned in [13], [33], [34]. In addition, a manual search was performed on Academic Google to find the 10 top venues (h-5 index). Finally, we manually analyzed the top 10 journals based on the JCR. After joining these indicators, the venues that were better classified were:

- SIGCSE - ACM Technical Symposium on Computer Science Education
- EDUCON - IEEE Global Engineering Education Conference
- FIE - IEEE Frontiers in Education Conference
- Koli Calling - ACM Koli Calling International Conference on Computing Education Research
- ICER - ACM International Computing Education Research Conference
- ITiCSE - ACM Conference on Innovation and Technology in Computer Science Education
- ICCSE - IEEE International Conference on Computer Science and Education
- TOE - IEEE Transactions on Education (JCR = 2.116)
- TOCE - ACM Transactions on Computing Education (JCR = 1.526)
- CSE - Computer Science Education (JCR = 1.15)

IV. Results

In this section, the answers to the research questions will be presented.

A. *RQ1: What are the metadata extracted from the databases?*

Table I presents the metadata for the analyzed databases. Scopus and Web of Science have more than 20 types of information about a paper, including title, abstract, affiliation, conference/journal, and others. IEEE Xplore is in third position with regard to the amount information about the paper. Google Scholar has less information about each paper.

B. *RQ2: What kind of visualization tools are available?*

On Scopus, it is possible to have a global view of the documents accessed through graphics, where the researcher can map the documents searched. For example, Figure 1 presents publications on the Computer Science Education research area by year. It is possible to observe that IEEE FIE has one of the highest levels of publications on this topic. The database also has a graph by author, institution, country, institutions that financed the research, and the area of knowledge where the research topic was most published.

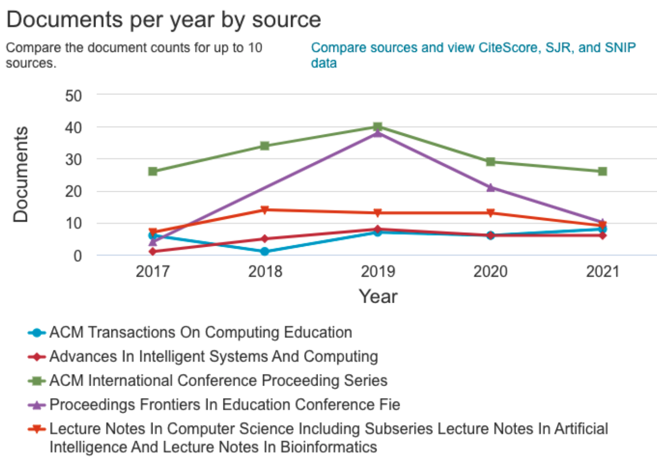

Fig. 1. Source publications per year - Scopus.

On Web of Science, it is possible to view the documents searched through charts, as shown in Figure 2. In addition to this graph, it is possible to check publications by year, author, country, and document type.

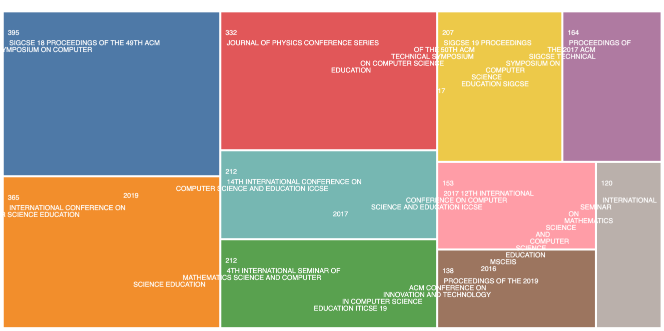

Fig. 2. Source publications per year - Web of Science.

IEEE Xplore has information about the document, including the abstract; however, it is not as complete as Scopus and Web of Science. On ACM Digital Library is possible to view abstracts, document name, year, and access metadata. On Google Scholar it is possible to view the name of the document, author, year, citations, and repository.

C. RQ3: Do the documents returned by the databases cover the research topic?

To answer this research question, the following procedure was executed: manual analyses were performed by two co-authors on 500 documents to identify what percentage of the returned papers was related to the topic. As expected, since we used the search string "computer science education", the vast majority of the 500 documents were related to the topic,

TABLE I
AVAILABLE METADATA.

Mensure	**Scopus**	**WoS**	**IEEE**	**ACM**	**GS**
Author(s)	x	x	x	x	x
Author(s) ID	x	x	x		
Document title	x	x	x	x	x
Year	x	x	x	x	x
Source title	x	x	x		
Volume, issue and pages	x	x	x	x	
Abstract	x	x	x	x	
Author keywords	x	x	x		
Index keywords	x	x	x	x	
Citation count	x	x			x
Source document type	x	x			
Publication stage	x	x		x	
DOI	x	x	x	x	
Open Access	x	x			
Affiliations	x	x			
Identifiers (e.g. ISSN)	x	x	x		
Publisher	x	x	x	x	
Editor(s) Books	x	x	x		
Language of document	x	x			
Correspondence address	x	x			
Abbreviated source title	x	x	x		
Number	x	x	x		
Acronym	x				
Sponsor	x				
Conference information	x	x	x	x	
Include references	x	x			
ORCIDs		x			
Funding Orgs		x			
Cited References		x			
Times Cited, all databases		x			
180 Day All Usage Count		x			
Supplement		x			
Special Issue		x			
Highly Cited Status		x			
Hot Paper Status		x			
Patent Citation Count			x		
License			x		

only eight articles were classified as out of topic. The conflicts were settled in meetings by two co-authors.

However, when we analyzed the document type, 51 documents were abstracts. Web of Science and ACM returned the highest number of abstracts, 34 and 14, respectively. From Google Scholar, we identified papers from arXiv, PhD Theses, and technical reports. Another observation is that the ACM Digital Library publishes, for example, panel summaries and keynote summaries, which are not, generally, used in a systematic literature review process.

D. RQ4: Do the databases have papers from the main CSE venues?

Google Scholar and Scopus index articles from 10 venues. Web of Science indexes articles from all three journals but does not index all conference editions. ACM Digital Library and IEEE Xplore (IEEEX) index documents from their own venues and partners. Details of the analysis for each database are presented below. Table II presents a summary of venues and databases.

a) Scopus: Scopus has had publications from the SIGCSE conference since the year 1972, from the EDUCON

TABLE II
VENUS AND DATABASES.

	Scopus	ACM DL	IEEEX	WoS	GS
SIGCSE	x	x	-	x	x
EDUCON	x	-	x	x	x
FIE	x	-	x	x	x
Koli	x	x	-	x	x
ICER	x	x	-	x	x
ITiCSE	x	x	-	x	x
ICCSE	x	-	x	x	x
TOE	x	-	x	x	x
TOCE	x	x	-	x	x
CSE	x	-	-	x	x

conferences since 2010, and the FIE from 1998. Koli Calling has had its documents attached since 2006, except for the 2007 edition. For ICER we found a gap in article indexing, for example in 2014. ICCSE aggregates documents in the database since the year 2009. The journal, IEEE Transactions on Education (TOE), has documents attached from the year 1963, the documents of ACM Transactions on Education in Computing (TOCE) have been in Scopus since 2010. Finally, the CSE documents have been indexed in Scopus since 1988.

b) Web of Science: Regarding the SIGCSE event, some gaps were found in the indexing of the articles, for example, 2013 and 2015. The FIE conference has had documents attached since 1989, though some gaps were found. The EDUCON conference has indexed documents in the database as of 2013. At the Koli Calling conference, the documents were attached only two years, 2017 and 2019. Regarding the ICER and ITiCSE, similar to SIGCSE, gaps were found in 2013 and 2015. ICCSE has had publications since the year 2006.

c) IEEE Xplore: In IEEE Xplore, SIGCSE, Koli Calling, ICER, ITiCSE, TOCE and CSE are not indexed. Furthermore, only the IEEE Transactions on Education journal is indexed. It has EDUCON data from the year 2010, ICCSE from 2009, TOE from 1998 and FIE from 1982.

d) ACM Digital Library: All SIGCSE conferences attached to ACM and Koli Calling publications have been indexed in the database since 1977, ICER has been indexed since the year 2005. At the ITiCSE the documents have been attached since 1996. However, there are no EDUCON, FIE, TOE, ICCSE and CSE publications attached to ACM.

E. RQ5: How many databases are required to perform a literature review in CSE?

To answer this question, the authors excluded all articles that were not full papers in a conference or journal, totaling 401 full papers. Research was carried out concerning the repetition of any given article in the different databases, using 401 documents, Google Scholar has 100% of the papers, Scopus 93%, Web of Science 64.3%, ACM Digital Library 46.8% and IEEE Xplore 33.5%. Figure 3 shows a Venn Diagram for those documents in each database.

Table III presents the possible combinations of two academic databases. Google Scholar is not included because it has

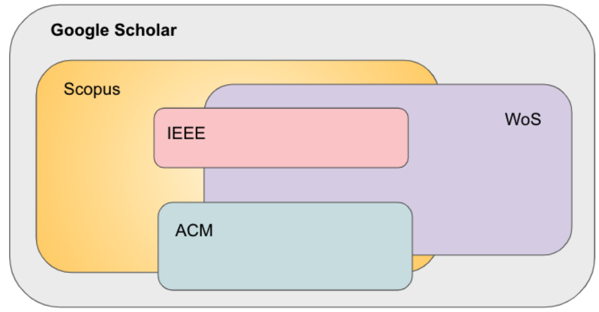

Fig. 3. Venn Diagram of the Academic Databases.

TABLE III
RELATIONS WITH ACADEMIC DATABASES.

Union	Intersection
$Scopus \cup ACM = 96.5\%$	$Scopus \cap ACM = 43.3\%$
$Scopus \cup WoS = 95\%$	$Scopus \cap WoS = 62.8\%$
$Scopus \cup IEEE = 93\%$	$Scopus \cap IEEE = 33.5\%$
$ACM \cup IEEE = 79.5\%$	$ACM \cap IEEE = 0\%$
$ACM \cup WoS = 81\%$	$ACM \cap WoS = 82\%$
$WoS \cup IEEE = 82\%$	$WoS \cap IEEE = 24\%$

100% of papers but, it has significant drawbacks, more details in next section. Scopus with ACM Digital Libary, Scopus with IEEE, and Scopus with Web of Science have more than 90% of the papers. More than 60% of papers are in both databases, Scopus and Web of Science. We did not find papers in ACM Digital Library and IEEE Xplore.

IEEE Xplore was the platform that had most documents repeated in other databases using the string of this research. All the papers found in IEEE Xplore, were also found in the combined search of Scopus and Web of Science.

V. ANALYSIS OF RESULTS

In general, and confirming what has already been reported in the literature in other areas of knowledge, Scopus and Web of Science have robust search engines and visualization tools, however access to search for relevant papers is not freely available except for the institutions that paid the subscription for the platform. However, free access for search engines is provided by IEEE Xplore, and ACM Digital Library. It should be highlighted that in all these databases there is a charge to access the full paper.

The challenge in using Google Scholar for a systematic literature review process is the number of documents of different types which are returned. For the search string in this article ”computer science education” from 2015 to 2019, Google Scholar returned 20,800 documents, while Scopus returned 1,380, and Web of Science 3,355. In addition, Google Scholar has limited search filters, it is not possible to select only conference papers or journal articles, and it does not have automatic download functionality for metadata.

Turning now to the remaining four databases, we observed that no single database had 100% of the 401 papers analyzed.

The database with the highest number of articles was Scopus, where of the 401 articles analyzed, only 28 were not in its database. Scopus indexes articles that are important for computer education that are not indexed by the ACM DIgital Library or IEEE Xplore, such as articles published in Computers Education (Elsevier), Education and Information Technologies (Springer). Some observations about documents that are not indexed by Scopus are highlighted here:

- Scopus indexes papers from Communications of the ACM, however, for example, papers such as blogs [35] were not indexed. These papers were indexed in the ACM Digital Library and in the Web of Science;
- Scopus indexes ACM Inroads papers, however these opinion papers [36]–[38] were not indexed. These papers are indexed in the ACM Digital Library and Web of Science;
- Some papers from conferences were not in the CSE field.

Finally, the merger between Scopus and ACM DL had a good result, as it included all articles indexed by Scopus plus opinion articles from ACM DL journals relevant to the CSE area.

VI. Limitations

The research selected 500 articles: 100 from each database. Despite being a good sample, it does not take into account all papers. The search string, "computer Science education", was also very comprehensive, not limiting the search to specific subjects. We did not analyze the quality of papers and this paper focus on quantitative papers in each academic database. However we used the relevant papers and the main venues.

VII. Conclusion

This paper presented an analysis of academic databases focused on the area of Computer Science in Education. It was observed that, given the amount of academic documents available as papers from conferences, journals, books, theses, dissertations and others, a literature review that encompasses the main works in the research area becomes a challenge. Increasingly, literature review processes have been defined with specified protocols and activities to try to avoid problems.

In this research, it has been shown that Scopus is the most complete repository: the database presented the lowest index of repeated documents, in addition, the results were consistent with the search term. The best combination with two databases was Scopus and ACM Digital Library 96.5%. However, when combining two databases, it covered approximately 80% of the articles, therefore, it is possible to have satisfactory coverage in a survey.

There are two main problems with Google Scholar: it is not possible to filter only by academic articles, and it is not possible to automatically download the metadata. On the other hand, Google Scholar can be used for systematic mapping, as it is possible to find information that can assist the researcher to search for articles that are part of the scope of his research.

However, if the researcher does not have access to non-free databases, he can use Google Scholar, as the repository can bring relevant documents if the advanced search facility is used. It was also noted that there was a large number of documents that were in other databases considered reliable.

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