



Advances in database systems education: Methods, tools, curricula, and way forward

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Abstract

Fundamentals of Database Systems is a core course in computing disciplines as almost all small, medium, large, or enterprise systems essentially require data storage component. Database System Education (DSE) provides the foundation as well as advanced concepts in the area of data modeling and its implementation. The first course in DSE holds a pivotal role in developing students' interest in this area. Over the years, the researchers have devised several different tools and methods to teach this course effectively, and have also been revisiting the curricula for database systems education. In this study a Systematic Literature Review (SLR) is presented that distills the existing literature pertaining to the DSE to discuss these three perspectives for the first course in database systems. Whereby, this SLR also discusses how the developed teaching and learning assistant tools, teaching and assessment methods and database curricula have evolved over the years due to rapid change in database technology. To this end, more than 65 articles related to DSE published between 1995 and 2022 have been shortlisted through a structured mechanism and have been reviewed to find the answers of the aforementioned objectives. The article also provides useful guidelines to the instructors, and discusses ideas to extend this research from several perspectives. To the best of our knowledge, this is the first research work that presents a broader review about the research conducted in the area of DSE.

Keywords Higher education · Database · Education · Database curriculum · Tools · Teaching methods

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1 Introduction

Database systems play a pivotal role in the successful implementation of the information systems to ensure the smooth running of many different organizations and companies (Etemad & K p cu, 2018; Morien, 2006). Therefore, at least one course about the fundamentals of database systems is taught in every computing and information systems degree (Nagataki et al., 2013). Database System Education (DSE) is concerned with different aspects of data management while developing software (Park et al., 2017). The IEEE/ACM computing curricula guidelines endorse 30–50 dedicated hours for teaching fundamentals of design and implementation of database systems so as to build a very strong theoretical and practical understanding of the DSE topics (Cvetanovic et al., 2010).

Practically, most of the universities offer one user-oriented course at undergraduate level that covers topics related to the data modeling and design, querying, and a limited number of hours on theory (Conklin & Heinrichs, 2005; Robbert & Ricardo, 2003), where it is often debatable whether to utilize a design-first or query-first approach. Furthermore, in order to update the course contents, some recent trends, including big data and the notion of NoSQL should also be introduced in this basic course (Dietrich et al., 2008; Garcia-Molina, 2008). Whereas, the graduate course is more theoretical and includes topics related to DB architecture, transactions, concurrency, reliability, distribution, parallelism, replication, query optimization, along with some specialized classes.

Researchers have designed a variety of tools for making different concepts of introductory database course more interesting and easier to teach and learn interactively (Brusilovsky et al., 2010) either using visual support (Nagataki et al., 2013), or with the help of gamification (Fisher & Khine, 2006). Similarly, the instructors have been improvising different methods to teach (Abid et al., 2015; Dom nguez & Jaime, 2010) and evaluate (Kawash et al., 2020) this theoretical and practical course. Also, the emerging and hot topics such as cloud computing and big data has also created the need to revise the curriculum and methods to teach DSE (Manzoor et al., 2020).

The research in database systems education has evolved over the years with respect to modern contents influenced by technological advancements, supportive tools to engage the learners for better learning, and improvisations in teaching and assessment methods. Particularly, in recent years there is a shift from self-describing data-driven systems to a problem-driven paradigm that is the bottom-up approach where data exists before being designed. This mainly relies on scientific, quantitative, and empirical methods for building models, while pushing the boundaries of typical data management by involving mathematics, statistics, data mining, and machine learning, thus opening a multidisciplinary perspective. Hence, it is important to devote a few lectures to introducing the relevance of such advance topics.

Researchers have provided useful review articles on other areas including Introductory Programming Language (Mehmood et al., 2020), use of gamification (Obaid et al., 2020), research trends in the use of enterprise service bus (Aziz et al., 2020), and the role of IoT in agriculture (Farooq et al., 2019, 2020) However, to the best of our knowledge, no such study was found in the area of database systems education.

Therefore, this study discusses research work published in different areas of database systems education involving curricula, tools, and approaches that have been proposed to teach an introductory course on database systems in an effective manner. The rest of the article has been structured in the following manner: Sect. 2 presents related work and provides a comparison of the related surveys with this study. Section 3 presents the research methodology for this study. Section 4 analyses the major findings of the literature reviewed in this research and categorizes it into different important aspects. Section 5 represents advices for the instructors and future directions. Lastly, Sect. 6 concludes the article.

2 Related work

Systematic Literature Reviews have been found to be a very useful artifact for covering and understanding a domain. A number of interesting review studies have been found in different fields (Farooq et al., 2021; Ishaq et al., 2021). Review articles are generally categorized into narrative or traditional reviews (Abid et al., 2016; Ramzan et al., 2019), systematic literature review (Naeem et al., 2020) and meta reviews or mapping study (Aria & Cuccurullo, 2017; Cobo et al., 2012; Tehseen et al., 2020). This study presents a systematic literature review on database system education.

The database systems education has been discussed from many different perspectives which include teaching and learning methods, curriculum development, and the facilitation of instructors and students by developing different tools. For instance, a number of research articles have been published focusing on developing tools for teaching database systems course (Abut & Ozturk, 1997; Connolly et al., 2005; Pahl et al., 2004). Furthermore, few authors have evaluated the DSE tools by conducting surveys and performing empirical experiments so as to gauge the effectiveness of these tools and their degree of acceptance among important stakeholders, teachers and students (Brusilovsky et al., 2010; Nelson & Fatimazahra, 2010). On the other hand, some case studies have also been discussed to evaluate the effectiveness of the improvised approaches and developed tools. For example, Regueras et al. (2007) presented a case study using the QUEST system, in which e-learning strategies are used to teach the database course at undergraduate level, while, Myers and Skinner (1997) identified the conflicts that arise when theories in text books regarding the development of databases do not work on specific applications.

Another important facet of DSE research focuses on the curriculum design and evolution for database systems, whereby (Alrumaih, 2016; Bhogal et al., 2012; Cvetanovic et al., 2010; Sahami et al., 2011) have proposed solutions for improvements in database curriculum for the better understanding of DSE among the students, while also keeping the evolving technology into the perspective. Similarly, Mingyu et al. (2017) have shared their experience in reforming the DSE curriculum by adding topics related to Big Data. A few authors have also developed and evaluated different tools to help the instructors teaching DSE.

There are further studies which focus on different aspects including specialized tools for specific topics in DSE (Mcintyre et al, 1995; Nelson & Fatimazahra, 2010). For instance, McIntyre et al. (1995) conducted a survey about using state of the art software tools to teach advanced relational database design courses at Cleveland State University. However, the authors did not discuss the DSE curricula and pedagogy in their study. Similarly, a review has been conducted by Nelson and Fatimazahra (2010) to highlight the fact that the understanding of basic knowledge of database is important for students of the computer science domain as well as those belonging to other domains. They highlighted the issues encountered while teaching the database course in universities and suggested the instructors investigate these difficulties so as to make this course more effective for the students. Although authors have discussed and analyzed the tools to teach database, the tools are yet to be categorized according to different methods and research types within DSE. There also exists an interesting systematic mapping study by Taipalus and Seppänen (2020) that focuses on teaching SQL which is a specific topic of DSE. Whereby, they categorized the selected primary studies into six categories based on their research types. They utilized directed content analysis, such as, student errors in query formulation, characteristics and presentation of the exercise database, specific or non-specific teaching approach suggestions, patterns and visualization, and easing teacher workload.

Another relevant study that focuses on collaborative learning techniques to teach the database course has been conducted by Martin et al. (2013) This research discusses collaborative learning techniques and adapted it for the introductory database course at the Barcelona School of Informatics. The motive of the authors was to introduce active learning methods to improve learning and encourage the acquisition of competence. However, the focus of the study was only on a few methods for teaching the course of database systems, while other important perspectives, including database curricula, and tools for teaching DSE were not discussed in this study.

The above discussion shows that a considerable amount of research work has been conducted in the field of DSE to propose various teaching methods; develop and test different supportive tools, techniques, and strategies; and to improve the curricula for DSE. However, to the best of our knowledge, there is no study that puts all these relevant and pertinent aspects together while also classifying and discussing the supporting methods, and techniques. This review is considerably different from previous studies. Table 1 highlights the differences between this study and other relevant studies in the field of DSE using ✓ and – symbol reflecting "included" and "not included" respectively. Therefore, this study aims to conduct a systematic mapping study on DSE that focuses on compiling, classifying, and discussing the existing work related to pedagogy, supporting tools, and curricula.

3 Research methodology

In order to preserve the principal aim of this study, which is to review the research conducted in the area of database systems education, a piece of advice has been collected from existing methods described in various studies (Elberzhager et al., 2012;

Table 1 Comparison with other related research articles

Study	(McIntyre et al., 1995)	(Myers & Skinner, 1997)	(Beecham et al., 2008)	(Dietrich et al., 2008)	(Regueras et al., 2007)	(Nelson & Fatimazahra, 2010)	(Martin et al., 2013)	(Abbasi et al., 2017)	(Luxton-Reilly et al., 2018)	(Taipalus & Seppänen, 2020)	This article
Focus	Database	Database	Software Engineering	Database	Database	Database	Database	OOP	Program-ming	Data Base	Database System
Research Types Classifications	-	-	-	-	-	-	-	-	-	✓	✓
Teaching Methods	-	✓	-	-	-	-	✓	-	✓	✓	✓
Tools to aid teaching	✓	-	✓	✓	✓	✓	-	✓	✓	✓	✓
Curricula considered	-	-	-	✓	-	-	✓	-	✓	-	✓
Evolution	-	-	-	-	-	-	-	-	-	-	✓
Year	1995	1997	2008	2008	2009	2015	2013	2017	2018	2020	2022

Keele et al., 2007; Mushtaq et al., 2017) to search for the relevant papers. Thus, proper research objectives were formulated, and based on them appropriate research questions and search strategy were formulated as shown in Fig. 1.

4 Research objectives

The Following are the research objectives of this study:

- i. To find high quality research work in DSE.
- ii. To categorize different aspects of DSE covered by other researchers in the field.
- iii. To provide a thorough discussion of the existing work in this study to provide useful information in the form of evolution, teaching guidelines, and future research directions of the instructors.

5 Research questions

In order to fulfill the research objectives, some relevant research questions have been formulated. These questions along with their motivations have been presented in Table 2.

5.1 Search strategy

The Following search string used to find relevant articles to conduct this study. “Database” AND (“System” OR “Management”) AND (“Education*” OR “Train*” OR “Tech*” OR “Learn*” OR “Guide*” OR “Curricul*”).

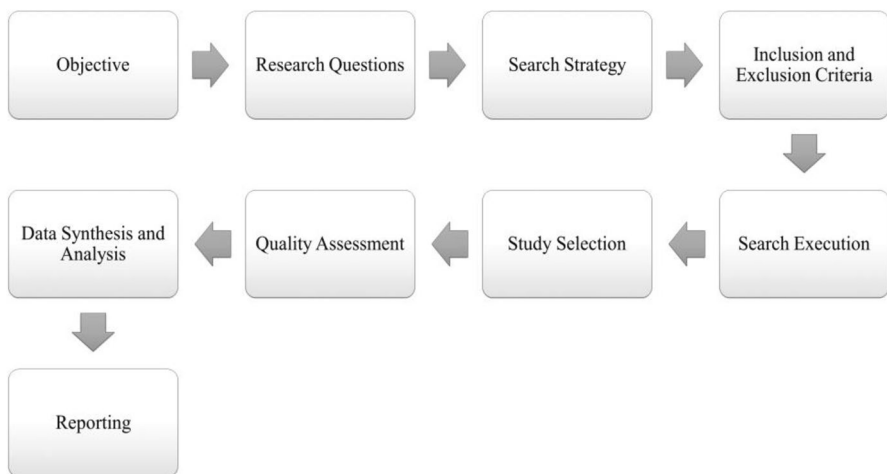


Fig. 1 Research methodology

Table 2 Study selection results

No	Research questions	Motivations
RQ1	What are the developments in DSE with respect to tools, methods, and curriculum?	- Identify focal areas of research in DSE - Discuss the work done in each area
RQ2	How the research in DSE evolved in past 25 years?	- Discuss the focus of research in different time spans while mapping it onto the technological advancement

Articles have been taken from different sources i.e. IEEE, Springer, ACM, Science Direct and other well-known journals and conferences such as Wiley Online Library, PLOS and ArXiv. The planning for search to find the primary study in the field of DSE is a vital task.

5.2 Study selection

A total of 29,370 initial studies were found. These articles went through a selection process, and two authors were designated to shortlist the articles based on the defined inclusion criteria as shown in Fig. 2. Their conflicts were resolved by involving a third author; while the inclusion/exclusion criteria were also refined after resolving the conflicts as shown in Table 3. Cohen's Kappa coefficient 0.89 was observed between the two authors who selected the articles, which reflects almost perfect agreement between them (Landis & Koch, 1977). While, the number of papers in different stages of the selection process for all involved portals has been presented in Table 4.

Title based search: Papers that are irrelevant based on their title are manually excluded in the first stage. At this stage, there was a large portion of irrelevant papers. Only 609 papers remained after this stage.

Abstract based search: At this stage, abstracts of the selected papers in the previous stage are studied and the papers are categorized for the analysis along with research approach. After this stage only 152 papers were left.

Full text based analysis: Empirical quality of the selected articles in the previous stage is evaluated at this stage. The analysis of full text of the article has been

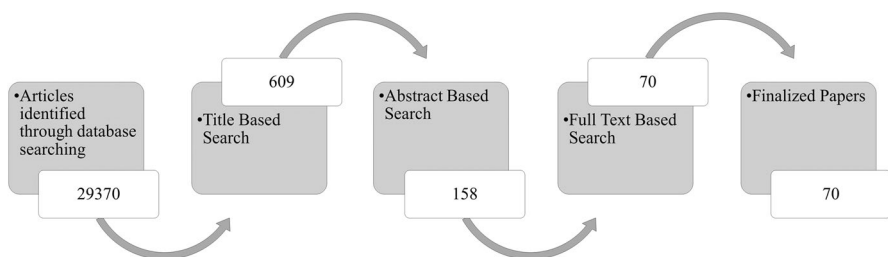
**Fig. 2** Study selection

Table 3 Selection criteria

IC	Inclusion criteria
IC 1	The study related to the database and education
IC 2	The years of research publication must be from 1995 to 2022
IC 3	Only full length papers are included
IC 4	Research papers written in English language are included
EC	Exclusion criteria
EC1	Incomplete papers, i.e., presentation, posters or essay
EC2	Research articles without abstract
EC3	Research articles other than English language
EC4	Papers that do not include education as their primary focus

Table 4 Study selection results

Phase	Process	Selection stage	IEEE	Springer	ACM	Elsevier	Others	Total
1	Search	Search string	500	5312	10,802	5696	7045	29,370
2	Screening	Title	153	121	115	133	87	609
3	Screening	Abstract	45	23	29	21	40	158
4	Screening	Full text	10	1	20	2	37	70

conducted. The total of 70 papers were extracted from 152 papers for primary study. Following questions are defined for the conduction of final data extraction.

5.2.1 Quality assessment criteria

Following are the criteria used to assess the quality of the selected primary studies. This quality assessment was conducted by two authors as explained above.

- The study focuses on curricula, tools, approach, or assessments in DSE, the possible answers were Yes (1), No (0)
- The study presents a solution to the problem in DSE, the possible answers to this question were Yes (1), Partially (0.5), No (0)
- The study focuses on empirical results, Yes (1), No (0)
- The study is published in a well reputed venue that is adjudged through the CORE ranking of conferences, and Scientific Journal Ranking (SJR). The possible answers to this question are given in Table 5.

Almost 50.00% of papers had scored more than average and 33.33% of papers had scored between the average range i.e., 2.50–3.50. Some articles with the score below 2.50 have also been included in this study as they present some useful information and were published in education-based journals. Also, these studies discuss important demography and technology based aspects that are directly related to DSE.

Table 5 Score pattern of publication channels

Channel type	Quartile number	Score
Journal Quartile Ranking	Q1	2
	Q2	1.5
	Q3	1
	Q4	0.5
	Other	0
Conference/Workshop/ Symposium/Core Ranking	Core A	1.5
	Core B	1
	Core C	0.5
	Other	0

5.3 Threats to validity

The validity of this study could be influenced by the following factors during the literature of this publication.

Construct validity In this study this validity identifies the primary study for research (Elberzhager et al., 2012). To ensure that many primary studies have been included in this literature two authors have proposed possible search keywords in multiple repetitions. Search string is comprised of different terms related to DS and education. Though, list might be incomplete, count of final papers found can be changed by the alternative terms (Ampatzoglou et al., 2013). IEEE digital library, Science direct, ACM digital library, Wiley Online Library, PLOS, ArXiv and Google scholar are the main libraries where search is done. We believe according to the statistics of search engines of literature the most research can be found on these digital libraries (Garousi et al., 2013). Researchers also searched related papers in main DS research sites (VLDB, ICDM, EDBT) in order to minimize the risk of missing important publication.

Including the papers that does not belong to top journals or conferences may reduce the quality of primary studies in this research but it indicates that the representativeness of the primary studies is improved. However, certain papers which were not from the top publication sources are included because of their relativeness with the literature, even though they reduce the average score for primary studies. It also reduces the possibility of alteration of results which might have caused by the improper handling of duplicate papers. Some cases of duplications were found which were inspected later whether they were the same study or not. The two authors who have conducted the search has taken the final decision to the select the papers. If there is no agreement between then there must be discussion until an agreement is reached.

Internal validity This validity deals with extraction and data analysis (Elberzhager et al., 2012). Two authors carried out the data extraction and primary studies classification. While the conflicts between them were resolved by involving a third author.

The Kappa coefficient was 0.89, according to Landis and Koch (1977), this value indicates almost perfect level of agreement between the authors that reduces this threat significantly.

Conclusion validity This threat deals with the identification of improper results which may cause the improper conclusions. In this case this threat deals with the factors like missing studies and wrong data extraction (Ampatzoglou et al., 2013). The objective of this is to limit these factors so that other authors can perform study and produce the proper conclusions (Elberzhager et al., 2012).

Interpretation of results might be affected by the selection and classification of primary studies and analyzing the selected study. Previous section has clearly described each step performed in primary study selection and data extraction activity to minimize this threat. The traceability between the result and data extracted was supported through the different charts. In our point of view, slight difference based on the publication selection and misclassification would not alter the main results.

External validity This threat deals with the simplification of this research (Mateo et al., 2012). The results of this study were only considered that related to the DSE filed and validation of the conclusions extracted from this study only concerns the DSE context. The selected study representativeness was not affected because there was no restriction on time to find the published research. Therefore, this external validity threat is not valid in the context of this research. DS researchers can take search string and the paper classification scheme represented in this study as an initial point and more papers can be searched and categorized according to this scheme.

6 Analysis of compiled research articles

This section presents the analysis of the compiled research articles carefully selected for this study. It presents the findings with respect to the research questions described in Table 2.

6.1 Selection results

A total of 70 papers were identified and analyzed for the answers of RQs described above. Table 6 represents a list of the nominated papers with detail of the classification results and their quality assessment scores.

6.1.1 RQ1. Categorization of research work in DSE field

The analysis in this study reveals that the literature can be categorized as: Tools: any additional application that helps instructors in teaching and students in learning. Methods: any improvisation aimed at improving pedagogy or cognition.

Table 6 Classification and quality assessment of selected articles

Ref	Channel	Year	Research Type	a	b	c	d	Total
Tools				Quality Assessment				
(Mcintyre et al., 1995)	Journal	1995	Review	1	1	0	2	4
(Abut & Ozturk, 1997)	Conference	1997	Experiment	1	1	0	0	2
(Yau & Karim, 2003)	Conference	2003	Experiment	1	0.5	0	1	2.5
(Pahl et al., 2004)	Journal	2004	Experiment	1	1	0	0	2
(Connolly et al., 2005)	Conference	2005	Experiment	1	0.5	1	1	3.5
(Regueras et al., 2007)	Conference	2007	Case Study	1	1	1	0	3
(Sciore, 2007)	Symposium	2007	Case Study	1	0	1	1.5	3.5
(Holliday & Wang, 2009)	Conference	2009	Experiment	1	0.5	1	0.5	3
(Brusilovsky et al., 2010)	Journal	2010	Experiment	1	1	1	2	5
(Cvetanovic et al., 2010)	Journal	2010	Experiment	1	1	0	2	4
(Nelson & Fatimazahra, 2010)	Journal	2010	Review	1	1	0	1	3
(Wang et al., 2010)	Conference	2010	Experiment	1	1	0	1.5	3.5
(Nagataki et al., 2013)	Journal	2013	Experiment	0	1	1	2	4
(Yue, 2013)	Journal	2013	Experiment	1	1	1	1.5	4.5
(Abelló Gamazo et al., 2016)	Journal	2016	Experiment	1	1	1	2	5
(Taipalus & Perälä, 2019)	Symposium	2019	Review	1	1	1	1.5	4.5
Methods				Quality Assessment				
(Dietrich & Urban, 1996)	Conference	1996	Review	1	1	0	1.5	3.5
(Urban & Dietrich, 1997)	Journal	1997	Experiment	1	1	0	0	2
(Nelson et al., 2003)	Workshop	2003	Review	1	1	0	0	2
(Amadio, 2003)	Conference	2003	Experiment	1	0.5	1	0.5	3
(Connolly & Begg, 2006)	Journal	2006	Experiment	1	1	0	2	4
(Morien, 2006)	Journal	2006	Experiment	1	0.5	1	2	4.5
(Prince & Felder, 2006)	Journal	2006	Review	0	0.5	0	2	2.5
(Martinez-González & Duffing, 2007)	Journal	2007	Review	1	1	0	2	4
(Gudivada et al., 2007)	Conference	2007	Review	1	0.5	0	0	1.5
(Svahnberg et al., 2008)	Symposium	2008	Review	1	0	0	1.5	2.5
(Brusilovsky et al., 2008)	Conference	2008	Experiment	1	0.5	1	1.5	4
(Dominguez & Jaime, 2010)	Journal	2010	Experiment	1	1	1	2	5
(Efendiouglu & Yelken 2010)	Journal	2010	Experiment	1	1	1	0	3
(Hou & Chen, 2010)	Conference	2010	Review	1	0.5	1	0	2.5
(Yuelan et al., 2011)	Conference	2011	Experiment	1	0.5	0	0	1.5
(Zheng & Dong, 2011)	Conference	2011	Review	1	1	0	1	3
(Al-Shuaily, 2012)	Workshop	2012	Review	1	1	1	0	3
(Juxiang & Zhihong, 2012)	Conference	2012	Review	1	0.5	0	0	1.5
(Chen et al., 2012)	Journal	2012	Review	1	1	1	2	5
(Martin et al., 2013)	Journal	2013	Review	1	1	1	2	5
(Rashid & Al-Radhy, 2014)	conference	2014	Review	1	0.5	1	0	2.5
(Wang & Chen, 2014)	Conference	2014	Experiment	1	0	1	0	2
(Dicheva et al., 2015)	Journal	2015	Review	1	1	0	1	3
(Rashid, 2015)	Journal	2015	Review	1	0.5	1	2	4.5

Table 6 (continued)

Ref	Channel	Year	Research Type	a	b	c	d	Total
(Etemad & K�p�c�, 2018)	Journal	2018	Experiment	0	0.5	1	2	3.5
(Kui et al., 2018)	Conference	2018	Experiment	1	1	0	1	3
(Taipalus et al., 2018)	Journal	2018	Review	1	1	0	2	4
(Zhang et al., 2018)	conference	2018	Experiment	1	1	1	0	3
(Shebaro, 2018)	Journal	2018	Review	1	0.5	1	0	2.5
(Cai & Gao, 2019)	Conference	2019	Review	1	1	0	0	2
(Kawash et al., 2020)	Symposium	2020	Experiment	1	1	1	1.5	4.5
(Taipalus & Sepp�nen, 2020)	Journal	2020	Review	1	1	1	2	5
(Canedo et al., 2021)	Journal	2021	Experiment	1	1	1	1	4
(Naik & Gajjar, 2021)	Journal	2021	Case Study	1	1	1	0	3
(Ko et al., 2021)	Journal	2021	Review	1	1	1	2	5
(Sibia et al., 2022)	Workshop	2022	Case Study	1	1	1	0	3
Curriculum							Quality Assessment	
(Dean & Milani, 1995)	Conference	1995	Experiment	1	0.5	1	0.5	3
(Urban & Dietrich, 2001)	Symposium	2001	Case Study	1	0	1	1.5	3.5
(Calero et al., 2003)	Journal	2003	Review	1	1	0	2	4
(Robbert & Ricardo, 2003)	Conference	2003	Review	1	1	0	1.5	3.5
(Adams et al., 2004)	Journal	2004	Experiment	1	1	0	0	2
(Conklin & Heinrichs, 2005)	Journal	2005	Review	1	1	1	0	3
(Dietrich et al., 2008)	Journal	2008	Case Study	0	1	1	2	4
(Luo et al., 2008)	Conference	2008	Experiment	1	1	1	0	3
(Marshall, 2011)	Conference	2011	Review	1	1	1	0	3
(Bhagal et al., 2012)	Workshop	2012	Case Study	1	1	0	0	2
(Picciano, 2012)	Journal	2012	Review	1	1	0	0	2
(Abid et al., 2015)	Journal	2015	Review	1	1	1	1	4
(Taipalus & Sepp�nen, 2020)	Journal	2015	Experiment	1	1	1	2	5
(Abourezq & Idrissi, 2016)	Journal	2016	Experiment	1	1	0	0.5	2.5
(Silva et al., 2016)	Conference	2016	Experiment	1	1	0	1.5	3.5
(Zhanquan et al., 2016)	Journal	2016	Review	1	1	1	0	3
(Mingyu et al., 2017)	Conference	2017	Experiment	1	1	1	0	3
(Andersson et al., 2019)	Conference	2019	Review	1	0.5	0	0	1.5

Curriculum: refers to the course content domains and their relative importance in a degree program, as shown in Fig. 3.

Most of the articles provide a solution by gathering the data and also prove the novelty of their research through results. These papers are categorized as experiments w.r.t. their research types. Whereas, some of them case study papers which are used to generate an in depth, multifaceted understanding of a complex issue in its real-life context, while few others are review studies analyzing the previously used approaches. On the other hand, a majority of included articles

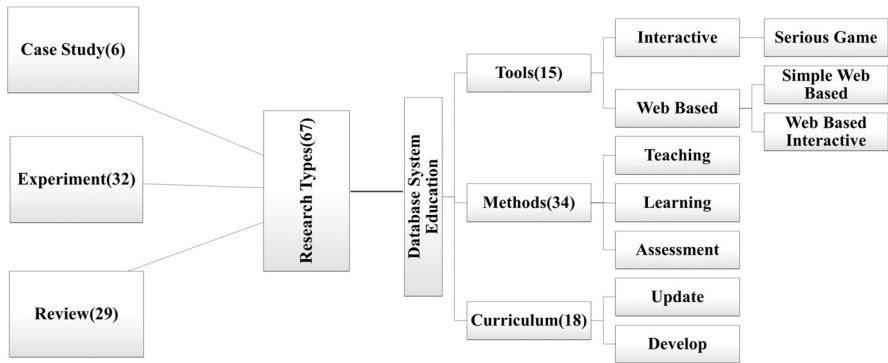


Fig. 3 Taxonomy of DSE study types

have evaluated their results with the help of experiments, while others conducted reviews to establish an opinion as shown in Fig. 4.

A. Tools

Educational tools, especially those related to technology, are making their place in market faster than ever before (Calderon et al., 2011). The transition to active learning approaches, with the learner more engaged in the process rather than passively taking in information, necessitates a variety of tools to help ensure success. As with most educational initiatives, time should be taken to consider the goals of the activity, the type of learners, and the tools needed to meet the goals. Constant reassessment of tools is important to discover innovation and reforms that improve teaching and learning (Irby & Wilkerson, 2003). For this purpose, various type of educational tools such as, interactive, web-based and game based have been introduced to aid the instructors in order to explain the topic in more effective way.

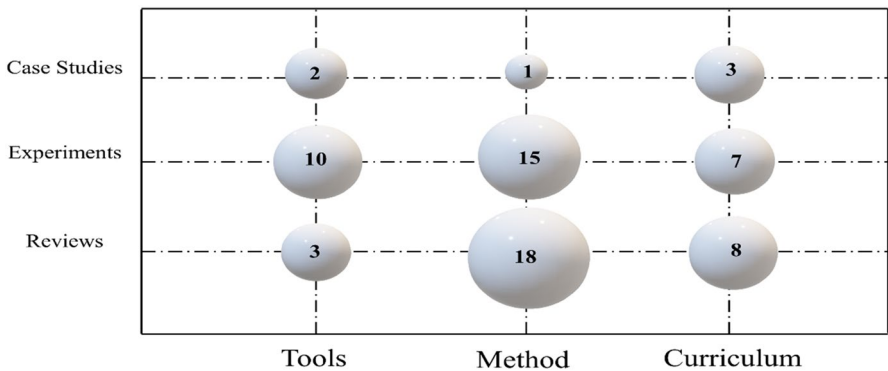


Fig. 4 Cross Mapping of DSE study type and research Types

The inclusion of technology into the classroom may help learners to compete in the competitive market when approaching the start of their career. It is important for the instructors to acknowledge that the students are more interested in using technology to learn database course instead of merely being taught traditional theory, project, and practice-based methods of teaching (Adams et al., 2004). Keeping these aspects in view many authors have done significant research which includes web-based and interactive tools to help the learners gain better understanding of basic database concepts.

Great research has been conducted with the focus of students learning. In this study we have discussed the students learning supportive with two major finding's objectives i.e., tools which prove to be more helpful than other tools. Whereas, proposed tools with same outcome as traditional classroom environment. Such as, Abut and Ozturk (1997) proposed an interactive classroom environment to conduct database classes. The online tools such as electronic "Whiteboard", electronic textbooks, advance telecommunication networks and few other resources such as Matlab and World Wide Web were the main highlights of their proposed smart classroom. Also, Pahl et al. (2004) presented an interactive multimedia-based system for the knowledge and skill oriented Web-based education of database course students. The authors had differentiated their proposed classroom environment from traditional classroom-based approach by using tool mediated independent learning and training in an authentic setting. On the other hand, some authors have also evaluated the educational tools based on their usage and impact on students' learning. For example, Brusilovsky et al. (2010)s evaluated the technical and conceptual difficulties of using several interactive educational tools in the context of a single course. A combined Exploratorium has been presented for database courses and an experimental platform, which delivers modified access to numerous types of interactive learning activities.

Also, Taipalus and Perälä (2019) investigated the types of errors that are persistent in writing SQL by the students. The authors also contemplated the errors while mapping them onto different query concepts. Moreover, Abelló Gamazo et al. (2016) presented a software tool for the e-assessment of relational database skills named LearnSQL. The proposed software allows the automatic and efficient e-learning and e-assessment of relational database skills. Apart from these, Yue (2013) proposed the database tool named Sakila as a unified platform to support instructions and multiple assignments of a graduate database course for five semesters. According to this study, students find this tool more useful and interesting than the highly simplified databases developed by the instructor, or obtained from textbook. On the other hand, authors have proposed tools with the main objective to help the student's grip on the topic by addressing the pedagogical problems in using the educational tools. Connolly et al. (2005) discussed some of the pedagogical problems sustaining the development of a constructive learning environment using problem-based learning, a simulation game and interactive visualizations to help teach database analysis and design. Also, Yau and Karim (2003) proposed smart classroom with prevalent computing technology which will facilitate collaborative learning among the learners. The major aim of this smart classroom is to improve the quality of interaction between the instructors and students during lecture.

Student satisfaction is also an important factor for the educational tools to more effective. While it supports in students learning process it should also be flexible to achieve the student's confidence by making it as per student's needs (Brusilovsky et al., 2010; Connolly et al., 2005; Pahl et al., 2004). Also, Cvetanovic et al. (2010) has proposed a web-based educational system named ADVICE. The proposed solution helps the students to reduce the gap between DBMS, theory and its practice. On the other hand, authors have enhanced the already existing educational tools in the traditional classroom environment to address the student's concerns (Nelson & Fatimazahra, 2010; Regueras et al., 2007) Table 7.

Hands on database development is the main concern in most of the institute as well as in industry. However, tools assisting the students in database development and query writing is still major concern especially in SQL (Brusilovsky et al., 2010; Nagataki et al., 2013).

Student's grades reflect their conceptual clarity and database development skills. They are also important to secure jobs and scholarships after passing out, which is why it is important to have the educational learning tools to help the students to perform well in the exams (Cvetanovic et al., 2010; Taipalus et al., 2018). While, few authors (Wang et al., 2010) proposed Metube which is a variation of YouTube. Subsequently, existing educational tools needs to be upgraded or replaced by the more suitable assessment oriented interactive tools to attend challenging students needs (Pahl et al., 2004; Yuelan et al., 2011).

One other objective of developing the educational tools is to increase the interaction between the students and the instructors. In the modern era, almost every institute follows the student centered learning(SCL). In SCL the interaction between students and instructor increases with most of the interaction involves from the students. In order to support SCL the educational based interactive and web-based tools need to assign more roles to students than the instructors (Abbasi et al., 2016; Taipalus & Perälä, 2019; Yau & Karim, 2003).

B. Methods

Theory versus practice is still one of the main issues in DSE teaching methods. The traditional teaching method supports theory first and then the concepts learned in the theoretical lectures implemented in the lab. Whereas, others think that it is better to start by teaching how to write query, which should be followed by teaching the design principles for database, while a limited amount of credit hours are also allocated for the general database theory topics. This part of the article discusses different trends of teaching and learning style along with curriculum and assessments methods discussed in DSE literature.

A variety of teaching methods have been designed, experimented, and evaluated by different researchers (Yuelan et al., 2011; Chen et al., 2012; Connolly & Begg, 2006). Some authors have reformed teaching methods based on the requirements of modern way of delivering lectures such as Yuelan et al. (2011) reform teaching method by using various approaches e.g. a) Modern ways of education: includes multimedia sound, animation, and simulating the process and working of

Table 7 Tools: Adopted in DSE and their impacts

Objective	Findings	References	Target Topic/ exposition platform
Support of Students' learning	More supportive	<ul style="list-style-type: none"> • (Abut & Ozturk, 1997) • (Pahl et al., 2004) • (Brusilovsky et al., 2010) • Conceptual database design, Logical database design, Physical database design • Online games • (Abbasi et al., 2016) • (Yue, 2013) • (Nelson & Fatimazahra, 2010) • (Connolly et al., 2005) • (Yau & Karim, 2003) 	<ul style="list-style-type: none"> • Data models and data modelling principles • IDLE (the Interactive Database Learning Environment) • Data models • IDLE • SQL • SQL-Knot, SQL-Lab • SQL • Interactive • Relational Database • LearnSQL • Relational Calculus, XML generation, XPath, and XQuery • Sakila • Introductory Database topics • TLAD • Conceptual database design, Logical database design, Physical database design • Online games • Introductory Database topics • RCSM
	Same as others		

Table 7 (continued)

Objective	Findings	References	Target Topic/ exposition platform
Students' Satisfaction	Satisfied	<ul style="list-style-type: none"> • (Brusilovsky et al., 2010) • (Cvetanovic et al., 2010) • (Connolly et al., 2005) • (Pahl et al., 2004) • (Nelson & Fatimazahra, 2010) • (Regueras et al., 2007) • (Nagataki et al., 2013) • (Brusilovsky et al., 2010) • (Mcintyre et al., 1995) 	<ul style="list-style-type: none"> • SQL • SQL-Knot, SQL-Lab • SQL, formal query languages, and normalization • ADVICE • Data models • IDLE • Introductory Database topics • TLAD • Entity Relationship Model • QUEST • SQL • sAccess • SQL • SQL-Knot, SQL-Lab • Relational Database Design • Expert IT system
Students' motivation towards database development	<p>Similar satisfaction as compared to traditional classroom environment</p> <p>Same impact as other approaches</p> <p>Helped students to develop better data-base development strategies</p>		

Table 7 (continued)

Objective	Findings	References	Target Topic/ exposition platform
Students' course performance	Better performance	<ul style="list-style-type: none"> • (Cvetanovic et al., 2010) • (Wang et al., 2010) • (Holliday & Wang, 2009) • (Taipalus & Perälä, 2019) 	<ul style="list-style-type: none"> • SQL, formal query languages, and normalization • ADVICE • Entity Relationship Model, SQL • MeTube • MySQL • MeTube • SQL • Interactive
		<ul style="list-style-type: none"> • (Pahl et al., 2004) 	<ul style="list-style-type: none"> • Data models • IDLE
	Same performance as other approaches	<ul style="list-style-type: none"> • (Yue, 2013) 	<ul style="list-style-type: none"> • Relational Calculus, XML-generation, XPath, and XQuery • Sakila
Student and instructor interaction percentage	Increased	<ul style="list-style-type: none"> • (Abut & Ozturk, 1997) • (Yau & Karim, 2003) • (Taipalus & Perälä, 2019) 	<ul style="list-style-type: none"> • Introductory Database topics • “Whiteboard” • Introductory Database topics • RSCSM • SQL • Interactive

database systems to motivate and inspire the students. b) Project driven approach: aims to make the students familiar with system operations by implementing a project. c) Strengthening the experimental aspects: to help the students get a strong grip on the basic knowledge of database and also enable them to adopt a self-learning ability. d) Improving the traditional assessment method: the students should turn in their research and development work as the content of the exam, so that they can solve their problem on their own.

The main aim of any teaching method is to make student learn the subject effectively. Student must show interest in order to gain something from the lectures delivered by the instructors. For this, teaching methods should be interactive and interesting enough to develop the interest of the students in the subject. Students can show interest in the subject by asking more relative questions or completing the home task and assignments on time. Authors have proposed few teaching methods to make topic more interesting such as, Chen et al. (2012) proposed a scaffold concept mapping strategy, which considers a student's prior knowledge, and provides flexible learning aids (scaffolding and fading) for reading and drawing concept maps. Also, Connolly & Begg (2006) examined different problems in database analysis and design teaching, and proposed a teaching approach driven by principles found in the constructivist epistemology to overcome these problems. This constructivist approach is based on the cognitive apprenticeship model and project-based learning. Similarly, Domínguez & Jaime (2010) proposed an active method for database design through practical tasks development in a face-to-face course. They analyzed results of five academic years using quasi experimental. The first three years a traditional strategy was followed and a course management system was used as material repository. On the other hand, Dietrich and Urban (1996) have described the use of cooperative group learning concepts in support of an undergraduate database management course. They have designed the project deliverables in such a way that students develop skills for database implementation. Similarly, Zhang et al. (2018) have discussed several effective classroom teaching measures from the aspects of the innovation of teaching content, teaching methods, teaching evaluation and assessment methods. They have practiced the various teaching measures by implementing the database technologies and applications in Qinghai University. Moreover, Hou and Chen (2010) proposed a new teaching method based on blending learning theory, which merges traditional and constructivist methods. They adopted the method by applying the blending learning theory on Access Database programming course teaching.

Problem solving skills is a key aspect to any type of learning at any age. Student must possess this skill to tackle the hurdles in institute and also in industry. Create mind and innovative students find various and unique ways to solve the daily task which is why they are more likeable to secure good grades and jobs. Authors have been working to introduce teaching methods to develop problem solving skills in the students (Al-Shuaily, 2012; Cai & Gao, 2019; Martinez-González & Duffing, 2007; Gudivada et al., 2007). For instance, Al-Shuaily (2012) has explored four cognitive factors such as i) Novices' ability in understanding, ii) Novices' ability to translate, iii) Novice's ability to write, iv) Novices' skills that might influence SQL teaching, and learning methods and approaches. Also, Cai and Gao (2019) have reformed the

teaching method in the database course of two higher education institutes in China. Skills and knowledge, innovation ability, and data abstraction were the main objective of their study. Similarly, Martínez-González and Duffing (2007) analyzed the impact of convergence of European Union (EU) in different universities across Europe. According to their study, these institutes need to restructure their degree program and teaching methodologies. Moreover, Gudivada et al. (2007) proposed a student's learning method to work with the large datasets. They have used the Amazon Web Services API and .NET/C# application to extract a subset of the product database to enhance student learning in a relational database course.

On the other hand, authors have also evaluated the traditional teaching methods to enhance the problem-solving skills among the students (Eaglestone & Nunes, 2004; Wang & Chen, 2014; Efendiouglu & Yelken, 2010). Such as, Eaglestone and Nunes (2004) shared their experiences of delivering a database design course at Sheffield University and discussed some of the issues they faced, regarding teaching, learning and assessments. Likewise, Wang and Chen (2014) summarized the problems mainly in teaching of the traditional database theory and application. According to the authors the teaching method is outdated and does not focus on the important combination of theory and practice. Moreover, Efendiouglu and Yelken (2010) investigated the effects of two different methods Programmed Instruction (PI) and Meaningful Learning (ML) on primary school teacher candidates' academic achievements and attitudes toward computer-based education, and to define their views on these methods. The results show that PI is not favoured for teaching applications because of its behavioural structure Table 8.

Students become creative and innovative when they try to study on their own and also from different resources rather than curriculum books only. In the modern era, there are various resources available on both online and offline platforms. Modern teaching methods must emphasize on making the students independent from the curriculum books and educate them to learn independently (Amadio et al., 2003; Cai & Gao, 2019; Martin et al., 2013). Also, in the work of Kawash et al. (2020) proposed the group study-based learning approach called Graded Group Activities (GGAs). In this method students team up in order to take the exam as a group. On the other hand, few studies have emphasized on course content to prepare students for the final exams such as, Zheng and Dong (2011) have discussed the issues of computer science teaching with particular focus on database systems, where different characteristics of the course, teaching content and suggestions to teach this course effectively have been presented.

As technology is evolving at rapid speed, so students need to have practical experience from the start. Basic theoretical concepts of database are important but they are of no use without its implementation in real world projects. Most of the students study in the institutes with the aim of only clearing the exams with the help of theoretical knowledge and very few students want to have practical experience (Wang & Chen, 2014; Zheng & Dong, 2011). To reduce the gap between the theory and its implementation, authors have proposed teaching methods to develop the student's interest in the real-world projects (Naik & Gajjar, 2021; Svahnberg et al., 2008; Taipalus et al., 2018). Moreover, Juxiang and Zhihong (2012) have proposed that the teaching organization starts from application

Table 8 Methods: Teaching approaches adopted in DSE

Objective	Findings	References	Target Topic/ Approach or Method
Develop interest in Subject	Students begin to ask more relative questions	<ul style="list-style-type: none"> • (Chen et al., 2012) • (Connolly & Beggs, 2006) • (Dominguez & Jaime, 2010) • (Rashid & Al-Radhy, 2014) • (Yuelan et al., 2011) • (Taipalus & Seppänen, 2020) • (Brusilovsky et al., 2008) • (Hou & Chen, 2010) 	<ul style="list-style-type: none"> • Data modeling, relational databases, database query languages • Scaffolded Concept • Database concepts, Database Analysis and Design, Implementation • Constructivist-Based Approach • Database design • Project-based learning • Database Analysis and Design • Project based learning, Assessment based learning • Principles of Database, SQL Server • Project-driven approach • SQL • Group learning and projects • SQL • SQL Exploratorium • Access • Blending Learning
	Same effect as others traditional teaching methods	<ul style="list-style-type: none"> • (Dietrich & Urban, 1996) • (Kui et al., 2018) • (Rashid, 2015) • (Zhang et al., 2018) 	<ul style="list-style-type: none"> • ER Model, Relational Design, SQL • Teaching and learning strategies • E-R model, relational model, SQL • Flipped Classroom • Entity Relational Database, Relational Algebra, Normalization, • Learning and Assessment Methods • Data Models, Physical Data Design • Project teaching mode, Discussion teaching mode, Demonstrative teaching mode

Table 8 (continued)

Objective	Findings	References	Target Topic/ Approach or Method
Develop problem solving skills	Students become creative and try new methods to solve tasks	<ul style="list-style-type: none"> • (Al-Shuaibly, 2012) • (Cai & Gao, 2019) • (Martin et al., 2013) • (Martinez-González & Duffing, 2007) • (Prince & Felder, 2006) • (Urban & Dietrich, 1997) • (Gudivada et al., 2007) • (Eaglestone & Nunes, 2004) • (Wang et al., 2010) • (Efendioglu & Yelken 2010) 	<ul style="list-style-type: none"> • SQL • Cognitive task, Comprehension Task • E-R model, relational model, SQL • Database Course for Liberal Arts Majors • SQL and relational algebra, The relational model, Transaction management • Collaborative Learning • Data Models, Physical Data Design, SQL • European convergence in higher education • SQL • Inductive teaching and learning • Relational database mapping and prototyping, Database system implementation • cooperative group project based learning • SQL, Logical design, Physical Design • Working with large datasets from Amazon • SQL, ER Model • Pedagogical model, teaching and learning strategies • SQL Server and Oracle • Refine Teaching Method • SQL • Programmed instruction and meaningful learning
	Use same methods as mentioned in books		

Table 8 (continued)

Objective	Findings	References	Target Topic/ Approach or Method
Motivate students to explore topics through independent study	Students begin to read books and internet to enhance their knowledge independently or in groups	<ul style="list-style-type: none"> • (Cai & Gao, 2019) • (Kawash et al., 2020) • (Martin et al., 2013) • (Martinez-González & Duffing, 2007) • (Amadio, 2003) • (Morien, 2006) • (Eaglestone & Nunes, 2004) • (Zheng & Dong, 2011) 	<ul style="list-style-type: none"> • SQL, E-R model, relational model • Database Course for Liberal Arts Majors • SQL, Entity Relationship, Relational model • Group Exams • SQL, Relational Model, UML • Collaborative Learning • SQL, Data Models, Physical Data Design • European convergence in higher education • SQL Programming • Team Learning • Entity modeling, relational modelling • Teaching Reform • SQL, ER Model • Pedagogical model, teaching and learning strategies • SQL, ER Model • Teaching Reform and Practice
	Students stick to the course content		

Table 8 (continued)

Objective	Findings	References	Target Topic/ Approach or Method
Focus on theory and practical Gap	Students begin to apply theoretical knowledge on developing database applications	<ul style="list-style-type: none"> • (Al-Shuaibi, 2012) • (Etemad & Küpçü, 2018) • (Svahnberg et al., 2008) • (Taipalus et al., 2018) • (Juxiang & Zhihong, 2012) • (Connolly & Begg, 2006) • (Rashid & Al-Radhy, 2014) • (Naik & Gajjar, 2021) • (Wang et al., 2010) • (Zheng & Dong, 2011) • (Nelson et al., 2003) 	<ul style="list-style-type: none"> • SQL • Cognitive task, Comprehension Task • SQL • cooperative group project-based learning • SQL • Industrial project-based learning • SQL • Group learning and projects • SQL, ER Model • Computational Thinking • Database concepts, Database Analysis and Design, Implementation • Constructivist-Based Approach • Database Analysis and Design • Project based learning, Assessment based learning • database designing, transaction management, SQL • ENABLE, Project based learning • SQL Server and Oracle • Refine Teaching Method • SQL, ER Model • Teaching Reform and Practice • Advanced relational design, UML, data warehousing • Teaching Methods, Assessment Methods
	Students only focus on theory to clear exams		

scenarios, and associate database theoretical knowledge with the process from analysis, modeling to establishing database application. Also, Svahnberg et al. (2008) explained that in particular conditions, there is a possibility to use students as subjects for experimental studies in DSE and influencing them by providing responses that are in line with industrial practice.

On the other hand, Nelson et al. (2003) evaluated the different teaching methods used to teach different modules of database in the School of Computing and Technology at the University of Sunderland. They outlined suggestions for changes to the database curriculum to further integrate research and state-of-the-art systems in databases.

III. Curriculum

Database curriculum has been revisited many times in the form of guidelines that not only present the contents but also suggest approximate time to cover different topics. According to the ACM curriculum guidelines (Lunt et al., 2008) for the undergraduate programs in computer science, the overall coverage time for this course is 46.50 h distributed in such a way that 11 h is the total coverage time for the core topics such as, Information Models (4 core hours), Database Systems (3 core hours) and Data Modeling (4 course hours). Whereas, the remaining hours are allocated for elective topics such as Indexing, Relational Databases, Query Languages, Relational Database Design, Transaction Processing, Distributed Databases, Physical Database Design, Data Mining, Information Storage and Retrieval, Hypermedia, Multimedia Systems, and Digital Libraries (Marshall, 2012). While, according to the ACM curriculum guidelines (2013) for undergraduate programs in computer science, this course should be completed in 15 weeks with two and half hour lecture per week and lab session of four hours per week on average (Brady et al., 2004). Thus, the revised version emphasizes on the practice based learning with the help of lab component. Numerous organizations have exerted efforts in this field to classify DSE (Dietrich et al., 2008). DSE model curricula, bodies of knowledge (BOKs), and some standardization aspects in this field are discussed below:

Model curricula There are standard bodies who set the curriculum guidelines for teaching undergraduate degree programs in computing disciplines. Curricula which include the guidelines to teach database are: Computer Engineering Curricula (CEC) (Meier et al., 2008), Information Technology Curricula (ITC) (Alrumaih, 2016), Computing Curriculum Software Engineering (CCSE) (Meyer, 2001), Cyber Security Curricula (CSC) (Brady et al., 2004; Bishop et al., 2017).

Bodies of knowledge (BOK) A BOK includes the set of thoughts and activities related to the professional area, while in model curriculum set of guidelines are given to address the education issues (Sahami et al., 2011). Database body of Knowledge comprises of (a) The Data Management Body of Knowledge (DM-BOK), (b)

Software Engineering Education Knowledge (SEEK) (Sobel, 2003) (Sobel, 2003), and (c) The SE body of knowledge (SWEBOK) (Swebok Evolution: IEEE Computer Society n.d.).

Standards Apart from the model curricula, and bodies of knowledge, there also exist some standards related to the database and its different modules: ISO/IEC 9075–1:2016 (Computing Curricula, 1991), ISO/IEC 10,026–1: 1998 (Surnyn, 2003).

We also utilize advices from some studies (Elberzhager et al., 2012; Keele et al., 2007) to search for relevant papers. In order to conduct this systematic study, it is essential to formulate the primary research questions (Mushtaq et al., 2017). Since the data management techniques and software are evolving rapidly, the database curriculum should also be updated accordingly to meet these new requirements. Some authors have described ways of updating the content of courses to keep pace with specific developments in the field and others have developed new database curricula to keep up with the new data management techniques.

Furthermore, some authors have suggested updates for the database curriculum based on the continuously evolving technology and introduction of big data. For instance Bhogal et al. (2012) have shown that database curricula need to be updated and modernized, which can be achieved by extending the current database concepts that cover the strategies to handle the ever changing user requirements and how database technology has evolved to meet the requirements. Likewise, Picciano (2012) examines the evolving world of big data and analytics in American higher education. According to the author, the “data driven” decision making method should be used to help the institutes evaluate strategies that can improve retention and update the curriculum that has big data basic concepts and applications, since data driven decision making has already entered in the big data and learning analytic era. Furthermore, Marshall (2011) presented the challenges faced when developing a curriculum for a Computer Science degree program in the South African context that is earmarked for international recognition. According to the author, the Curricula needs to adhere both to the policy and content requirements in order to be rated as being of a particular quality.

Similarly, some studies (Abourezq & Idrissi, 2016; Mingyu et al., 2017) described big data influence from a social perspective and also proceeded with the gaps in database curriculum of computer science, especially, in the big data era and discovers the teaching improvements in practical and theoretical teaching mode, teaching content and teaching practice platform in database curriculum. Also Silva et al. (2016) propose teaching SQL as a general language that can be used in a wide range of database systems from traditional relational database management systems to big data systems.

On the other hand, different authors have developed a database curriculum based on the different academic background of students. Such as, Dean and Milani (1995) have recommended changes in computer science curricula based on the practice in United States Military Academy (USMA). They emphasized greatly on the practical demonstration of the topic rather than the theoretical explanation. Especially, for the non-computer science major students. Furthermore, Urban and Dietrich (2001) described the development of a second course on database systems for

undergraduates, preparing students for the advanced database concepts that they will exercise in the industry. They also shared their experience with teaching the course, elaborating on the topics and assignments. Also, Andersson et al. (2019) proposed variations in core topics of database management course for the students with the engineering background. Moreover, Dietrich et al. (2014) described two animations developed with images and color that visually and dynamically introduce fundamental relational database concepts and querying to students of many majors. The goal is that the educators, in diverse academic disciplines, should be able to incorporate these animations in their existing courses to meet their pedagogical needs.

The information systems have evolved into large scale distributed systems that store and process a huge amount of data across different servers, and process them using different distributed data processing frameworks. This evolution has given birth to new paradigms in database systems domain termed as NoSQL and Big Data systems, which significantly deviate from conventional relational and distributed database management systems. It is pertinent to mention that in order to offer a sustainable and practical CS education, these new paradigms and methodologies as shown in Fig. 5 should be included into database education (Kleiner, 2015). Tables 9 and 10 shows the summarized findings of the curriculum based reviewed studies. This section also proposed appropriate text book based on the theory, project, and practice-based teaching methodology as shown in Table 9. The proposed books are selected purely on the bases of their usage in top universities around the world such as, Massachusetts Institute of Technology, Stanford University, Harvard University, University of Oxford, University of Cambridge and, University of Singapore and the coverage of core topics mentioned in the database curriculum.

6.1.2 RQ.2 Evolution of DSE research

This section discusses the evolution of database while focusing the DSE over the past 25 years as shown in Fig. 6.

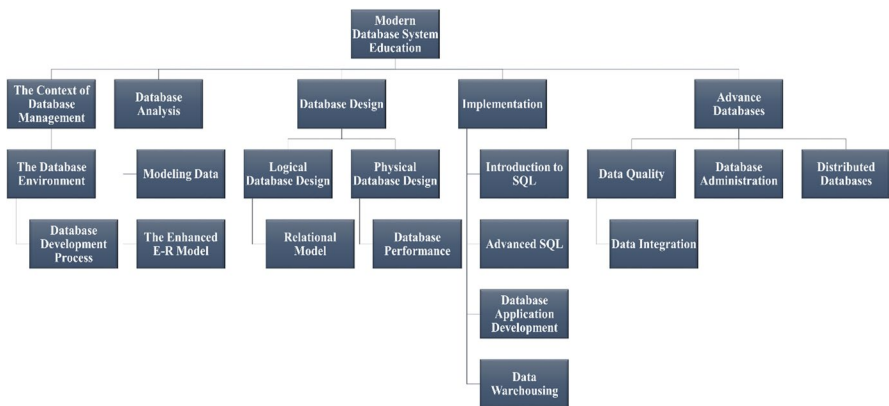


Fig. 5 Concepts in Database Systems Education (Kleiner, 2015)

Table 9 Recommended text books for DSE

Methodology	Book title	Author(s)	Edition	Year
Theory	Database Management Systems	Ramakrishnan, Raghu, and Johannes Gehrke	3	2002
	Database Systems: The Complete Book	Garcia-Molina, Ullman and Widom	2	2008
	Introduction to Database Systems	C. J. Date Addison-Wesley	8	2003
	Introduction to Database Systems	S. Bressan and B. Catania	1	2005
	Database system concepts	Silberschatz, A., Korth, H.F. and Sudarshan, S	7	2019
	A first course in database systems	Ullman, J. and Widom, J	3	2007
	Modern Database Management	Jeffrey A. Hoffer, Ramesh Venkataraman and HeikkiTopi	12	2015
Project	Database Systems: A Practical Approach to Design, Implementation, and Management	Thomas M. Connolly,Carolyn E. Begg	6	2015
	Fundamentals of SQL Programming	R. A. Mata-Toledo and P. Cushman. Schaum's	1	2000
Practice	Readings in Database Systems (The Red Book)	Hellerstein, Joseph, and Michael Stonebraker	4	2005

Table 10 Curriculum: Findings of Reviewed Literature

Objective	Findings	References	Topic(s)/ Curricula	Standard bodies
Recommendations and revisions	Proposed variations based on the scope in the region	<ul style="list-style-type: none"> • (Abouzeq & Idrissi, 2016) • (Brogali et al., 2012) • (Mingyu et al., 2017) • (Peciano, 2012) • (Silva et al., 2016) • (Calero et al., 2003) • (Conklin & Heinrichs, 2005) • (Zhangqian et al., 2016) • (Robbert & Ricardo, 2003) • (Luo et al., 2008) • (Dietrich & Urban, 1996) • (Marshall, 2012) • (Dean & Miami, 1995) • (Dietrich et al., 2014) • (Urban & Dietrich, 2001) • (Andersson et al., 2019) 	<ul style="list-style-type: none"> • Big Data, SQL • Computer Science Curricula • Big Data • Computer Science/Engineering Curriculum • Big Data, NoSQL • Computer Science Curricula • Big Data • Computer Science Curricula • Big Data, MapReduce, NoSQL and NoSQL • Computer Science Curricula • Database Design, Database Administration, Database Application • SWEBOK, DBBOK • Database theory and database practice • Computer Science Curricula • Database principles design • Coursea, Udacity, edx • Data Models, Physical Data Design, SQL • Computer Science Curricula • SQL Server and Oracle • Computer Science Curricula • Object oriented database (OODB) systems; object relational database (ORDB) systems • Curriculum and Laboratory Improvement Educational Materials Development (CCLiEMD) • Data Models, Physical Data Design, Database Schema and Design, SQL • CS-Bok • SQL • Computer Science Curricula • Relational Databases • Computer Science Curricula • Relational algebra, Relational calculus, and SQL • Engineering Curriculum 2000 • ER Model, Relational Model, SQL • Engineering Curriculum 	<ul style="list-style-type: none"> • CS 2008 • CS 2008/CE 2004 • CS 2013 • CS 2008 • CS 2013 • N/A • IS 2002 • CC2001 • CC2004 • N/A • CC 2001 • CC 2004 • N/A • N/A • CC 2008 • CC 2001 • CE 2000
	Proposed variations based on the educational background of the students			

Table 10 (continued)

Objective	Findings	References	Topic(s)/ Curricula	Standard bodies
Relating Curriculum to assessment	Proposed variations based on the assessment methods	<ul style="list-style-type: none"> • (Abid et al., 2015) • (Adams et al., 2004) 	<ul style="list-style-type: none"> • Data Models, Physical Data Design, Database Schemas and Design, SQL • Computer Science Curricula • ER, EER, and UML • Computer Science Curricula 	<ul style="list-style-type: none"> • CS 2008 • CC 2001

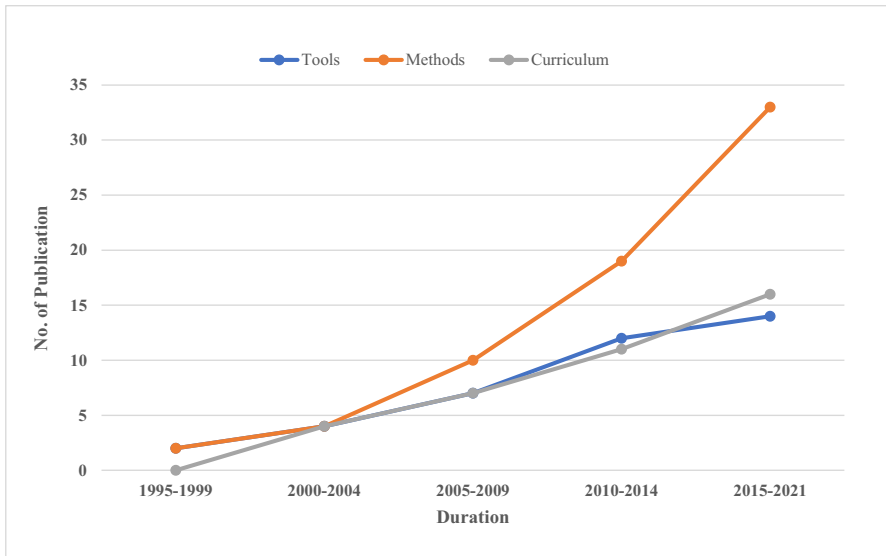


Fig. 6 Evolution of DSE studies

This study shows that there is significant increase in research in DSE after 2004 with 78% of the selected papers are published after 2004. The main reason of this outcome is that some of the papers are published in well-recognized channels like IEEE Transactions on Education, ACM Transactions on Computing Education, International Conference on Computer Science and Education (ICCSE), and Teaching, Learning and Assessment of Database (TLAD) workshop. It is also evident that several of these papers were published before 2004 and only a few articles were published during late 1990s. This is because of the fact that DSE started to gain interest after the introduction of Body of Knowledge and DSE standards. The data intensive scientific discovery has been discussed as the fourth paradigm (Hey et al., 2009): where the first involves empirical science and observations; second contains theoretical science and mathematically driven insights; third considers computational science and simulation driven insights; while the fourth involves data driven insights of modern scientific research.

Tools Over the past few decades, students have gone from attending one-room class to having the world at their fingertips, and it is a great challenge for the instructors to develop the interest of students in learning database. This challenge has led to the development of the different types of interactive tools to help the instructors teach DSE in this technology oriented era. Keeping the importance of interactive tools in DSE in perspective, various authors have proposed different interactive tools over the years, such as during 1995–2003, when different authors proposed various interactive tools. Some studies (Abut & Ozturk, 1997; McIntyre et al., 1995) introduced state of the art interactive tools to teach and enhance the collaborative learning among the students. Similarly, during 2004–2005 more interactive tools in the field

of DSE were proposed such as Pahl et al. (2004), Connolly et al. (2005) introduced multimedia system based interactive model and game based collaborative learning environment.

The Internet has started to become more common in the first decade of the twenty-first century and its positive impact on the education sector was undeniable. Cost effective, student teacher peer interaction, keeping in touch with the latest information were the main reasons which made the instructors employ web-based tools to teach database in the education sector. Due to this spike in the demand of web-based tools, authors also started to introduce new instruments to assist with teaching database. In 2007 Regueras et al. (2007) proposed an e-learning tool named QUEST with a feedback module to help the students to learn from their mistakes. Similarly, in 2010, multiple authors have proposed and evaluated various web-based tools. Cvetanovic et al. (2010) proposed ADVICE with the functionality to monitor student's progress, while, few authors (Wang et al., 2010) proposed Metube which is a variation of YouTube. Furthermore, Nelson and Fatimazahra (2010) evaluated different web-based tools to highlight the complexities of using these web-based instruments.

Methods Technology has changed the teaching methods in the education sector but technology cannot replace teachers, and despite the amount of time most students spend online, virtual learning will never recreate the teacher-student bond. In the modern era, innovation in technology used in educational sectors is not meant to replace the instructors or teaching methods.

During the 1990s some studies (Dietrich & Urban, 1996; Urban & Dietrich, 1997) proposed learning and teaching methods respectively keeping the evolving technology in view. The highlight of their work was project deliverables and assignments where students progressively advanced to a step-by-step extension, from a tutorial exercise and then attempting more difficult extension of assignment.

During 2002–2007 various authors have discussed a number of teaching and learning methods to keep up the pace with the ever changing database technology, such as Connolly and Begg (2006) proposing a constructive approach to teach database analysis and design. Similarly, Prince and Felder (2006) reviewed the effectiveness of inquiry learning, problem based learning, project-based learning, case-based teaching, discovery learning, and just-in-time teaching. Also, McIntyre et al. (McIntyre et al., 1995) brought to light the impact of convergence of European Union (EU) in different universities across Europe. They suggested a reconstruction of teaching and learning methodologies in order to effectively teach database.

During 2008–2013 more work had been done to address the different methods of teaching and learning in the field of DSE, like the work of Dominguez and Jaime (2010) who proposed an active learning approach. The focus of their study was to develop the interest of students in designing and developing databases. Also, Zheng and Dong (2011) have highlighted various characteristics of the database course and its teaching content. Similarly, Yuelan et al. (2011) have reformed database teaching methods. The main focus of their study were the Modern ways of education, project driven approach, strengthening the experimental aspects, and improving the traditional assessment method. Likewise, Al-Shuaily (2012) has explored 4 cognitive

factors that can affect the learning process of database. The main focus of their study was to facilitate the students in learning SQL. Subsequently, Chen et al. (2012) also proposed scaffolding-based concept mapping strategy. This strategy helps the students to better understand database management courses. Correspondingly, Martin et al. (2013) discussed various collaborative learning techniques in the field of DSE while keeping database as an introductory course.

In the years between 2014 and 2021, research in the field of DSE increased, which was the main reason that the most of teaching, learning and assessment methods were proposed and discussed during this period. Rashid and Al-Radhy (2014) discussed the issues of traditional teaching, learning, assessing methods of database courses at different universities in Kurdistan and the main focus of their study being reformation issues, such as absence of teaching determination and contradiction between content and theory. Similarly, Wang and Chen (2014) summarized the main problems in teaching the traditional database theory and its application. Curriculum assessment mode was the main focus of their study. Eaglestone and Nunes (2004) shared their experiences of delivering a databases design course at Sheffield University. Their focus of study included was to teach the database design module to a diverse group of students from different backgrounds. Rashid (2015) discussed some important features of database courses, whereby reforming the conventional teaching, learning, and assessing strategies of database courses at universities were the main focus of this study. Kui et al. (2018) reformed the teaching mode of database courses based on flipped classroom. Initiative learning of database courses was their main focus in this study. Similarly, Zhang et al. (2018) discussed several effective classroom teaching measures. The main focus of their study was teaching content, teaching methods, teaching evaluation and assessment methods. Cai and Gao (2019) also carried out the teaching reforms in the database course of liberal arts. Diversified teaching modes, such as flipping classroom, case oriented teaching and task oriented were the focus of their study. Teaching Kawash et al. (2020) proposed a learning approach called Graded Group Activities (GGAs). Their main focus of the study was reforming learning and assessment method.

Curriculum Database course covers several topics that range from data modeling to data implementation and examination. Over the years, various authors have given their suggestions to update these topics in database curriculum to meet the requirements of modern technologies. On the other hand, authors have also proposed a new curriculum for the students of different academic backgrounds and different areas. These reformations in curriculum helped the students in their preparation, practically and theoretically, and enabled them to compete in the competitive market after graduation.

During 2003 and 2006 authors have proposed various suggestions to update and develop computer science curriculum across different universities. Robbert and Ricardo (2003) evaluated three reviews from 1999 to 2002 that were given to the groups of educators. The focus of their study was to highlight the trends that occurred in database curriculum. Also, Calero et al. (2003) proposed a first draft for this Database Body of Knowledge (DBBOK). Database (DB), Database Design (DBD), Database Administration (DBAd), Database Application (DBAp) and

Advance Databases (ADVDB) were the main focus of their study. Furthermore, Conklin and Heinrichs (Conklin & Heinrichs, 2005) compared the content included in 13 database textbooks and the main focus of their study was IS 2002, CC2001, and CC2004 model curricula.

The years from 2007 and 2011, authors managed to developed various database curricula, like Luo et al. (2008) developed curricula in Zhejiang University City College. The aim of their study to nurture students to be qualified computer scientists. Likewise, Dietrich et al. (2008) proposed the techniques to assess the development of an advanced database course. The purpose behind the addition of an advanced database course at undergraduate level was to prepare the students to respond to industrial requirements. Also, Marshall (2011) developed a new database curriculum for Computer Science degree program in the South African context.

During 2012 and 2021 various authors suggested updates for the database curriculum such as Bhogal et al. (2012) who suggested updating and modernizing the database curriculum. Data management and data analytics were the focus of their study. Similarly, Picciano (2012) examined the curriculum in the higher level of American education. The focus of their study was big data and analytics. Also, Zhanquan et al. (2016) proposed the design for the course content and teaching methods in the classroom. Massive Open Online Courses (MOOCs) were the focus of their study. Likewise, Mingyu et al. (2017) suggested updating the database curriculum while keeping new technology concerning the database in perspective. The focus of their study was big data.

The above discussion clearly shows that the SQL is most discussed topic in the literature where more than 25% of the studies have discussed it in the previous decade as shown in Fig. 7. It is pertinent to mention that other SQL databases such as Oracle, MS access are discussed under the SQL banner (Chen et al., 2012; Hou & Chen, 2010; Wang & Chen, 2014). It is mainly because of its ability to handle data in a relational database management system and direct implementation of database

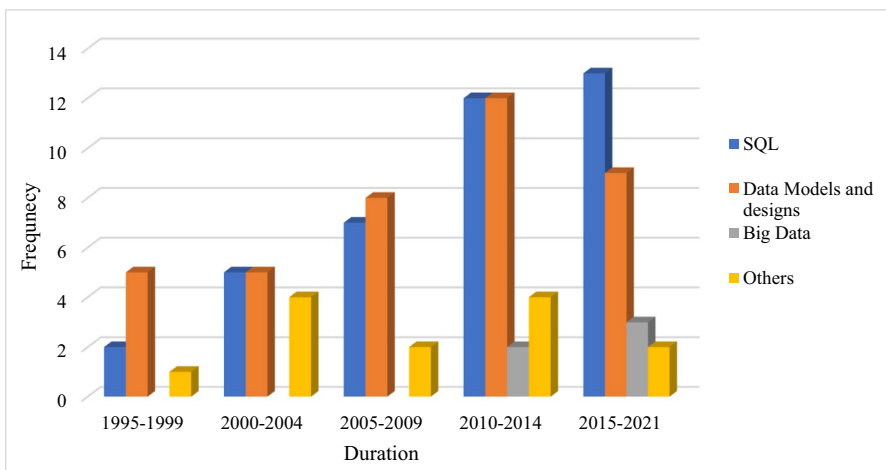


Fig. 7 Evolution of Database topics discussed in literature

theoretical concepts. Also, other database topics such as transaction management, application programming etc. are also the main highlights of the topics discussed in the literature.

7 Research synthesis, advice for instructors, and way forward

This section presents the synthesized information extracted after reading and analyzing the research articles considered in this study. To this end, it firstly contextualizes the tools and methods to help the instructors find suitable tools and methods for their settings. Similarly, developments in curriculum design have also been discussed. Subsequently, general advice for instructors have been discussed. Lastly, promising future research directions for developing new tools, methods, and for revising the curriculum have also been discussed in this section.

7.1 Methods, tools, and curriculum

Methods and tools Web-based tools proposed by Cvetanovic et al. (2010) and Wang et al. (2010) have been quite useful, as they are growing increasingly pertinent as online mode of education is prevalent all around the globe during COVID-19. On the other hand, interactive tools and smart class room methodology has also been used successfully to develop the interest of students in database class. (Brusilovsky et al., 2010; Connolly et al., 2005; Pahl et al., 2004; Canedo et al., 2021; Ko et al., 2021).

One of the most promising combination of methodology and tool has been proposed by Cvetanovic et al. (2010), whereby they developed a tool named ADVICE that helps students learn and implement database concepts while using project centric methodology, while a game based collaborative learning environment was proposed by Connolly et al. (2005) that involves a methodology comprising of modeling, articulation, feedback, and exploration. As a whole, project centric teaching (Connolly & Begg, 2006; Domínguez & Jaime, 2010) and teaching database design and problem solving skills Wang and Chen (2014), are two successful approaches for DSE. Whereas, other studies (Urban & Dietrich, 1997) proposed teaching methods that are more inclined towards practicing database concepts. While a topic specific approach has been proposed by Abbasi et al. (2016), Taipalus et al. (2018) and Silva et al. (2016) to teach and learn SQL. On the other hand, Cai and Gao (2019) developed a teaching method for students who do not have a computer science background. Lastly, some useful ways for defining assessments for DSE have been proposed by Kawash et al. (2020) and Zhang et al. (2018).

Curriculum Curriculum of database adopted by various institutes around the world does not address how to teach the database course to the students who do not have a strong computer science background. Such as Marshall (2012), Luo et al. (2008) and Zhanquan et al. (2016) have proposed the updates in current database curriculum for the students who are not from computer science background. While Abid

et al. (2015) proposed a combined course content and various methodologies that can be used for teaching database systems course. On the other hand, current database curriculum does not include the topics related to latest technologies in database domain. This factor was discussed by many other studies as well (Bhogal et al., 2012; Mehmood et al., 2020; Picciano, 2012).

7.2 Guidelines for instructors

The major conclusion of this study are the suggestions based on the impact and importance for instructors who are teaching DSE. Furthermore, an overview of productivity of every method can be provided by the empirical studies. These instructions are for instructors which are the focal audience of this study. These suggestions are subjective opinions after literature analysis in form of guidelines according to the authors and their meaning and purpose were maintained. According to the literature reviewed, various issues have been found in this section. Some other issues were also found, but those were not relevant to DSE. Following are some suggestions that provide interesting information:

7.2.1 Project centric and applied approach

- To inculcate database development skills for the students, basic elements of database development need to be incorporated into teaching and learning at all levels including undergraduate studies (Bakar et al., 2011). To fulfill this objective, instructors should also improve the data quality in DSE by assigning the projects and assignments to the students where they can assess, measure and improve the data quality using already deployed databases. They should demonstrate that the quality of data is determined not only by the effective design of a database, but also through the perception of the end user (Mathieu & Khalil, 1997)
- The gap between the database course theory and industrial practice is big. Fresh graduate students find it difficult to cope up with the industrial pressure because of the contrast between what they have been taught in institutes and its application in industry (Allsopp et al., 2006). Involve top performers from classes in industrial projects so that they are able to acquiring sufficient knowledge and practice, especially for post graduate courses. There must be some other activities in which industry practitioners come and present the real projects and also share their industrial experiences with the students. The gap between theoretical and the practical sides of database has been identified by Myers and Skinner (1997). In order to build practical DS concepts, instructors should provide the students an accurate view of reality and proper tools.

7.2.2 Importance of software development standards and impact of DB in software success

- They should have the strategies, ability and skills that can align the DSE course with the contemporary Global Software Development (GSD) (Akbar & Safdar, 2015; Damian et al., 2006).

- Enable the students to explain the approaches to problem solving, development tools and methodologies. Also, the DS courses are usually taught in normal lecture format. The result of this method is that students cannot see the influence on the success or failure of projects because they do not realize the importance of DS activities.

7.2.3 Pedagogy and the use of education technology

- Some studies have shown that teaching through play and practical activities helps to improve the knowledge and learning outcome of students (Dicheva et al., 2015).
- Interactive classrooms can help the instructors to deliver their lecture in a more effective way by using virtual white board, digital textbooks, and data over network (Abut & Ozturk, 1997). We suggest that in order to follow the new concept of smart classroom, instructors should use the experience of Yau and Karim (2003) which benefits in cooperative learning among students and can also be adopted in DSE.
- The instructors also need to update themselves with full spectrum of technology in education, in general, and for DSE, in particular. This is becoming more imperative as during COVID the world is relying strongly on the use of technology, particularly in education sector.

7.2.4 Periodic Curriculum Revision

- There is also a need to revisit the existing series of courses periodically, so that they are able to offer the following benefits: (a) include the modern day database system concepts; (b) can be offered as a specialization track; (c) a specialized undergraduate degree program may also be designed.

7.3 DSE: Way forward

This research combines a significant work done on DSE at one place, thus providing a point to find better ways forward in order to improvise different possible dimensions for improving the teaching process of a database system course in future. This section discusses technology, methods, and modifications in curriculum would most impact the delivery of lectures in coming years.

Tools Several tools have already been developed for effective teaching and learning in database systems. However, there is a great room for developing new tools. Recent rise of the notion of “serious games” is marking its success in several domains. Majority of the research work discussed in this review revolves around web-based tools. The success of serious games invites researchers to explore this new paradigm of developing useful tools for learning and practice database systems concepts.

Likewise, due to COVID-19 the world is setting up new norms, which are expected to affect the methods of teaching as well. This invites the researchers to design, develop, and test flexible tools for online teaching in a more interactive manner. At the same time, it is also imperative to devise new techniques for assessments, especially conducting online exams at massive scale. Moreover, the researchers can implement the idea of instructional design in web-based teaching in which an online classroom can be designed around the learners' unique backgrounds and effectively delivering the concepts that are considered to be highly important by the instructors.

Methods The teaching, learning and assessment methods discussed in this study can help the instructors to improve their methods in order to teach the database system course in a better way. It is noticed that only 16% of authors have the assessment methods as their focus of study, which clearly highlights that there is still plenty of work needed to be done in this particular domain. Assessment techniques in the database course will help the learners to learn from their mistakes. Also, instructors must realize that there is a massive gap between database theory and practice which can only be reduced with maximum practice and real world database projects.

Similarly, the technology is continuously influencing the development and expansion of modern education, whereas the instructors' abilities to teach using online platforms are critical to the quality of online education.

In the same way, the ideas like flipped classroom in which students have to prepare the lesson prior to the class can be implemented on web-based teaching. This ensures that the class time can be used for further discussion of the lesson, share ideas and allow students to interact in a dynamic learning environment.

Curriculum The increasing impact of big data systems, and data science and its anticipated impact on the job market invites the researchers to revisit the fundamental course of database systems as well. There is a need to extend the boundaries of existing contents by including the concepts related to distributed big data systems data storage, processing, and transaction management, with possible glimpse of modern tools and technologies.

As a whole, an interesting and long term extension is to establish a generic and comprehensive framework that engages all the stakeholders with the support of technology to make the teaching, learning, practicing, and assessing easier and more effective.

8 Conclusion

This SLR presents review on the research work published in the area of database system education, with particular focus on teaching the first course in database systems. The study was carried out by systematically selecting research papers published between 1995 and 2021. Based on the study, a high level categorization presents a taxonomy of the published under the heads of Tools, Methods, and

Curriculum. All the selected articles were evaluated on the basis of a quality criteria. Several methods have been developed to effectively teach the database course. These methods focus on improving learning experience, improve student satisfaction, improve students' course performance, or support the instructors. Similarly, many tools have been developed, whereby some tools are topic based, while others are general purpose tools that apply for whole course. Similarly, the curriculum development activities have also been discussed, where some guidelines provided by ACM/IEEE along with certain standards have been discussed. Apart from this, the evolution in these three areas has also been presented which shows that the researchers have been presenting many different teaching methods throughout the selected period; however, there is a decrease in research articles that address the curriculum and tools in the past five years. Besides, some guidelines for the instructors have also been shared. Also, this SLR proposes a way forward in DSE by emphasizing on the tools: that need to be developed to facilitate instructors and students especially post Covid-19 era, methods: to be adopted by the instructors to close the gap between the theory and practical, Database curricula update after the introduction of emerging technologies such as big data and data science. We also urge that the recognized publication venues for database research including VLDB, ICDM, EDBT should also consider publishing articles related to DSE. The study also highlights the importance of reviving the curricula, tools, and methodologies to cater for recent advancements in the field of database systems.

Data availability Not Applicable.

Code availability Not Applicable.

Declarations

Conflict of interest None.

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