Evolution of Technologies in Libraries: A Text Mining Study

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Abstract *The advancement of technologies has sparked library systems, with their wide range of applications. This study aims to analyse the evolution of technologies in libraries. It utilised Scopus to find literature through a structured search string. After a manual screening, a total of 926 documents, dealing with technologies in libraries, were identified and selected for creating a dataset. Furthermore, a custom list of keywords representing various types of technologies used in libraries was prepared for matching and extracting the technological terms. This study employed a text mining approach to automatically identify technologies from the corpus of articles' abstracts. Google Sheets and Python were used for data cleaning, pre-processing, analysis, and visualisations. The study found a dynamic transformation of technologies over the years. The frequency of the most prevalent terms and features was presented. This study outlines the library practices and professional expertise in libraries. It holds practical implications for library professionals, researchers, and decision-makers to understand the trends of technologies.*

Keywords: Technology adoption; Digital libraries: Web technologies: Library technology integration: Artificial intelligence

Introduction

Libraries play a key role in disseminating knowledge and shaping the society. We can see the transformation of libraries' settings from traditional to hybrid. The advancement of information communication technologies (ICT) has an impact on library operations and services. The use of technologies was traced earlier for providing services like reference and referral and engaging in automated library operations (Cochrane, 1992). The rapid growth of technologies and new formats of information entailed library practitioners to design new services and platforms to support information access and analysis (Griffiths, 1995). Decades ago, Arora (2009) discussed *Library 2.0* and innovative technologies such as synchronous communication, bookmarking, collaborative publishing, social networks, and programming tools. Regardless, this transformation is dynamic. Shreds of evidence suggest that libraries are experiencing the applications and integrations of *artificial intelligence* (AI), *Internet of Things* (IoT), *blockchain*, *machine learning* (ML), *RFID* (Radio Frequency Identification), *metaverse, robotics, augmented reality and virtual reality* (AR-VR) and *web developments* (Bharti & Verma, 2021; Bi et al., 2022; Sediyaningsih et al., 2023; Williamson et al., 2022).

The integration of technology into library operations can pose both challenges and opportunities (Serholt et al., 2018). Technology allows libraries to enhance services, improve access to information, and engage users widely. It also brings about complexities related to infrastructure, resource allocation, and technology skills of library professionals or practitioners. Despite these challenges, awareness and strategic implementation of technology can empower libraries to meet users' needs. Understanding the evolution of technologies in libraries is very important for steering the dynamism of technology adoption and practices. Existing literature (e.g., Bharti & Verma, 2021; Bi et al., 2022) reported emerging technologies. But there is room for exposing how the technologies evolved over the years. Hence, by examining documents published from 2014 to 2023, this study

aims to provide insights into how library and information science (LIS) practitioners are adapting and utilising technologies and enhancing the future of information access and knowledge dissemination through libraries.

In the following subsections, research questions and objectives are stated. The second section of this study includes the literature review. The methodology is presented in the third section, followed by results and discussion in the fourth section. Section five discusses the implications and limitations of the study. The sixth or the last section illuminates the concluding remarks.

Research Questions

This study states three research questions (RQ) as follows:

RQ1. What are the technologies used in libraries and library and information science discussed in the documents, and how have their mentions evolved (2014-2023)?

RQ2: How do the different types of technologies vary across various subfields in the context of libraries and what are the top 20 trending technologies that gained traction?

RQ3: What are the major themes derived from technologies discussed in the documents, and what are the top technologies identified?

Objectives of the Study

Based on the RQs, this study specifically aims to (1) explore the trends of technologies discussed in documents published from 2014 to 2023; (2) identify the most popular technologies over the years; (3) examine the nature of their appearance; and (4) categorise and analyse themes derived from technological terms.

Literature Review

This study reviews closely related research papers that assessed emerging technologies and their applications in libraries.

Adoption and implementation of technologies

In university libraries, major technologies that emerged throughout the years include integrated library management systems, RFID, IoT, digital repositories, mobile apps, virtual reality, face recognition, and cloud computing (Bharti & Verma, 2021). Similarly, based on awareness and acceptance of technologies for sophisticated academic library services, library websites, web-OPAC, institutional repositories, library guide apps, and use of social media are identified as significant technologies libraries (Saibakumu, 2021). The competencies of librarians in dealing with existing and rising technologies within library systems are also essential. For instance, the information retrieval process and utilisation of web technologies play vital roles in the context of library services and meeting users' needs (Omehia et al., 2021). There can be several factors affecting the implementation of emerging technologies and their applicability through librarians, such as working with inadequate ICT facilities and power supply. However, continuing professional development programmes helped librarians cope with the advancement of ICT (Aiyebelehin, 2018). Technologies like AI, immersive technologies, and big data analytics are instantaneously aligning with library services. Nonetheless, looking at their usability and accessibility is crucial for libraries (Clark & Lischer-Katz, 2023).

Impact of technologies

The use of technologies enhances libraries' involvement in learning, scientific methods, making strategies, use patterns, library services, and promoting the values of the library (Awoyemi, 2023). ICT has changed the dimension of information use as libraries face a decline in library use. A study informed alternative services,

the use of technologies, and ways libraries can be compatible with the current information age (Muunga, 2020). Technologies related to web search services have the potential to impact searching relevant resources and users' expectations (Fernandez, 2018). The impact of technology on engaging millennial learners in academic libraries is a vital aspect. Technology influences the integration of advanced tools in the learning process, communication, and accessibility (Trembach & Deng, 2018). The trend of technologies in libraries can be found in blogs and wikis. AI, robotics, IoT, Google, and ML have the upper hand in impacting library services (Oyelude, 2017).

Research analyses on emerging technologies

Khan et al. (2023) identified some key technologies in the context of libraries using bibliometric. Keyword co-occurrence analysis revealed AI, big data, data mining, smart libraries, digital libraries, and IoT. AI-aided IoT applied in the smart library includes RFID, Wi-Fi, BLE (a version of bluetooth), NLP, deep learning, and recommender systems (Bi et al., 2022). In another study, a keyword analysis revealed some trends in technologies including digital libraries, web 2.0, e-resources, e-learning, RFID, automation, blogs, and open-source software (Singh & Kataria, 2018).

These reviewed studies stated about trending rather emerging technologies in the context of libraries as well as library and information science. Researchers utilised reviews, surveys, and case studies to comprehend technology trends. In some cases, using bibliometric approach, researchers identified top technological keywords or terms. Thus, there is a need for a study that identifies evolving technologies and their use in libraries serving end-users and practising aspects among LIS researchers. This study conducts a text mining of abstracts and explores relevant technologies mentioned by authors from 2014 to 2023.

Methodology

Phase 1: Document search, screening, and primary dataset creation

This study is based on three phases (Figure 1). A literature search was conducted on Scopus (accessed on 11/03/2023) to identify relevant literature published between 2014 and 2023. The search string ("technology" AND ("libraries" OR "library")) employed was in the title field only. It aimed to retrieve specific documents relating to this study's objectives. A total of 1036 documents were retrieved from the initial search results. After that, a manual screening was undertaken to assess the relevance of each document and a total of 926 documents were included. The most common document types found in the dataset include articles (n=545), conference papers (n=204), and book chapters (n=75). Some documents did not include abstracts. So, the titles of the documents were taken as part of the text. After completing data pre-processing tasks (cleaning and transforming), the first dataset, consisting of authors, titles, years, abstracts, sources, keywords, funding, and affiliations was organised and prepared using Google Sheets. This study only focuses on the abstracts of the documents (corpus).

Phase 2: Keyword extraction and string matching

A custom list of keywords related to technological terms was identified and compiled from the retrieved 926 documents' keywords (see Figure 1). The keywords were matched with the abstracts (Dataset 1) using regular expression (regex) and boolean operators in Python. Additional search techniques like wildcards and stemming were also used. This facilitated the identification of relevant documents associated with technological terms. Further, the keywords were grouped into 82 broad categories. Finally, a second dataset consisting of all technological terms and categories was created for further analysis.

Phase 3: Data analysis and visualisation

Data analysis (see Figure 1) of this study includes (1) bibliographic-level statistics, including trends in publication trends, significant sources, research funders, and most productive countries, (2) frequency analysis of technologies during 2014-2023, (3) relationship between years and appearances of identified technologies in the dataset and top 20 trending technologies over the years, and (4) themes identified from relevant

technological terms. Results were visualised through subplots (column and bar charts), heatmaps, line charts, and wordcloud using Python.
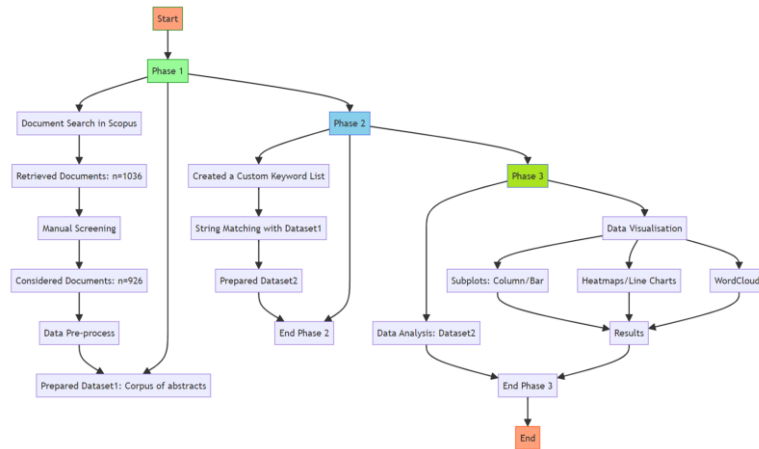

Fig 1: Process involved in this study (The flowchart was created using Mermaid https://mermaid.live/)

Results and Discussion

Preliminary analysis

Publication growth can be found in Figure 2 (A), which shows fluctuations in publication trends over the years. The peak of the publications was found in 2019, 2020, and 2020, where each year saw more than 100 publications (Σ=361 and $\bar{x}$=120). On the other hand, the rest of the years have decent publication growth (Σ=565 and $\bar{x}$=80). In Figure 1 (B), the top 10 significant sources are presented. It shows the researchers' preferences in selecting journals for their scholarly communication. As the result shows *Library Philosophy and Practice (LPP)* has been identified with the most number of publications (n=104), followed by *Library Hi Tech News (LHTN)* (n=56), *DESIDOC Journal of Library and Information Technology (DJLIT)* (n=23), *Library Hi Tech (LH)* (n=20), and *Journal of Physics: Conference Series (JP)* (n=19). The *Lecture Notes in Electrical Engineering (LNEE)* and *Journal of Academic Librarianship (JAL)* have 14 publications each, followed by *Advanced Materials Research (AMR)* (n=11). Lastly, *Lecture Notes in Computer Science* (LNCS) (n=9) and *Information Technology and Libraries* (ITL) (n=9) have the same number of scientific outputs. It can be observed that researchers preferred various types of sources including journals and conference proceedings. This study also tried to find out how many publications received funding or sponsorship (Figure 2 (C)). It is important to showcase how funders are supporting researchers to enhance technological advancements within library settings. A surprising result came out, showing only 116 publications (12.53%) received research funding. A significant portion of the research conducted in this particular area has not been financially supported by external sources. The reason behind this may warrant further investigation. In terms of the most productive countries, the United States (USA) (n=269, 29%) and China (n=262, 28%) were discovered with the highest number of publications. On the other hand, India (n=159, 17%) and Nigeria (n=142, 15%) have notable research production. Other countries such as Indonesia, South Africa, Germany, Pakistan, and the United Kingdom (UK) have moderate levels of research production. Collectively, these four distinct results imply valuable insights into the trends of research in this field.
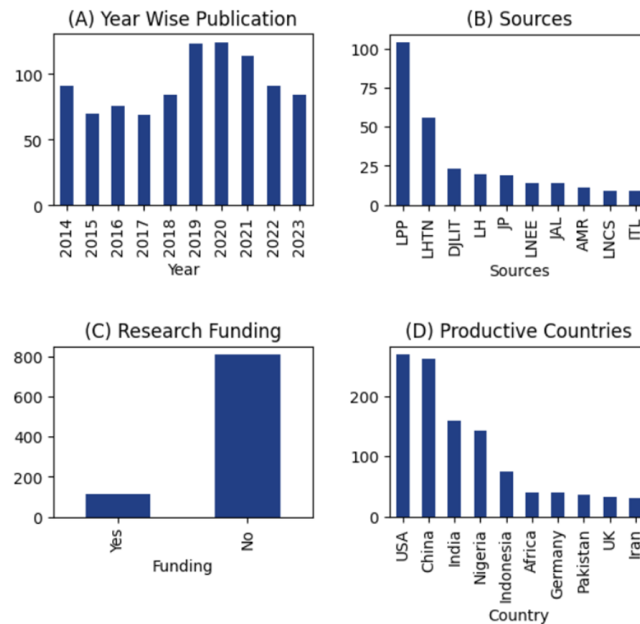
Fig 2: Publication-related statistics (Year Wise Publication, Sources, Research Funding, and Productive Countries. The source names are abbreviated by the authors of this study (Figure 2 (B))

Year-wise top 5 technologies discussed in the documents (n=926)

This section specifically focused on answering RQ1. Figure 3 illustrates instances of the top 5 technologies from 2014 to 2023. According to the analysis, *web technologies* (e.g., web 2.0, web design, and web development) exhibited most of the time throughout the years compared to other technologies, especially in 2015, 2016, 2017, 2019, and 2020. Similarly, *digital library*-related technologies (e.g., digital archive, digital repository, digital collections, digital and resources) ranked top in 2014, 2018, and 2020 by maintaining a significant level of mentions. Discussion on *software tools* has been invariably made in publications. It also suggests the on-going development related to software applications in the field. *Mobile applications* show a moderate presence in earlier years. However, their appearances reflect shifts in focus on technological advancements in later years. *Information systems* (e.g., information search, system, and informatics) remain relatively steady with a decent appearance. *Automation* (automation systems, integrated library systems, and library management systems) reveals an apparent increase in later years, which means there is a growing concern about automation technologies and their impact on library services. *RFID* technologies jumped into the top 5 in 2019. While *e-resources and learning* shows variability in mentions across documents. The potential reason could be the dynamics in research foci in digital resource management and educational technology. Now, one of the significant outcomes of the study is the appearance of the concept of *data science and management* (e.g., data governance, data mining, and data services) in library practices and research that emerged in 2022. However, working with data is not new to the libraries. Regardless, the trends show their applicability. One more emerging technology– *blockchain technologies* appeared prominently in 2022; it signifies the growing interest in exploring its application in the context of libraries. Lastly, the appearance of *artificial intelligence* across documents shows that there is on-going attention to AI and its potential impact on library services and activities. So, this analysis highlights the dynamic nature of research interests with certain technologies during the period. Some technologies maintain a consistent presence over there.
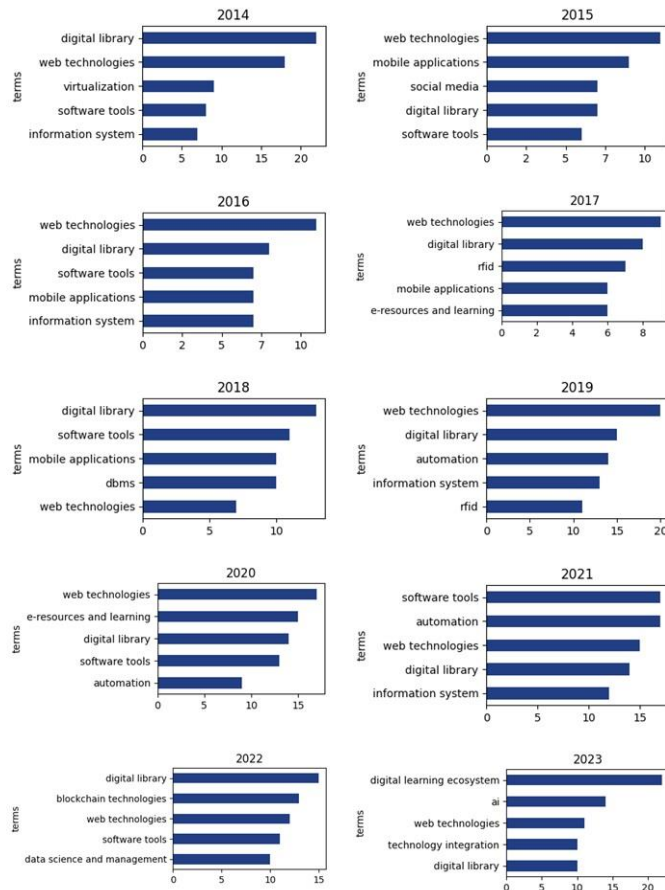
Fig 3: Top 5 technologies over the years

Analysis of all identified technologies

To address RQ2, the analysis of this section identified and revealed a total of 82 unique technologies mentioned in the documents (Figure 3A-3C). This highlights the scales of each technology. Furthermore, the 20 trending technologies are shown in Figure 4. Figure 3A illustrates the distribution of 29 technologies (terms). Certain technologies, such as *AR-VR* and *AI* coherently evolved in recent years. It denotes a promising interest and relevance in this field. *Audio-video technologies* (e.g., multimedia) also took substantial attention. On the other hand, *automation* has been the most dominant among all technologies. Most of the years witnessed its appearance. Emerging technologies like *blockchain* and *big data* showed an increasing trend, which reflects the evolving aspect of technology research in the field. Additionally, *cloud computing* indicates its continuing significance in documents embracing technological advancements over time. These results are also aligned with some instances provided in previous studies (Bharti & Verma, 2021; Khan et al., 2023). As mentioned in Section 4.2, *data science and management* have emerged as prominent prospects and are now widely accepted in the context of library and information science. *DBMS* (Database management System) is another prevailing technology, pointing to an incessant relevance in management practices in libraries. All these findings provide insights regarding the evolving nature of technological trends in the documents.
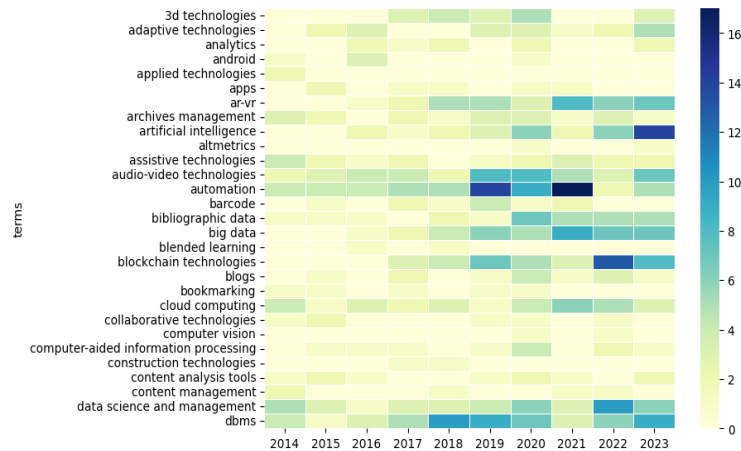
Fig 3A: Heatmap of technologies (n=29) by year

Figure 3B visualises the representation of 26 technologies and related terms. As we can see, *digital library* stands out considerably throughout the years. It can be pivoted that the adoption and implementation of digital libraries (e.g., DSpace and Greenstone) are ascertained in library practices (e.g., D. Arora, 2018). *E-resources and learning* and *digital learning and collaboration ecosystem* have also emerged as significant prospects. These reflect the focus on digital learning, collaborative tools, and e-resources in academics (e.g. Shahzad & Khan, 2023). In some cases, these outcomes are consistent with an earlier approach (Singh & Kataria, 2018). Furthermore, *information security* and its related technologies are emphasised in the documents (e.g., Holland, 2023). It can be said that the enhancement of securing digital assets and ensuring data protection within library systems are crucial. *Information system,* such as technologies involved in system management and organisational frameworks are also stressed in documents almost every year (e.g., Wang & Sha, 2021). Lastly, *IoT* (Bharti & Verma, 2021; Bi et al., 2022; Oyelude, 2017) and *digital humanities* are also traced as emerging technologies. Together these results provide valuable and unique insights into the integration of technologies and their impact on library and information science practices.
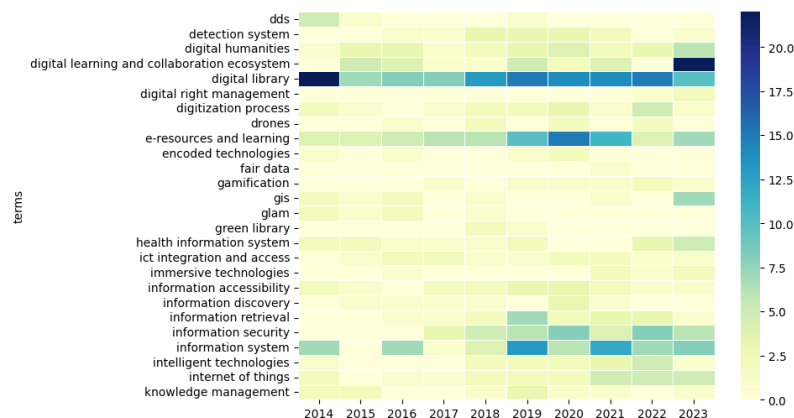

Fig 3B: Heatmap of technologies (n=26) by year

The last part of this section deals with the remaining technologies (n=27). Figure 3C illustrates some significant technologies. For instance, *web technologies* are the most prevalent technologies discovered with the highest appearance. Using web-based tools and platforms in libraries has been a consistent practice (e.g., Idiegbeyan-ose et al., 2019). Software *tools* (e.g., mailing apps) and their applications have been concentrated in the documents (e.g., Eichelberger & Imler, 2015). The evolving aspect of *mobile applications* has already been mentioned (see Section 4.2), indicating some important technologies like mobile apps, mobile services, and mobile computing. Now, *social media* (Asare & Holmner, 2021) is not so far behind other technologies discussed in this section. The growing role of social media platforms (e.g., Facebook) in information dissemination and user engagement (e.g., X, YouTube) has been underscored. This particular finding matches

those observed in an earlier study (Saibakumu, 2021). *Technology integration* and *virtualisation* augment the importance of seamlessly integrating modern technologies to enhance library services. The use of *RFID* technologies in libraries (Bharti & Verma, 2021; Bi et al., 2022; Singh & Kataria, 2018) indicates more attention to state-of-the-art library services with sophisticated security and self-transaction within library settings. Other technologies, such as *smart technologies, linked data,* and *machine learning* have evolved and emerged significantly.
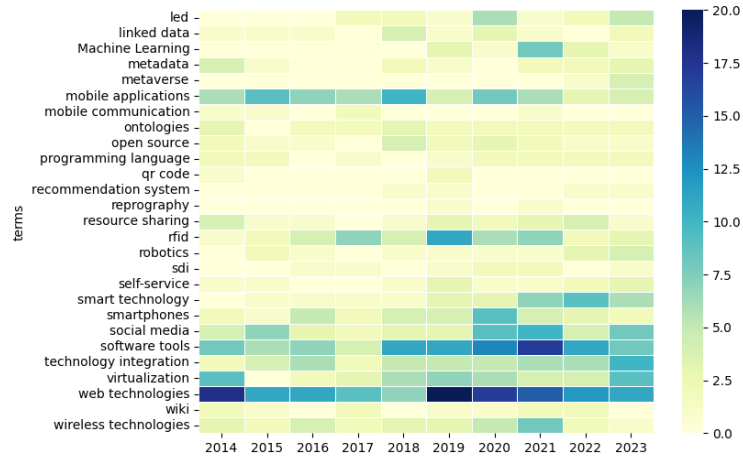

Fig 3C: Heatmap of technologies (n=27) by year

Using Figure 4, we can determine the trend of the top 20 technologies from 2014 to 2023. If we look at technologies like *web technologies* ($\bar{x}$=13.1), *digital library (*$\bar{x}$*= 12.6), software tools* ($\bar{x}$=9.6), *e-resources and learning* ($\bar{x}$=7.2), *automation* ($\bar{x}$=7), *information system* ($\bar{x}$=6.5), and mobile applications ($\bar{x}$=6.3), we can realise how they are constantly being practised in libraries and research. All of a sudden, *RFID*, *blockchain technologies*, *big data*, *information security*, and *AI* exhibit increasing attention. However, all 20 technologies have fluctuating aspects over the years.
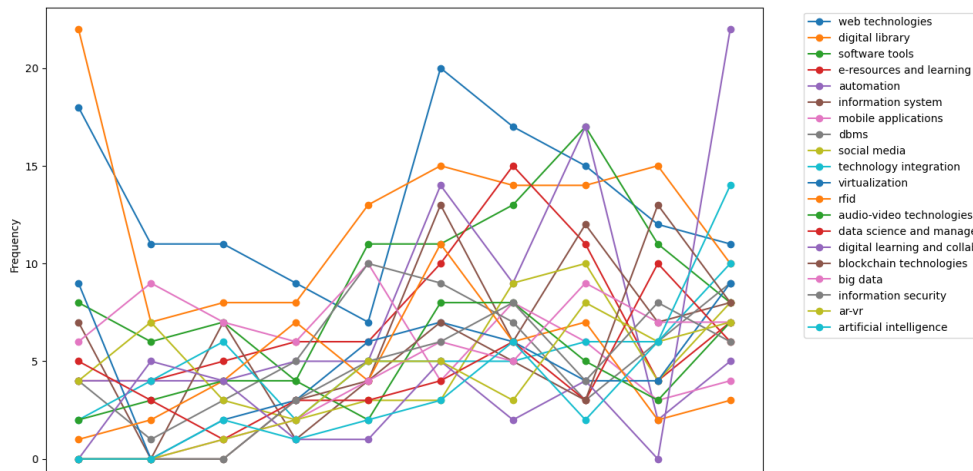

Fig 4: Top 20 trending technologies from 2014-2023

Theme analysis

Based on the RQ3, this study has codified four themes derived from technologies or technological terms (Figure 5). First, "*emerging technologies*" (Figure 5 (A)) include 46 categories where *web technologies* (n=131), *software tools* (n=96), *automation* (n=69), *mobile applications* (n=63), *technological integration* (n=51), *virtualisation* (n=50), *audio-visual technologies* (n=46), *blockchain technologies* (n=43), *big data* (n=41), *AR-VR* (n=37), *AI* (n=36), *wireless technology* (n=33), *smart technology* (n=32), and *cloud computing* (n=32) were highly frequent. These illuminate the research interests mentioned in the documents. The second theme,

"*information management and access*" (Figure 5 (B)) collates 21 categories. It can be ascertained that *information system* (n=65), *databases and management* (n=57), *RFID* (n=47), *data science and management* (n=44), *information security* (n=40), *bibliographic data* (n=28), *information retrieval* and *ontologies* (n=20 each) are reflective in the theme. Third, "*library services*" is recognised as the third theme, which includes 10 categories, such as *digital library* (n=126), *e-resources and learning* (n=72), *resource sharing* (n=20), *information accessibility* and *health information system* (n=17 each), and *self-service* (n=13). The fourth theme deals with 12 categories. Some major categories are *social media* (n=53), *digital learning and collaboration* (n=44), *programming* (n=14), *blogs* (n=13), and *wiki* (n=11). It must be noted that some technologies are overlapped in four themes. What emerges from these analyses mentioned here is that researchers in library and information science or information domain are well aware of technological developments and their rapid progress to enrich library practices and services.
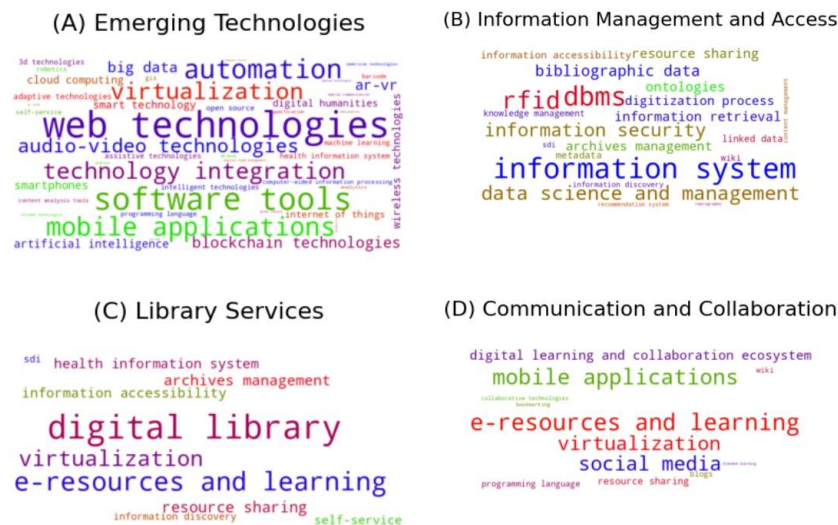

Fig 5: Theme-wise word cloud of the technologies ((A) Emerging Technologies, (B) Information Management and (C) Access, Library Services, and (D) Communication and Collaboration)

Research implications and limitations

There can be multiple implications of this study. Most importantly, this study identified the technological awareness and understanding among researchers in this field. This awareness is very crucial for implementing or experimenting with technologies in library practices. Future research could be conducted on technological integration that aligns with library users' requirements. Moreover, the evaluation and examination of the impact and challenges associated with the adoption of technology in libraries can be informed. The results reported in this study show crucial aspects regarding evolving technologies, showing their potential for library professionals, practitioners, researchers, and decision-makers within libraries.

This study acknowledges a couple of limitations. Firstly, the dataset is restricted to a specific time frame and search string, which may limit its comprehensiveness. Secondly, string matching between custom keywords' list and abstracts may not capture all technological terms. Working with full-text documents may be used for that. This study believes more advanced techniques, such as text classification or word embedding can be applied for extended study. Therefore, the results of this study should be interpreted carefully. However, this study reveals valuable information in the mention of technologies in such documents. Notably, this study is unique in its methodological approach to discovering technologies practised in libraries.

6. Conclusion

This study analysed the evolution of technologies in libraries from 2014 to 2023. Through preliminary analysis, various findings regarding publication trends were determined. Mainly, using technological categories (terms),

the study has exposed technology adoption trends, mentions and implementation within libraries in the modern era. Web technologies, digital library, software, automation, and e-resources and learning were the dominant technologies mentioned in the documents. These technologies also have evolved as emerging technologies during the period. This study serves as a unique exploration towards future research and unveils the awareness of technological developments among researchers and practitioners in the context of library and information science. Future research could be conducted to inform about the impact of technologies implemented in libraries and provide information on strategies for technology integration effectively.

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