Data Visualizations in Campus Portals: A Scoping Review

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Abstract: Data visualization in campus portals is essential for simplifying complex data into clear and meaningful insights. This powerful tool allows complex data to be transformed into visually compelling representations, thereby facilitating better decision-making and increased user engagement. This study employs the Context-Content-Process (CCP) framework in analyzing twenty journal articles to investigate the impact and potential of data visualization. It particularly focuses on how data visualization enhances user engagement, clarifies information, and supports decision-making processes in administrative and pedagogical contexts. The findings of this study show the need for a comprehensive evaluation of data visualization technologies and data analysis methods to further improve human-computer interfaces. This involves a systematic approach to data management, starting from data collection and storage to processing and transformation of data into compelling visual narratives within campus portals. These visual narratives can help users more effectively interpret and utilize the data presented. The insights gained and areas identified for improvement provide valuable guidance for future research endeavors. These efforts aim to enhance data visualization techniques to foster positive educational outcomes. By leveraging the knowledge gained from this study, researchers and practitioners can work collaboratively to refine data visualization practices. This collaboration will empower educational institutions to make data-driven insights more accessible and understandable. Consequently, these improvements can lead to more informed decision-making and heightened user engagement within educational settings.

Keywords: Data Visualization, Context-Content-Process, Campus Portal, University Portal, Scoping Review

1. INTRODUCTION

Efficient communication through visually appealing data representation has become crucial across various sectors in today's information-driven world. Data visualization entails the representation of data associated with functionality, titles, colors, and layout [1], [2], [3]. These visual representation of information are employed to convey complex data relationships and insights in a more understandable and analyzable manner especially when confronted with large volumes of information. Data visualization facilitates data exploration and analysis by providing both static and dynamic visual representations of data [4], [5], [6], [7]. In the context of campus portals, data visualization serves as a solution for faculty, staff, and students, offering graphical representations of information such as student academic performance, financial details, enrollment management, dropout rates, and attendance [6], [8], [9].

Campus portal acts as gateways to information, providing users with centralized access to organization data through a single interface. Different data visualization techniques, such as charts, graphs, maps, tables, grids, infographics, data animation, and network diagrams, are utilized through software tools like Tableau, Google charts, QlikView, Power BI, and Visual analytics within campus portals to develop dashboards and present information relevant to campus operations [6], [8], [10], [11]. However, challenges persist with data visualization tools in operational processes, including issues such as limited technology acceptance, accessibility concerns for individuals with disabilities, and difficulties in customization, particularly with colors, axes, and legends

[1], [11], [12], [13]. Despite the growing potential of data visualization, there remains a lack of understanding regarding how campuses would adopt and integrate these tools to evaluate their datasets.

The integration of Information and Communication Technologies (ICT) with the Internet has revolutionized the delivery of services in educational institutions. As web applications continue to advance, students are increasingly exposed to new features that enhance personalization and interactivity [9]. Many studies have explored the significance of campus portals in diverse educational institutions, emphasizing their impact on service delivery and communication among faculty, staff, and students [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29]. However, there is a need for synthesis and analysis of the scope of data visualizations in campus portals. Current research on data visualization in campus portals is fragmented, lacking systematic sorting, and comparative studies between different portals. This study aims to address these gaps by synthesizing and analyzing existing literature on data visualizations in campus portals, identifying research gaps, and providing recommendations for future studies. Through a scoping review procedure, this study aims to enhance understanding and serve as a valuable resource for developers, implementers, administrators, and researchers in the field of information systems.

2. MATERIALS AND METHODS

The scoping review of data visualization literature followed a systematic process, encompassing the identification of the research question, development of a search strategy, selection of relevant studies, data analysis for themes, and synthesis of results. Adhering to the structured guidelines outlined in the 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR), this study aimed to provide a comprehensive overview of existing literature, identify research gaps, and offer insights into data visualization practices. Leveraging the extensive resources of Google Scholar and IEEE Xplore databases, a diverse range of scholarly literature, including both peer-reviewed and non-peer-reviewed sources, was systematically explored, selected, and analyzed to compile and synthesize studies focused on data visualizations in campus portals. Moreover, references of included studies and relevant reviews were examined, and relevant papers were identified using Google Scholar and IEEE Xplore tools. The search strategy, as shown in Table I, incorporated three keywords: *Data Visualization*, *Campus Portal*, and *Usability and Satisfaction*, ensuring a comprehensive coverage of relevant literature. Each keyword had to be present in the selected articles to ensure their relevance to the objectives of this study.

Figure 1 illustrates the accumulation of literature results retrieved from the database using the aforementioned keywords. Through exploration of Google Scholar and
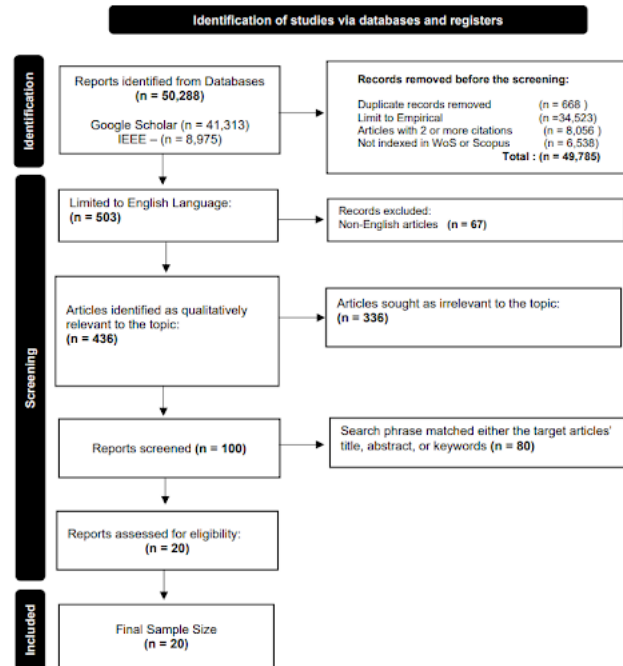

Figure 1. PRISMA-ScR flow diagram

IEEE Xplore databases, a total of 50,288 results were identified, comprising 41,313 articles from Google Scholar and 8,975 articles from IEEE. Subsequent refinement steps were implemented, including the removal of 668 duplicate records, narrowing down to empirical records, resulting in the exclusion of 34,523 articles. Further refinement involved filtering records with two or more citations, leading to the removal of 8,056 articles, and excluding those not accessible via Scopus or Web of Science databases, resulting in the elimination of 6,538 articles, leaving 503 journal articles. The search process had no restrictions on publication dates; however, the earliest eligible article dated back to 2012. During the screening phase, a total of 503 records were examined, with 67 records excluded due to non-English language, resulting in 436 articles. This language-based exclusion was a careful measure undertaken to maintain the consistency and relevance of the dataset. Additionally, a criterion involving thorough examination of the relevance of the journal articles led to the elimination of 336 articles deemed irrelevant, leaving 100 journal articles for further screening based on title, abstract, and keywords. These articles were systematically catalogued and stored in a dedicated Google Drive repository, serving as a repository of relevant literature. Following comprehensive review of the scope and discussions of each article, the researchers synthesized and organized the 100 articles into a structured journal assessment matrix. This matrix encompassed distilled hypotheses, methodologies, results, discussions, and merits for each article. Through this selection process, 20 academic journal articles meeting the predetermined inclusion criteria were identified for the

TABLE I. Keywords used in the search strings.

Keywords	Search Strings
Data Visualization [6], [8], [20], [30], [31], [32], [33], [34], [35], [36]	"Visualization" OR "Data Visualizations"
Campus Portal [6], [8], [14], [25], [27], [30]	"Campus Portal" OR "Student Portal" OR "University Portal" OR "Campus Portals" OR "Student Portals" OR "University Portals
Usability and Satisfaction [10], [14], [20], [25], [32], [35], [37], [38]	"learning analytics" OR "information visualization" OR "learning dashboards" OR "Perceived Usefulness" OR "Satisfaction"

sample size.

A. Scoping Analysis

To gain a deeper understanding of the role of data visualization in campus portals, the researchers conducted a scoping review analysis on twenty (20) journal articles focusing on the implementation and effectiveness of dashboards within campus settings. The researchers employed the Content-Context-Process (CCP) framework, as illustrated in Figure 2, to examine the literature, providing a comprehensive approach to understanding the scope of data visualizations in campus portals [39], [40].
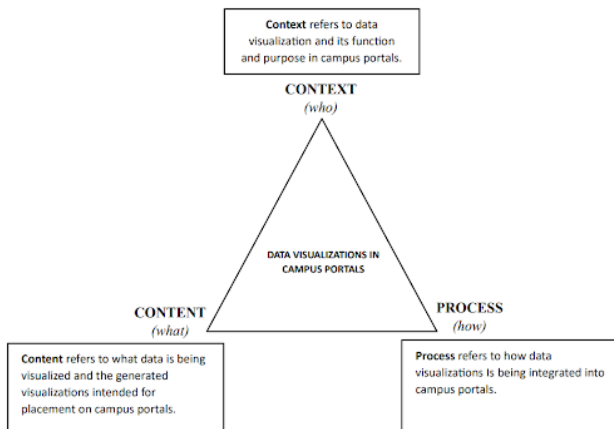

Figure 2. Context-Content-Process (CCP)

The CCP framework was initially employed in organizational strategy, where it was used to evaluate both internal and external environmental factors in IS research [24], [29]. Authors recommended CCP for documenting each step to ensure that all relevant information are captured accurately [39], [41], [42]. The CCP Framework served as a guiding tool, facilitating the analysis of the scope of data visualizations in campus portals.

The study analyzed the Context or *"who"* of data visualizations within the campus portal system, which refers to the function and purpose of data visualization in these portals. Functions refer to the practical applications and specific roles that data visualizations play, which is concerned with their practical utility and tangible uses

within the campus portal system. Purpose delves into the intended objectives or reasons driving the implementation of data visualizations, providing insight into the broader goals behind their use within campus portals. Purpose encapsulates the strategic and aspirational aspects of employing data visualizations to achieve overarching objectives within the campus portal system.

Furthermore, the study explored the Content or *"what"*, which refers to the scope of the study on what data is being shown visually and how it is presented through different visualizations to communicate information effectively [8], [10], [20], [30], [31], [32], [33], [35], [36], [43], [44], [45], [46]. This exploration aimed to provide insights into applying Data Visualization on specific datasets and their practical applications within the campus portal system. This includes an examination of what specific data is typically visualized. The type of visualization was then analyzed to identify various ways used for visualizing data. Data visualization involves representing information or data in a visual format. This was accomplished by tallying the data within campus portals that undergo any form of visualization and identifying the type of visualization used for its presentation.

Additionally, the study also analyzed the Process or *"how"* of data visualization, focusing on the selection and integration of data into visualizations within the campus portal [8], [10], [20], [31], [35], [36], [37], [38], [43], [45], [46]. This analysis revolved around the workflow, involving key stages of transforming raw data into valuable insights, and collected information on data visualization frameworks utilized in the sample group, organizing them into themes.

To synthesize the literature, the researcher employed an inductive coding approach to quickly gather essential factors and themes [10], [35], [37], [38], [45], [46]. This involved examining and synthesizing the 20 journal articles on data visualizations in campus portals, categorizing them based on common themes such as *Functions*, *Purpose*, *Applications*, *Data Visualization*, and *Workflow*. The study utilized a spreadsheet to organize the collected variables, providing a structured and easily accessible format for analysis. This approach facilitated the systematic understanding of trends within the dataset.

B. Research Gap Analysis

This section discusses the gaps identified in the data visualization literature in campus portals. Twenty journal articles were analyzed to determine common conclusions, limitations, and recommendations [47], [48], [49], [50], [51]. The conclusions, limitations, and recommendations of each article were consolidated, and a tally was used to identify recurring themes, enabling the synthesis of conclusions, limitations, and recommendations. Qualitative inductive and deductive coding techniques were employed to evaluate the articles based on their respective conclusions, limitations, and recommendations.

Common conclusions refer to shared findings among the sample studies, extracted by analyzing the conclusions of each of the twenty articles [50]. Common limitations are related to the scope constraints of the studies, identified by evaluating common issues in the studies [48], [50]. Common recommendations are commonly shared suggestions mentioned in the studies, identified by examining the recommendation sections of each study [50], [51].

The findings from these three categories are presented using a structured tabular format for categorization. Additionally, a mind map diagram, a visual tool for organizing and structuring information, is utilized. When applied to studies on data visualization in campus portals, mind mapping offers a comprehensive overview of recommendations proposed by field experts. By organizing these recommendations into a map, the relationships between different ideas become clearer, facilitating prioritization and implementation. This mapping of recurring themes and ideas provides valuable insights and supplementary information on data visualization in campus portals for future research and reference.

3. RESULTS AND DISCUSSION

The study conducted a scoping review of 20 journal articles on data visualization within campus portals. The analysis revealed diverse functionalities including *student performance and engagement analysis*, *feedback and continuous engagement*, *academic operations*, *profiles and list Management*, and *resource and content management*. These functionalities served purposes such as *communication and transparency*, *enhance information comprehension metrics*, *administrative decision support and strategic planning*, *student performance monitoring*, *optimization of learning processes and promote resource allocation efficiency*, *facilitate faculty performance evaluation*, and *financial analysis and budgeting*. The content of the framework revealed the application of the data visualization on *academic performance*, *data management*, *education and training*, *evaluation and feedback*, *digital resources*, *financial transactions*, *forums and collaborations*, and *user profiles*. Commonly used visualization types like *bar charts*, *grouped bar charts*, *line charts*, *heatmaps*, *pie charts*, *bubble charts*, and

half-circle charts were identified, each tailored to specific applications. The procedural workflow was also identified encompassing stages like data *graphing*, *preprocessing*, *processing*, *collection*, and *storage*.
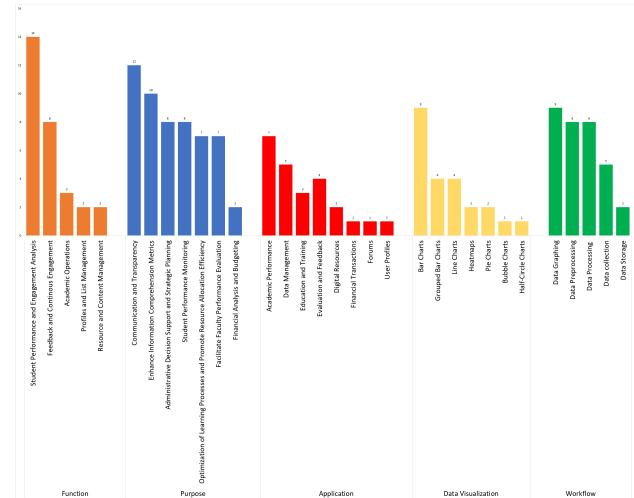

Figure 3. Scope of data visualizations in campus portals

Figure 3 illustrates the macro view of the CCP framework of data visualization in the campus portals. By analyzing themes from literature samples, it is evident that data visualization in campus portals predominantly focuses on Student Performance and Engagement Analysis. The recurring emphasis on Communication and Transparency across academic literature demonstrates a widespread interest in using data visualization to understand student outcomes and improve the educational experience. The prominent journals for Data Management emphasizes the need for organizing and interpreting data for strategic decision-making. Bar Charts, being the most commonly used visualization type to assist educators in deciphering complex data trends, facilitating effective communication and decision-making. Data Graphing emerges as well in the sample size which is a critical component for the process in making data visualizations both informative and accurate. These visual representations of data make it easier for educators to track student progress, identify areas for improvement, and ultimately enhance the overall educational experience. By utilizing tools such as bar charts and data graphs, educators can more efficiently analyze and interpret data, leading to more informed decision-making and ultimately better outcomes for students.

A. Scoping Analysis
1) Context

In this section of the CCP framework, the context of data visualization in campus portals is explored using a review of twenty sample journal articles. The main goal is to address the question: *What is the context of data visualizations in campus portals?* This question not only provides insights into common functionalities

but also explores the importance of data visualizations within campus portals. The analysis of data visualization in campus portals is systematically divided into two key domains based on the sample size: *"function"* and *"purpose"*. The *"function"* domain focuses on practical applications of data visualization within campus portals, such as displaying enrollment statistics, tracking student progress, or presenting financial information. On the other hand, the *"purpose"* domain examines the intended outcomes or goals of using data visualizations, which may include improving decision-making processes, enhancing user experience, or increasing institutional transparency and accountability. By categorizing the articles according to these domains, the CCP framework aims to provide a comprehensive understanding of the context aspects of data visualizations in campus portals.

A detailed analysis of journals, as outlined in Table II, highlights the diverse functionalities of data visualization in campus portals. The most prevalent theme is *"Student Performance and Engagement Analysis"* which is featured in 12 journals [6], [10], [25], [27], [30], [31], [32], [34], [36], [37], [44], [45]. Following closely is *"Feedback and Continuous Improvement"* observed in 8 journals [10], [25], [27], [30], [34], [36], [37], [45] , followed by *"Academic Operations"* which appears in 3 journals [25], [27], [30]. Additionally, *"Profile and List Management"*, *"Resource and Content Management"* and *"Financial Transactions"* are each present in 2 journals [25], [27], [8], [10]. Finally, *"Financial Transactions"* is represented in 1 journal [8]. This distribution offers a comprehensive overview of the emphasis placed on specific themes within the realm of data visualization in campus portals. The significant prevalence of *"Student Performance and Engagement Analysis"* suggests a widespread interest in leveraging data visualization tools to comprehend and improve student outcomes. The inclusion of other themes such as *"Feedback and Continuous Improvement"*, *"Academic Operations"*, and the management of *"Profiles and Lists"* highlights the diverse applications of data visualization in addressing various aspects of operations within a campus setting.

These findings show the widespread recognition of data visualization in campus portals for its role in monitoring and analyzing various operational aspects in educational institutions. These visualizations serve as potent tools, enhancing communication and transparency by simplifying complex data for users. Presenting data in an easily understandable visual format improves comprehension metrics, making information more memorable and engaging. Moreover, data visualizations facilitate real-time student performance monitoring, supporting resource allocation decisions and enhancing transparency, while also aiding administrative decision-making and strategic planning by revealing institutional performance patterns. Additionally, they optimize resource allocation efficiency by identifying trends in learning processes and aiding faculty performance evaluation. In the financial domain,

TABLE II. Categorized functionalities of data visualization in campus portals.

Function	Number of Studies
Student Performance and Engagement Analysis [6], [10], [25], [27], [30], [31], [32], [34], [36], [37], [44], [45]	12
Feedback and Continuous Improvement [10], [25], [27], [30], [34], [36], [37], [45]	8
Academic Operations [25], [27], [30]	3
Profile and List Management [25], [27]	2
Resource and Content Management [25], [27]	2
Financial Transactions [8], [10]	2

data visualizations simplify complex financial data, aiding in budgeting decisions and providing a clear overview of the institution's financial health.

Data visualizations are integral to educational institutions, promoting accessibility, understanding and transparency, and significantly contributing to informed decision-making and overall efficiency. This allows institutions to identify areas for improvement, strategize resource allocation, and enhance the educational experience for students. Moreover, with advancements in technology and data analytics, data visualization in campus portals has become essential for institutions to stay agile and data-driven in their decision-making processes.

Moreover, research indicates that interactive visualization tools developed by Unitelma Sapienza University and the IISLab of Tampere University of Technology as plug-ins for the Moodle LMS further enhance online teaching and learning [6]. These tools assist both students and teachers in monitoring, evaluating, and making decisions to improve learning outcomes [6], [8], [10], [20], [31], [34], [38], [46]. By utilizing discrete graphs to visualize learning logs, which collect data from e-texts and learning management systems, the tools facilitate observing learning activities' features for each grade and identifying activities that students should avoid. Moreover, integrating big data technology into teaching introduces advanced educational resources, enhancing learning efficiency and overall teaching quality [52]. The education sector actively explores combining big data technology with teaching management to optimize educational processes. Learning Analytics emerges as a powerful tool for teachers to iteratively improve course effectiveness and enhance student performance. Educational institutions leverage data visualizations to make more informed decisions, utilizing accumulated transactional data to attain their

goals. With the growing reliance on IT, particularly in financial management, institutions produce visual reports from transactional data stored in the financial management information system (FMIS) database accessible through their portals [8].

2) Content

This section of the CCP Framework focuses on exploring the content aspects of data visualizations in campus portals. This delves into the content of the visualizations, encompassing an analysis of what data are being visualized and what visualizations are being generated. This approach addresses the scope of the study, providing insights into how data is presented and interpreted in campus portals. By analyzing the content aspects of data visualizations in campus portals, researchers can gain a better understanding of the information being conveyed and the visual representations that are being used. This data involves the seamless transfer of information across diverse systems in educational institutions. This comprehensive category includes Data Management, which delves into class details and course overviews. Education and Training cover teaching tasks, grade management, and teaching resources for a dynamic learning environment. Evaluation and Feedback focus on continuous improvement by collecting insights on tasks, organizational performance, and course effectiveness. Financial Transactions handle monetary aspects for institutional financial health. Academic Performance monitors student dropout rates and teaching progress for data-driven enhancements. User Profiles maintain comprehensive profiles for personalized experiences. Digital Resources manage educational materials, including lecture uploads and an e-library. Finally, Forums and Collaboration bring students and teachers together for interactive discussions, fostering a sense of community.

Results illustrated in Table III, show that *"Academic Performance"* emerges as the most prominent theme which is featured in 7 journals [6], [10], [25], [27], [30], [45], [46]. Followed by *"Data Management"* which appeared in 5 journals [20], [25], [27], [34], [46]. *"Education and Training"* is addressed in 3 journals [27], [30], [35], while *"Evaluation and Feedback"* is discussed in 4 journals [10], [25], [27], [32]. *"Digital Resources"* is the focus of 2 journals [25], [43]. Finally, *"Financial Transactions"*, *"Forums and Collaboration"*, and *"User Profiles"* each have 1 journal citation [8], [25], [27].

This comprehensive examination reveals the areas of data visualization within campus portals, providing valuable insights into research focuses in the field. The prevalence of *"Academic Performance"* indicates the extensive visualization of student-related data on campus portals, suggesting a strong emphasis on monitoring student performance. Moreover, the significant number of journals dedicated to *"Data Management"* highlights the importance educational institutions place on effectively managing their

TABLE III. Applications of data visualization in campus portals.

Application	Number of Studies
Academic Performance [6], [10], [25], [27], [30], [45], [46]	7
Data Management [20], [25], [27], [34], [46]	5
Education and Training [27], [30], [35]	3
Evaluation and Feedback [10], [25], [27], [32]	4
Digital Resources [25], [43]	2
Financial Transactions [8]	1
Forums [25]	1
User Profiles [27]	1

data using campus portals.

The utilization of data visualizations in campus portals primarily revolves around Academic Performance, indicating a widespread inclination among educational institutions to visually represent student academic data for better comprehension and outcome enhancement. Concurrently, the emphasis on Data Management highlights the imperative for educational institutions to efficiently handle educational data. Moreover, themes such as Education and Training, Evaluation and Feedback, and Digital Resources indicate a diverse array of data subjected to visualization. Furthermore, themes like Financial Transactions, Forums, and User Profiles show the versatility of campus portals, extending their scope beyond academic aspects to encompass financial management, collaborative learning, and personalized user experiences in education.

Overall, these findings reflect the multifaceted nature of campus portals in addressing various aspects of education and data management. By providing clear visual representations of academic performance, campus portals empower educators and administrators to identify areas for improvement and allocate resources accordingly. These findings resonate with existing literature, contributing to the broader discourse on the advantages of data visualization in education. Furthermore, data visualizations in campus portals facilitate communication and collaboration among stakeholders. Educators, parents, and students can readily access and interpret relevant data, fostering informed discussions and data-driven decision-making. This promotes a collaborative environment where all parties collaborate to support student success. Additionally, the use of data visualizations can improve accountability and transparency within educational institutions by making academic performance data easily accessible [53], [54], [55].

TABLE IV. Data visualization types in campus portals.

Type	Number of Studies
Bar Charts [6], [20], [31], [32], [34], [35], [36], [38], [44]	9
Grouped Bar Charts [6], [20], [34], [35]	4
Line Charts [32], [35], [36], [44]	4
Heatmaps [20], [32]	2
Pie Charts [6], [38]	2
Bubble Charts [6]	1
Half-Circle Charts [8]	1

Table 5 presents the distribution of literature on various data visualization types used in campus portals. *"Bar Charts"* were employed in visualizations featured in 9 journals [6], [20], [31], [32], [34], [35], [36], [38], [44] , followed by *"Grouped Bar Charts"* and *"Line Charts"* in 4 journals each [6], [20], [34], [35], [32], [36], [44] . *"Pie Charts"* and *"Heatmaps"* were utilized in 2 journals each [6], [20], [32], [38] , while *"Bubble Charts"* and *"Half-Circle Charts"* were featured in 1 journal each [6], [8].

The breakdown of data visualization types in campus portals demonstrates a diverse range of options for representing different datasets. The prevalence of bar charts, featured in 9 journals, indicates their popularity and effectiveness in data representation. However, the presence of multiple journals employing other visualization types like grouped bar charts and line charts suggests the need for tailored visualization techniques based on specific datasets. Moreover, the inclusion of options such as pie charts, bubble charts, and half-circle charts highlights the versatility and availability of various visualization tools for effectively presenting data in campus portals.

This variety allows researchers and practitioners to choose techniques that best suit the characteristics of their data and their visualization objectives. This information offers valuable insights into the flexible and varied approaches adopted by professionals in visually presenting data in the domain of campus portal research. Furthermore, according to relevant research, relevant research indicate that choosing the proper visualization technique can improve the user experience of the campus portal [6], [30], [31], [32], [33], [35], [37] . Well-designed and visually appealing visualizations can streamline data navigation and exploration, fostering intuitive and engaging interactions for users. Consequently, this can lead to heightened user satisfaction and continued utilization of the portal for information needs [56], [57], [58].

3) Process

This section of the CCP Framework explores the process aspects of data visualizations within campus portals, focusing on the subprocesses involved in transforming raw data into actionable insights. These subprocesses include data graphing, data preprocessing, data processing, data collection, and data storage.

The data graphing stage entails creating visual representations of the data, such as charts and graphs, to enhance its understandability and interpretability. This visual presentation makes the data more appealing and easier to comprehend.

In the data preprocessing stage, the raw data undergoes cleaning and organization to ensure its accuracy and consistency. This step involves removing irrelevant or duplicate data and transforming the data into a suitable format for analysis.

The data processing stage involves the application of various algorithms and statistical techniques to the preprocessed data. This step aims to uncover patterns, trends, and relationships within the data.

Finally, the data collection and storage stage involve gathering and storing the data in a secure and accessible manner for future use and reference. This ensures that the data remains available for analysis and decision-making purposes.

The workflow of data visualization found in the literature is illustrated in Table V. *"Data Graphing"* is featured in 9 journal articles [6], [20], [31], [32], [34], [35], [36], [38], [44] . Following this, *"Data Preprocessing"* and *"Data Processing"*, each presented in 8 articles [6], [8], [10], [20], [31], [34], [38], [46], [25], [27], [30], [36], [37], [45] . *"Data Collection"* is discussed in 5 articles [10], [36], [44], [45], [46] , while *"Data Storage"* is associated with 2 articles [25], [43].

These findings highlight the intricate steps involved in the data visualization process, emphasizing the importance of each subprocess in facilitating effective representation and interpretation of data. The subprocesses identified in campus portal data visualization include data graphing, data preprocessing, data processing, data collection, and data storage.

Data graphing plays a crucial role in selecting suitable visualization modes and chart types to ensure visual continuity, aiding in efficient data processing. The abundance of articles focusing on this stage underscores its significance in visually conveying insights.

Data preprocessing lays the groundwork for efficient data analysis by organizing the data in a format that

TABLE V. Data visualization workflow in campus portals.

Workflow	Number of Studies
Data Graphing [6], [20], [31], [32], [34], [35], [36], [38], [44]	9
Data Preprocessing [6], [8], [10], [20], [31], [34], [38], [46]	8
Data Processing [10], [25], [27], [30], [34], [36], [37], [45]	8
Data Collection [10], [36], [44], [45], [46]	5
Data Storage [25], [43]	2

TABLE VI. Common conclusions found in the literature.

Conclusion	Number of Studies
Improves user engagement [6], [8], [10], [14], [20], [27], [30], [31], [33], [34], [35], [36], [38], [43], [44], [45]	16
Useful for decision-making and reporting [6], [8], [10], [14], [20], [30], [31], [32], [33], [35], [38], [43], [44], [45], [46]	15
User-friendly [6], [8], [20], [30], [31], [32], [33], [34], [35], [36], [43], [44], [45], [46]	14
Shapes the behavior or attitude of the user [6], [10], [20], [32], [33], [34], [35], [45]	9
Low visualization literacy [6]	1

is conducive to analysis techniques and algorithms. This organized and cleaned data becomes the foundation upon which insights are derived, making the subsequent visualization process more effective and meaningful.

Data processing refines data from analytical abstractions to visualization forms, enabling the derivation of insights from collected data. Studies highlight the importance of systems that offer unified interfaces for querying SQL databases, as well as the use of Python and R language tools for pattern identification, trend analysis, and statistical examination.

Data collection involves gathering information from various sources, including databases and surveys, with raw data often presenting challenges due to specific formats.

Data storage practices, such as utilizing big data storage for real-time manipulation and secure databases, contribute to the accessibility, security, and efficient management of large datasets. Subsequently, data processing refines data from analytical abstractions to visualization forms, enabling the derivation of insights from collected data. Studies highlight the importance of systems that offer unified interfaces for querying SQL databases, as well as the use of Python and R language tools for pattern identification, trend analysis, and statistical examination [6], [8], [44].

Overall, it is evident that data visualization process in campus portals is well-documented and researched in the academic community. Understanding these interconnected subprocesses is crucial for creating effective and informative visualizations, as they play a key role in communicating complex information clearly and concisely. This understanding not only helps the audience comprehend the conveyed message but also empowers them to analyze and explore the data themselves, leading to more informed decision-making and deeper insights [58], [59], [60].

B. Research Gap Analysis

1) Common Conclusions

This study analyzed 20 journal articles focused on data visualization within campus portals. The findings, summarized in Table VI, revealed several consistent conclusions across these studies. Specifically, 16 studies noted that the implementation of data visualization in campus portals correlates with increased user engagement in accessing and utilizing data [6], [8], [10], [14], [20], [27], [30], [31], [33], [34], [35], [36], [38], [43], [44], [45]. Additionally, 15 studies highlighted its widespread usefulness for decision-making and reporting purposes [6], [8], [10], [14], [20], [30], [31], [32], [33], [35], [38], [43], [44], [45], [46], while 14 studies emphasized its user-friendly nature, attributed to its clarity through simple designs [6], [8], [20], [30], [31], [32], [33], [34], [35], [36], [43], [44], [45], [46]. Furthermore, 9 studies indicated that user behavior or attitude is influenced by the significant impact of data visualization [6], [10], [20], [32], [33], [34], [35], [45]. Finally, one study pointed out that users' visualization literacy remains low [6].

The studies suggest that data visualization in campus portals enhances user engagement in accessing and utilizing data. They highlight its positive impact on user satisfaction, serving various purposes such as assessing academic performance, improving information comprehension metrics, strategic planning, and optimizing the learning process and resources. The utility of data visualization in campus portals is emphasized, aiding users in decision-making and reporting [56], [59]. The studies were primarily facilitated through functions such as student performance and engagement analysis, feedback mechanisms, academic operations, profile and list management, content management, collaboration and communication hubs, and financial transactions.

Moreover, some studies emphasize the user-friendly aspect of data visualization, noting its clarity, feasibility,

TABLE VII. Common limitations found in the literature.

Limitation	Number of Studies
Insufficient evaluation [6], [8], [10], [14], [20], [27], [31], [33], [35], [36], [37], [38], [43], [44], [45]	17
Limited exploration and improvement [14], [20], [25], [30], [27], [31], [32], [33], [38], [43], [44], [45], [46]	13
Lack of attention to data complexity [10], [36], [44], [45], [46]	5
Certain data visualization are not useful [6], [14], [25], [31], [44]	5
Limited use of data visualization [32], [33], [35]	3

and simplicity [61]. While some studies recommend its preferential use, others disagree, citing that some users cannot understand the relevance of certain data visualizations. Additionally, some studies suggest that data visualization shapes user behavior and attitudes, impacting how effectively users utilize campus portals. However, it was also found that visualization literacy remains low in some studies, attributed to users who were unable to engage in the exploration and research of data visualization.

2) Common Limitations

Table VII highlights common limitations identified across the studies. Seventeen studies were found to lack sufficient evaluation [6], [8], [10], [14], [20], [27], [31], [33], [35], [36], [37], [38], [43], [44], [45], while thirteen studies exhibited limited exploration for further improvement [14], [20], [25], [30], [27], [31], [32], [33], [38], [43], [44], [45], [46]. Additionally, five studies failed to adequately address the complexity of the data [10], [36], [44], [45], [46] with challenges arising particularly from the utilization of large datasets. Certain data visualizations were found to be unhelpful and not easily recognizable to users in five studies [6], [14], [25], [31], [44]. Moreover, three studies noted a limited incorporation of data visualizations across the research landscape [32], [33], [35].

The majority of studies primarily focus on evaluating data visualization technologies within campus portals, limiting the scope of insights into their effectiveness and efficiency in conveying information to users. This narrow focus restricts the understanding of how well users comprehend the conveyed information or how effectively data visualization facilitates understanding. Some studies emphasize the importance of evaluating data visualization to identify potential improvements or optimizations in design, interactivity, or clarity. This lack of evaluation may overlook opportunities for enhancing user experience and effectiveness [6], [8], [10], [14], [20], [27], [31], [32], [33], [35], [36], [37], [38], [43], [44].

Moreover, limited exploration and improvement within studies suggest a deliberate choice to narrow the focus or scope of research to specific dimensions of data visualization in campus portals. While some aspects of data visualization may be more feasible or practical to investigate given the research constraints, this approach may overlook opportunities for broader insights and enhancements [58], [59].

Attention to data complexity is also lacking in some studies, indicating insufficient consideration of the intricacies associated with visualized data structures. While some studies argue that certain data visualizations are unsuitable for handling complex data structures, others contend that they are compatible and user-friendly for managing large datasets. This discrepancy highlights the need for further research to better understand the suitability of different visualization techniques for diverse datasets [62].

Additionally, certain data visualizations are deemed ineffective in some studies, suggesting that they do not align with the specific needs and preferences of users. This discrepancy shows the importance of selecting appropriate visualization techniques tailored to the audience and context. While unfamiliarity with certain visualizations may hinder the ability of users to extract information, many studies refute this claim, citing instances where visualizations have improved understanding, decision-making, engagement, and user satisfaction.

Furthermore, some studies acknowledge limitations in the use of data visualization and advocate for usability testing to assess how users interact with visualizations and how these interactions impact user experience and effectiveness. This approach allows for iterative improvements and optimizations based on user feedback and preferences.

3) Common Recommendations

Outlined in Table VIII are common recommendations from the literature, intended to guide future research in the field of data visualization in campus portals. These recommendations include evaluating the impact of data visualization on decision-making processes of users within campus portals [6], [8], [10], [25], [30], [31], [32], [34], [35], [43], exploring various methods and techniques [14], [20], [25], [30], [31], [32], [33], [38], [43], [44], [45], [46], theoretical studies, and data processing. Recommendations also emphasize the importance of human-computer interaction [10], [25], [30], [31], [32], [35], [36], [44] with a focus on enhancing information visualization, user interface design, and usability. Additionally, some studies suggest integrating advanced data visualization with data analysis techniques [33], [36] and extending the data warehouse to explore other database technologies [8].

TABLE VIII. Common recommendations found in the literature.

Recommendation	Number of Studies
Research and exploration [14], [20], [25], [30], [31], [32], [33], [38], [43], [44], [45], [46]	12
Evaluate the impact of data visualization on decision making of users [6], [8], [10], [25], [30], [31], [32], [34], [35], [43]	10
Focus on human-computer interaction studies [10], [25], [30], [31], [32], [35], [36], [44]	8
Combine advanced data visualization with data analysis techniques [33], [36]	2
Explore other database technologies [8]	1

The literature highlights the importance of continued research and exploration in the field of data visualization within campus portals. This includes further investigation into various methods, theoretical studies, and data processing techniques [52], [58]. Research into methods ensures that campus portals remain updated with the latest visualization approaches, allowing for the integration of cutting-edge techniques. Developers are advised to gather feedback from users to understand their preferences and refine visualizations for continuous improvement on the effectiveness of the the campus portal.

Moreover, there is a call for additional research in theoretical studies to identify and understand concepts, functionalities, principles, and frameworks. Research on data processing is crucial to integrate, transform, and optimize performance, especially when dealing with real-time or near-real-time updates on campus portals. Additionally, evaluating the impact of data visualization on user decision-making is recommended, as most studies have focused on the data visualization process rather than its effects. Furthermore, while some studies have explored the short-term effects of data visualization on decision-making, there is limited exploration of its long-term impacts. Further study into the long-term effects is necessary to comprehensively understand the sustained influence of data visualization features.

Several studies have indicated a positive correlation between data visualization and enhanced academic performance among users. However, finding suggests that low-performing student users may derive limited understanding from data visualization tools. This highlights the need for further investigation into how data visualization impacts user groups, particularly those facing academic challenges.

Human-computer interaction studies, covering information visualization, user interface design, and usability testing for users, are also recommended by some studies. Additionally, combining data visualization with data analysis techniques is crucial to identify more trends, patterns, and outliers [55]. Advanced visualization is also suggested to make it easier for users to grasp the implications of the analysis.

Furthermore, extending the data warehouse is considered a recommendation for future research to incorporate newer database technologies, such as in-memory databases or NoSQL databases, providing more up-to-date insights for users in campus portals.

4. CONCLUSIONS

This scoping review, based on the Context-Content-Process (CCP) Framework, synthesizes the literature on data visualization in campus portals to demonstrate its pervasive use and central role in education. It encompasses three key dimensions: *context*, *content*, and *process*, each highlighting how data visualization enhances the educational experience.

In the context dimension, the analysis shows the significant impact of data visualization on student achievement and engagement. It illustrates the widespread application of data visualization across academic disciplines, emphasizing its crucial role in fostering an engaging educational environment.

The content analysis identifies the most common types of data visualizations utilized in campus portals, with bar charts emerging as particularly effective in presenting complex data clearly and accessibly. This emphasizes the importance of transparent communication for informed decision-making in educational settings.

The process analysis delineates the workflow for visualizing data, spanning from data collection to graphing. It shows the importance of each stage in transforming raw data into coherent visual narratives essential for effective communication and understanding. The emphasis on data processing and graphing stages highlights the significance of converting data into meaningful visual representations, thereby enhancing information dissemination and interpretation.

Integrating data visualization into campus portals is imperative as a strategic asset to enhance information comprehension, facilitate decision-making, and optimize learning methodologies. It has the potential to revolutionize higher education by offering a comprehensive understanding of various applications, visualization types, and delineated workflows. Data visualization can create personalized and compelling learning experiences, streamline administrative processes, and support informed decision-making within academic institutions.

These findings reinforce the importance of data-driven decision-making and the positive impact of data visualizations in education. Further research is recommended to explore the specific impact of data visualization features on user decision-making within campus portals.

REFERENCES

[1] A. Zentner, R. Covit, and D. Guevarra, "Exploring effective data visualization strategies in higher education," *Available at SSRN 3322856*, 2019.

[2] S. Chong, Y. H. Lee, and Y. W. Tang, "Data analytics and visualization to support the adult learner in higher education," in *2020 The 4th International Conference on E-Society, E-Education and E-Technology*, 2020, pp. 126–131.

[3] R. Yasmin, M. Salminen, E. Gilman, J. Petäjäjärvi, K. Mikhaylov, M. Pakanen, A. Niemelä, J. Riekki, S. Pirttikangas, and A. Pouttu, "Combining iot deployment and data visualization: experiences within campus maintenance use-case," in *2018 9th International Conference on the Network of the Future (NOF)*. IEEE, 2018, pp. 101–105.

[4] O. LLAHA and A. ALIU, "Students' performance evaluation in higher education using data visualization techniques." *Annals of Philosophy, Social & Human Disciplines*, vol. 2, 2022.

[5] O. Llaha, A. Aliu, E. Kadena *et al.*, "Application of clustering methods and data visualization for decision making in higher education," *JOURNAL OF AWARENESS*, vol. 8, no. 3, pp. 297–303, 2023.

[6] A. M. Kayanda and D. Machuve, "A web-based data visualization tool regarding school dropouts and user asssesment," *Engineering, Technology & Applied Science Research*, vol. 10, no. 4, pp. 5967–5973, 2020.

[7] A. Buja, D. Cook, and D. F. Swayne, "Interactive high-dimensional data visualization," *Journal of computational and graphical statistics*, vol. 5, no. 1, pp. 78–99, 1996.

[8] E. V. F. Lapura, J. K. J. Fernandez, M. J. K. Pagatpat, and D. D. Dinawanao, "Development of a university financial data warehouse and its visualization tool," *Procedia Computer Science*, vol. 135, pp. 587–595, 2018.

[9] Y. Xia, G. Song, and Y. Zheng, "Portal access to scientific computation and customized collaborative visualization on campus grid," in *2006 IEEE Asia-Pacific Conference on Services Computing (APSCC'06)*. IEEE, 2006, pp. 451–457.

[10] B. Williamson, "The hidden architecture of higher education: Building a big data infrastructure for the 'smarter university'," *International Journal of Educational Technology in Higher Education*, vol. 15, pp. 1–26, 2018.

[11] A. F. D. Gonçalves, A. Maciel, and R. L. Rodrigues, "Development of a data mining education framework for data visualization in distance learning environments," in *International conference on software engineering and knowledge engineering*, 2017.

[12] A. Tella and M. Bashorun, "Undergraduate students'satisfaction with the use of web portals," *International Journal of Web Portals (IJWP)*, vol. 4, no. 2, pp. 56–73, 2012.

[13] B. S. Chaparro, "Usability evaluation of a university portal website," *Usability News*, vol. 10, no. 2, pp. 1–7, 2008.

[14] M. Saghapour, M. Iranmanesh, S. Zailani, and G. G. G. Goh, "An empirical investigation of campus portal usage," *Education and Information Technologies*, vol. 23, pp. 777–795, 2018.

[15] A. Hussain, S. Aliyu, M. M. Barakat, and F. Maki, "Assessing and testing the usability of student portal," in *AIP Conference Proceedings*, vol. 2016, no. 1. AIP Publishing, 2018.

[16] J. O. Inoco and A. A. Hernandez, "Assessment on the effectiveness and satisfaction of students in estudent information portal," in *2017IEEE 9th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM)*. IEEE, 2017, pp. 1–4.

[17] B. Bach, M. Keck, F. Rajabiyazdi, T. Losev, I. Meirelles, J. Dykes, R. S. Laramee, M. AlKadi, C. Stoiber, S. Huron *et al.*, "Challenges and opportunities in data visualization education: A call to action," *IEEE Transactions on visualization and computer graphics*, 2023.

[18] W. E. Lacefield and E. B. Applegate, "Data visualization in public education: Longitudinal student-, intervention-, school-, and district-level performance modeling." *Online Submission*, 2018.

[19] P. S. Yalagi and S. D. Chaitrali, "Design of an academic web portal providing e-facilities," *International Journal of Computer Science Engineering and Information Technology Research (IJCSEITR) ISSN*, vol. 2249, p. 6831, 2013.

[20] J. Kim, I.-H. Jo, and Y. Park, "Effects of learning analytics dashboard: analyzing the relations among dashboard utilization, satisfaction, and learning achievement," *Asia Pacific Education Review*, vol. 17, pp. 13–24, 2016.

[21] T. Naps, S. Cooper, B. Koldehofe, C. Leska, G. Rößling, W. Dann, A. Korhonen, L. Malmi, J. Rantakokko, R. J. Ross *et al.*, "Evaluating the educational impact of visualization," *Acm sigcse bulletin*, vol. 35, no. 4, pp. 124–136, 2003.

[22] H.-Y. Chang, Y.-J. Chang, and M.-J. Tsai, "Strategies and difficulties during students' construction of data visualizations," *International Journal of STEM Education*, vol. 11, no. 1, p. 11, 2024.

[23] L. Corrin and P. De Barba, "Exploring students' interpretation of feedback delivered through learning analytics dashboards [pp. 629-633]. b. hegarty, j. mcdonald y s," *K. Loke, Rhetoric and Reality: Critical perspectives on educational technology. Dunedin: University of Melbourne. Recuperado de https://melbourne-cshe. unimelb. edu. au/research/research-projects/edutech/learninganalytics-dashboards*, 2014.

[24] A. M. Shaltoni, H. Khraim, A. Abuhamad, and M. Amer, "Exploring students' satisfaction with universities' portals in developing countries: A cultural perspective," *The International Journal of Information and Learning Technology*, vol. 32, no. 2, pp. 82–93, 2015.

[25] R. P. Bringula and R. S. Basa, "Factors affecting faculty web portal usability," *Journal of educational technology & society*, vol. 14, no. 4, pp. 253–265, 2011.

[26] M. Pašák and M. Palcut, "Comparing university students' performance in the statistical processing and visualization of

laboratory data before, during and after the covid-19 pandemic," *Education Sciences*, vol. 14, no. 3, p. 241, 2024.

[27] R. More, N. Chavan, N. Kendre, and A. Devmane, "Student portal of college."

[28] G. Zhang, Z. Zhu, S. Zhu, R. Liang, and G. Sun, "Towards a better understanding of the role of visualization in online learning: A review," *Visual Informatics*, vol. 6, no. 4, pp. 22–33, 2022.

[29] B. Yousuf and O. Conlan, "Visen: Motivating learner engagement through explorable visual narratives," in *Design for Teaching and Learning in a Networked World: 10th European Conference on Technology Enhanced Learning, EC-TEL 2015, Toledo, Spain, September 15-18, 2015, Proceedings 10.* Springer, 2015, pp. 367–380.

[30] P. Wang, P. Zhao, Y. Li *et al.*, "Design of education information platform on education big data visualization," *Wireless Communications and Mobile Computing*, vol. 2022, 2022.

[31] L. Roberts, J. Howell, and K. Seaman, "Give me a customizable dashboard: Personalized learning analytics dashboards in higher education. technology, knowledge and learning, 22 (3), 317–333," 2017.

[32] T. Auvinen, L. Hakulinen, and L. Malmi, "Increasing students' awareness of their behavior in online learning environments with visualizations and achievement badges," *IEEE Transactions on Learning Technologies*, vol. 8, no. 3, pp. 261–273, 2015.

[33] X. Zhu, B. Sun, and Y. Luo, "Interactive learning system" vismis" for scientific visualization course," in *Proceedings of the 3rd Asia-Europe Symposium on Simulation & Serious Gaming*, 2016, pp. 177–184.

[34] K. Verbert, E. Duval, J. Klerkx, S. Govaerts, and J. L. Santos, "Learning analytics dashboard applications," *American Behavioral Scientist*, vol. 57, no. 10, pp. 1500–1509, 2013.

[35] B. Yousuf and O. Conlan, "Supporting student engagement through explorable visual narratives," *IEEE Transactions on Learning Technologies*, vol. 11, no. 3, pp. 307–320, 2017.

[36] V. Podgorelec and S. Kuhar, "Taking advantage of education data: Advanced data analysis and reporting in virtual learning environments," *Elektronika ir Elektrotechnika*, vol. 114, no. 8, pp. 111–116, 2011.

[37] R. Conijn, C. Snijders, A. Kleingeld, and U. Matzat, "Predicting student performance from lms data: A comparison of 17 blended courses using moodle lms," *IEEE Transactions on Learning Technologies*, vol. 10, no. 1, pp. 17–29, 2016.

[38] H. B. Santoso, A. K. Batuparan, R. Y. K. Isal, and W. H. Goodridge, "The development of a learning dashboard for lecturers: A case study on a student-centered e-learning environment," *The Journal of Educators Online*, p. 1, 2018.

[39] R. Stockdale and C. Standing, "An interpretive approach to evaluating information systems: A content, context, process framework," *European journal of operational research*, vol. 173, no. 3, pp. 1090–1102, 2006.

[40] A. E. Andargoli, H. Scheepers, D. Rajendran, and A. Sohal, "Health information systems evaluation frameworks: A systematic review,"

International journal of medical informatics, vol. 97, pp. 195–209, 2017.

[41] H. Töhönen, M. Kauppinen, T. Männistö, and T. Itälä, "A conceptual framework for valuing it within a business system," *International journal of accounting information systems*, vol. 36, p. 100442, 2020.

[42] E. W. Bernroider, S. Koch, and V. Stix, "A comprehensive framework approach using content, context, process views to combine methods from operations research for it assessments," *Information Systems Management*, vol. 30, no. 1, pp. 75–88, 2013.

[43] J. Wang, A. Shimada, M. Oi, H. Ogata, and Y. Tabata, "Development and evaluation of a visualization system to support meaningful e-book learning," *Interactive Learning Environments*, vol. 31, no. 2, pp. 836–853, 2023.

[44] A. L. Dyckhoff, D. Zielke, M. Bültmann, M. A. Chatti, and U. Schroeder, "Design and implementation of a learning analytics toolkit for teachers," *Journal of Educational Technology & Society*, vol. 15, no. 3, pp. 58–76, 2012.

[45] A. Wolff, P. Mulholland, and Z. Zdrahal, "Using machine-learning and visualisation to facilitate learner interpretation of source material," *Interactive Learning Environments*, vol. 22, no. 6, pp. 771–788, 2014.

[46] P. Wu, F. Ma, and S. Yu, "Using a linked data-based knowledge navigation system to improve teaching effectiveness," *Interactive Learning Environments*, vol. 31, no. 5, pp. 3273–3284, 2023.

[47] J. Slayter, L. Casey, and C. O'Connell, "Patient reported outcome measures in adult spinal muscular atrophy: a scoping review and graphical visualization of the evidence," *Journal of Neuromuscular Diseases*, vol. 10, no. 2, pp. 239–250, 2023.

[48] J. Schoenherr and S. Schukajlow, "Characterizing external visualization in mathematics education research: a scoping review," *ZDM–Mathematics Education*, vol. 56, no. 1, pp. 73–85, 2024.

[49] N. Oubenali, S. Messaoud, A. Filiot, A. Lamer, and P. Andrey, "Visualization of medical concepts represented using word embeddings: a scoping review," *BMC medical informatics and decision making*, vol. 22, no. 1, p. 83, 2022.

[50] J. Scheer, A. Volkert, N. Brich, L. Weinert, N. Santhanam, M. Krone, T. Ganslandt, M. Boeker, and T. Nagel, "Visualization techniques of time-oriented data for the comparison of single patients with multiple patients or cohorts: Scoping review," *Journal of medical Internet research*, vol. 24, no. 10, p. e38041, 2022.

[51] L. N. Carroll, A. P. Au, L. T. Detwiler, T.-c. Fu, I. S. Painter, and N. F. Abernethy, "Visualization and analytics tools for infectious disease epidemiology: a systematic review," *Journal of biomedical informatics*, vol. 51, pp. 287–298, 2014.

[52] N. Bikakis and T. Sellis, "Exploration and visualization in the web of big linked data: A survey of the state of the art," *arXiv preprint arXiv:1601.08059*, 2016.

[53] C. Romero and S. Ventura, "Educational data mining: a review of the state of the art," *IEEE Transactions on Systems, Man, and Cybernetics, Part C (applications and reviews)*, vol. 40, no. 6, pp. 601–618, 2010.

[54] R. Bodily and K. Verbert, "Review of research on student-facing learning analytics dashboards and educational recommender

systems," *IEEE Transactions on Learning Technologies*, vol. 10, no. 4, pp. 405–418, 2017.

[55] S. Almasi, K. Bahaadinbeigy, H. Ahmadi, S. Sohrabei, R. Rabiei *et al.*, "Usability evaluation of dashboards: A systematic literature review of tools," *BioMed Research International*, vol. 2023, 2023.

[56] L. Meloncon and E. Warner, "Data visualizations: A literature review and opportunities for technical and professional communication," in *2017 IEEE International Professional Communication Conference (ProComm)*. IEEE, 2017, pp. 1–9.

[57] K. Börner, A. Bueckle, and M. Ginda, "Data visualization literacy: Definitions, conceptual frameworks, exercises, and assessments," *Proceedings of the National Academy of Sciences*, vol. 116, no. 6, pp. 1857–1864, 2019.

[58] M. S. Zakaria, "Data visualization as a research support service in academic libraries: An investigation of world-class universities," *The Journal of Academic Librarianship*, vol. 47, no. 5, p. 102397, 2021.

[59] Z. M. Khalid and S. R. Zeebaree, "Big data analysis for data visualization: A review," *International Journal of Science and Business*, vol. 5, no. 2, pp. 64–75, 2021.

[60] K. Eberhard, "The effects of visualization on judgment and decision-making: a systematic literature review," *Management Review Quarterly*, vol. 73, no. 1, pp. 167–214, 2023.

[61] D. Ifenthaler and J. Y.-K. Yau, "Utilising learning analytics to support study success in higher education: a systematic review," *Educational Technology Research and Development*, vol. 68, no. 4, pp. 1961–1990, 2020.

[62] M. A. A. Dewan, W. M. Pachon, and F. Lin, "A review on visualization of educational data in online learning," in *Learning Technologies and Systems: 19th International Conference on Web-Based Learning, ICWL 2020, and 5th International Symposium on Emerging Technologies for Education, SETE 2020, Ningbo, China, October 22–24, 2020, Proceedings 5*. Springer, 2021, pp. 15–24.

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