WEB-BASED DATA VISUALIZATION AS A STRATEGIC APPROACH FOR TRANSFORMING INFORMATION SYSTEMS AND LEARNING MEDIA: A LITERATURE REVIEW

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ABSTRACT

In the era of digital transformation, educational institutions generate large volumes of data that require strong data literacy competencies among educational practitioners. However, many schools continue to rely on manual data management practices, which are prone to input errors and limit the effective communication of information. This study aims to examine web-based data visualization strategies in the transformation of information systems and learning media through a comprehensive literature review of 20 relevant sources. The analysis indicates that the use of visualization tools such as Microsoft Excel and Google Data Studio significantly enhances students' digital literacy and supports more effective managerial decision-making. Furthermore, the implementation of web-based information systems including QR code–based attendance, online report systems, and e-library platforms has been shown to improve operational efficiency and academic transparency. In addition, the development of interactive, website-based learning media increases student engagement, as reflected by a high effectiveness score (N-Gain = 0.73). This study concludes that data visualization integration extends beyond a technical requirement and represents a critical component in establishing a transparent, data-driven educational ecosystem in the digital era.

Keywords : *Data Visualization; School Information Systems; Web-Based Learning Media; Data Literacy; Information Technology Education.*

INTRODUCTION

In the context of rapid digital transformation, educational institutions have increasingly become major producers of large-scale data (big data). These data are generated from multiple sources, including learning management systems (LMS), students' academic records, competency assessment results, and digital interactions within educational ecosystems. This phenomenon requires educational practitioners particularly students enrolled in Information Technology Education programs to possess strong data literacy competencies. For prospective educators, data processing skills are no longer considered supplementary technical abilities but rather fundamental capacities that support institutional transparency, accountability, and operational efficiency (Nadia, 2022). Nevertheless, empirical conditions indicate that many secondary schools continue to encounter substantial challenges in managing data through manual systems. Reliance on conventional practices exposes institutions to a high risk of input errors, delays in information access, and ineffective data presentation for stakeholders (Ikhwan et al., 2025).

A critical issue in contemporary educational management is that data are often stored locally on teachers' or administrative staff's computers, limiting their accessibility and reducing their potential to deliver meaningful insights to academic communities and the wider public. Such data are typically presented in raw formats with static displays, making them difficult to interpret quickly and accurately (Syam et al., 2017). Within this context, data visualization emerges as a strategic solution. Data visualization is an applied discipline that integrates statistics, computer science, graphic design, and business context to analyze quantitative data both structured and unstructured in order to transform hidden patterns into intuitive and interpretable information (Siregar et al., 2024).

The implementation of web-based visualization tools, such as Google Data Studio and Microsoft Excel, has been shown to effectively transform complex assessment and administrative data into interactive dashboards that are clearer and more dynamic (Sutisna & Wahyuni, 2024). Moreover, the integration of visualization techniques into website-based learning media including Google Sites, e-library platforms, and e-posters significantly enhances student engagement and conceptual understanding through visually appealing representations (Kamilah et al., 2023; RH & Winarsih, 2023). Nadawina, Giatman, and Ernawati (2022) further emphasize that the application of information technology in twenty-first-century learning enables the integration of digital media and innovative instructional strategies that are highly relevant to web-based data visualization contexts.

The growing importance of visual literacy among students has also become a major concern, particularly in response to the increasing demand for professionals with data analysis skills in the future workforce. Empirical evidence demonstrates that basic data visualization training using widely accessible software such as Microsoft Excel is effective in improving students' digital literacy, as indicated by significant gains in post-training evaluation results (Aritonang et al., 2024). Through this literature review, the present study aims to critically examine how the integration of data visualization within information systems and learning media can foster an educational ecosystem that not only functions effectively from a technical perspective but also delivers substantial value to society in the digital era.

METHOD

This study employed a comprehensive literature review approach to examine the role of data visualization within the ecosystem of information technology education. The process began with the identification and collection of secondary data from 20 relevant scholarly sources, including peer-reviewed journal articles, community service reports, and academic manuscript drafts that discuss the implementation of visualization tools and web-based information systems (Sugiyono, 2017). The literature analysis was structured around three primary dimensions: (1) the effectiveness of data visualization software, such as Microsoft Excel and Google Data Studio; (2) the development of interactive learning media, including Google Sites and e-poster based applications; and (3) the design and implementation of web-based school information systems, such as Web GIS, e-library platforms, and academic information systems. This analytical framework enabled the synthesis of evidence regarding the impact of technological integration on digital literacy enhancement and operational efficiency across various levels of secondary education (Nadia, 2025; Syam et al., 2017).

To further explore technical and practical dimensions, the review also incorporated principles derived from Research and Development (R&D) studies reported in empirical case analyses. The effectiveness of visualization-based interventions was evaluated through the examination of pre-test and post-test results, as well as user response questionnaires, to assess levels of understanding and the achievement of data visualization competencies (Aritonang et al., 2024; Siregar et al., 2024). Data analysis techniques primarily involved descriptive quantitative methods and the Normalized Gain (N-Gain) index to determine the effectiveness of the developed learning media (RH & Winarsih, 2023). Through this methodological approach, the study was able to map technical challenges associated with the digitalization of school administration such as the implementation of QR code based attendance systems and online report platforms while also formulating strategic recommendations for Information Technology Education curricula in response to the demands of data-driven education (Ikhwan et al., 2025; Kamilah et al., 2023).

HASIL PENELITIAN DAN PEMBAHASAN

Results

A summary of the evaluation of the twenty selected reference articles is presented in Table 1 to provide a comprehensive overview of prevailing trends, methodological approaches, and the contributions of previous studies to the transformation of learning practices in the digital era.

Table 1. Evaluation of Reference Articles (Literature)

No.	Author (Year)	Article Title	Research Method	Key Findings	Conclusion
1	Arfan (2025)	Design and Development of a Web-Based E-Library Application at SMA Kartika Wirabuana XX-1 Makassar	R&D (Waterfall)	The e-library system successfully visualizes book availability in real time.	Library digitalization accelerates students' access to literacy resources.

No.	Author (Year)	Article Title	Research Method	Key Findings	Conclusion
2	Aritonang et al. (2024)	Effectiveness of a Basic Data Visualization Workshop Using Microsoft Excel to Improve Digital Literacy	Quantitative Descriptive	Correct response scores increased from 54% to 79% after the training.	Data visualization using Excel effectively enhances students' digital literacy competencies.
3	Ikhwan et al. (2025)	Design of a Web-Based Academic Information System to Improve Data Management Efficiency	R&D (Prototyping)	Automated grade data processing produces accurate and timely visual reports (graphs).	Web-based systems reduce the risk of human error in academic data processing.
4	Ipnuwati et al. (2024)	Implementation of a Web-Based QR Code Attendance System at SMA Xaverius Pringsewu	R&D	Attendance data visualization is presented instantly and can be accessed at any time.	QR code technology improves administrative efficiency and student discipline.
5	Kamilah et al. (2023)	Development of Interactive Website-Based Learning Media Using Google Sites	R&D (ADDIE)	The learning media was rated highly feasible (93.3%) for visualizing ecosystem materials.	Google Sites facilitates the visual presentation of previously abstract learning content.
6	Nadawina et al. (2022)	Literature Review: Technology-Based Learning in the 21st Century in the Planning Drawing Course of Civil Engineering Education	Literature Review	Digital-based learning technologies enhance instructional effectiveness and students' visual comprehension in technical courses.	Technology integration supports a more innovative and adaptive transformation of 21st-century learning.
7	RH & Winarsih (2023)	Analysis of Students' Conceptual Understanding Through the Development of Website-Based E-Poster Learning Media	Descriptive (N-Gain)	An N-Gain score of 0.73 indicates high effectiveness in improving conceptual understanding.	Visual e-poster development encourages creative and analytical thinking among students.

No.	Author (Year)	Article Title	Research Method	Key Findings	Conclusion
8	Siregar et al. (2024)	Data Visualization Training Using Microsoft Excel at SMA Erenos Tangerang	Training (Pre–Post Test)	Participants' knowledge of data visualization (charts and pivots) increased by 19%.	Excel skills are essential for students' career readiness in the digital workforce.
9	Sutisna & Wahyuni (2024)	Visualization of Student Competency Test Results Using Google Data Studio	R&D	Interactive dashboards facilitate professional interpretation of student competency data.	Google Data Studio strengthens objectivity in educational decision-making.
10	Supriyono et al. (2024)	Web-Based Learning Media Development Training for Muhammadiyah Teachers	Training	Teachers successfully developed independent learning websites with multimedia visual elements.	Web design (CMS) mastery improves the quality of instructional media in schools.
11	Panjaitan et al. (2022)	Development of Website-Based Learning Media to Enhance Learning Motivation	R&D	Website-based mathematics learning media proved valid and increased student motivation.	Web media accessibility supports flexible and self-directed learning.
12	Widiastuti et al. (2023)	Development of Visualization-Based Local History Learning Media	R&D	Visualization of local history helps students understand chronological events more concretely.	Visualization strengthens students' memory retention of narrative learning materials.
13	Gumelar (2022)	Design and Development of a Web-Based Tracer Study Application at SMAN 1 Kutorejo	R&D	Web-based visualization of alumni distribution facilitates institutional evaluation.	Visual alumni information systems support continuous quality improvement in education.
14	Sudiatmika et al. (2020)	Implementation of a Web-Based Online	Mentoring	Parents can monitor graphical	Transparency of academic data

No.	Author (Year)	Article Title	Research Method	Key Findings	Conclusion
		Report System as a Medium for Academic Transparency		representations of students' academic progress online.	through web visualization builds parental trust.
15	Putra et al. (2020)	The Students' Learning-from-Home Experience During COVID-19 School Closures	Qualitative	Online learning requires more varied visual media to prevent student disengagement.	The effectiveness of online learning largely depends on the quality of visual data presentation.
16	Umairah (2020)	Improving Learning Motivation Using Google Classroom During the Pandemic	Action Research	Visual features in LMS platforms increase students' active participation.	Digital platforms with well-designed visual interfaces stimulate learning motivation.
17	Saputra & Effendi (2021)	Development of Learning Media Using Google Sites	R&D	Google Sites is effective as a visualization platform for electric motor techniques in vocational schools.	Easy visual access through web platforms enhances students' practical performance.
18	Sulasmianti (2021)	Web-Based Learning Utilizing Google Sites	Descriptive	Website utilization helps teachers organize learning data visually.	Google Sites provides a practical solution for classroom administration digitalization.
19	Purnadi (2021)	Utilization of Google Spreadsheet and Google Data Studio as a Dashboard	R&D	Dashboards successfully visualize temperature data dynamically and in real time.	The integration of Spreadsheet and Data Studio offers robust data visualization tools.
20	Altanny (2021)	Design of Visualization Dashboards and Web Applications for Data Input	R&D	Dashboards enable managers to monitor key performance indicators more efficiently.	Dashboard visualization shortens the analysis time for complex data.

Discussion

A. Enhancing Data Literacy through Visualization Tools (Excel and Google Data Studio)

Strengthening data literacy at the secondary education level has become an urgent priority amid the rapid expansion of digital information. The use of widely available software such as Microsoft Excel extends beyond basic office application training and represents a fundamental step in developing students' analytical capabilities. Empirical findings reported by Aritonang et al. (2024) indicate that basic data visualization workshops using Excel significantly increased students' comprehension levels, with correct response rates improving from 54% to 79%. These results demonstrate that, with appropriate guidance, students are able to transform abstract raw data into meaningful graphical representations. Such competencies are critical, as data visualization functions as a cognitive bridge that enables individuals to process complex information more efficiently and accurately than static numerical tables (Siregar et al., 2024).

Alongside the growing demand for online data transparency, cloud-based platforms such as Google Data Studio (GDS) have emerged as a new standard in school information management. GDS offers substantial advantages in terms of interactivity and automatic data synchronization through Google Spreadsheet integration. In practice, studies by Sutisna and Wahyuni (2024) as well as Syam et al. (2017) demonstrate that vocational school staff and teachers can effectively utilize GDS to visualize competency assessment results and institutional profiles through professional dashboards. This implementation not only facilitates internal monitoring of educational performance but also broadens access to school information for parents and the wider community through direct integration with school websites.

Furthermore, the synergy between data input tools such as Google Spreadsheet and visualization platforms like Google Data Studio enables the development of dynamic and real-time monitoring systems. Purnadi (2021) illustrates that this technological integration can be applied to monitoring physical environmental conditions, including laboratory temperature and humidity, which are presented through visual dashboards. Such dashboards are highly relevant to contemporary managerial needs, where decision-making processes increasingly rely on up-to-date data (data-driven decision making). For students of Information Technology Education, mastery of these tools constitutes a key competency within data storytelling strategies namely, the ability not only to process data technically but also to communicate the underlying meaning of data in an accurate, ethical, and accessible manner to non-expert audiences (Nadia, 2022; Altanny, 2021).

B. Digitalization of School Administration and Web-Based Information Systems

The transformation of school administration from manual procedures to web-based digital ecosystems represents a critical step toward improving the operational efficiency of educational institutions. A persistent challenge faced by secondary schools is their reliance on conventional data recording practices, which carry a high risk of input errors and delay information access for stakeholders. The implementation of Academic Information Systems (SIAKAD) developed using prototyping approaches has been shown to automate the processing of grades and attendance data with a high level of accuracy (Ikhwan et al., 2025). Through the integration of data visualization features, academic information is no longer confined to numerical records in administrative ledgers but becomes a digital asset that can be systematically managed and analyzed to monitor students' academic trajectories over time.

One innovation that has demonstrated a direct impact on student discipline and institutional transparency is the adoption of QR code based attendance systems. This technology enables student attendance data to be stored in real time on centralized servers and visualized instantly

through daily or monthly reports. According to Ipnuwati et al. (2024), web-based attendance applications provide rapid system responses and allow teachers to access attendance summaries anytime and anywhere. Beyond attendance management, digitalization extends to supporting services such as e-library platforms, where online visualization of book availability facilitates students' literacy activities without the need to manually inspect physical collections (Arfan, 2025). The integration of these services contributes to the development of a cohesive, transparent, and interconnected school information system.

Data visualization within information systems also plays a vital role as a communication medium between schools and parents. The use of web-based online report systems enables parents to periodically monitor graphical representations of their children's academic progress without waiting until the end of the semester. Training programs on the development of online report systems demonstrate that visual dashboards significantly assist parents in interpreting academic achievement in a more intuitive manner (Sudiatmika & Aryawan, 2019). Additionally, the application of Web GIS technology for mapping the distribution of educational facilities introduces a spatial dimension to data visualization, facilitating institutional monitoring of equity and quality distribution across regions (Priyono & Rudiyanto, 2017). For students of Information Technology Education, the ability to design information systems that are both functional and informative constitutes a foundational competency in realizing data-driven school management.

C. Development of Web-Based Interactive Learning Media

The development of website-based learning media represents an innovative strategy within Information Technology Education to address the limitations of conventional learning resources. Web-based media offer a significant advantage in their ability to integrate multiple multimedia elements such as text, images, videos, and interactive graphics that cannot be optimally delivered through printed materials. A study by Kamilah et al. (2023) demonstrated that the use of Google Sites as a learning platform for ecosystem-related content achieved a very high feasibility level, reaching 93.3% based on evaluations from subject-matter and instructional design experts. These findings indicate that well-structured web interfaces with effective visual representations can transform abstract learning concepts into more concrete and comprehensible forms for students.

Beyond serving as a medium for content delivery, websites also function as platforms for fostering students' creativity and deeper conceptual understanding through visual content production. One effective implementation is the development of website-based e-poster learning media. According to RH and Winarsih (2023), student engagement in creating visual learning content significantly enhances conceptual comprehension, as reflected by an N-Gain score of 0.73, which falls into the high effectiveness category. The process of translating information into digital poster formats requires students to synthesize data and apply critical thinking skills, thereby strengthening cognitive processing and promoting longer-term retention compared to rote memorization of textual information.

The utilization of websites as learning media has also been shown to increase students' learning motivation and autonomy, particularly within flexible learning environments. Panjaitan et al. (2022) reported that web-based mathematics learning media provide a more engaging and accessible learning experience that can be accessed anytime and anywhere. Furthermore, visualization plays a crucial role in narrative-based subjects such as local history, where visual representations help students reconstruct past events in a more tangible and meaningful manner (Widiastuti et al., 2023). Consequently, professional development programs

that train teachers in the use of Content Management Systems (CMS), such as WordPress or other practical web platforms, are essential to enable educators to independently develop instructional media enriched with data visualization and multimedia elements aligned with contemporary curriculum demands (Supriyono et al., 2024).

D. Theoretical Foundations, Methodology, and Ethics of Visualization

Within the field of Information Technology Education, a profound understanding of visual design theory represents a key distinction between merely producing graphical outputs and constructing effective data communication. Classical principles proposed by Tufte (2001), particularly the concept of the data ink ratio, emphasize that high-quality visualizations should maximize informational content while minimizing unnecessary visual clutter. This perspective is reinforced by Few (2012), who argues that the design of tables and charts must prioritize cognitive clarity over aesthetic appeal alone. For prospective IT educators, these theoretical foundations are essential to avoid the excessive use of decorative elements that may obscure the academic facts intended to be communicated to students and parents alike.

A rigorous research methodology also constitutes a central pillar in the development of educational technologies. The majority of the reviewed studies adopted a Research and Development (R&D) approach aligned with the standards outlined by Sugiyono (2017), ensuring that the resulting products are academically validated. Through a systematic visualization analysis framework (Munzner, 2014), each data attribute is mapped to a visual form that best corresponds to the users' cognitive tasks. This methodological approach guarantees that learning media and information systems are not only technically functional but also empirically evaluated for effectiveness using instruments such as the Normalized Gain (N-Gain) test to measure improvements in users' conceptual understanding (RH & Winarsih, 2023).

Equally critical is the ethical dimension of data presentation. In an era where visual manipulation can be easily performed, students of Information Technology Education must develop an awareness of the potential for data distortion that may mislead audiences. A literature review by Nadia (2022) highlights that visually appealing yet statistically inaccurate representations can generate misinformation within school environments. Therefore, data integrity must be preserved through the application of ethical visualization practices, ensuring that axes, scales, and graphical proportions accurately reflect empirical reality. This ethical stance aligns with the overarching objective of information technology education: to cultivate a society with high levels of digital literacy and the capacity to engage in responsible, data-driven decision-making.

CONCLUSIONS

The integration of web-based data visualization constitutes a strategic solution for transforming educational data management from conventional practices into a more adaptive digital ecosystem. Through widely accessible tools such as Microsoft Excel and Google Data Studio, complex raw data can be converted into intuitive visual information, thereby enhancing students' data literacy while simultaneously supporting data-driven decision-making among school administrators. The digitalization of school information systems including QR code based attendance and online report cards has been empirically shown to significantly improve transparency and operational efficiency.

Furthermore, the utilization of websites as learning media enables the visualization of abstract instructional content into more concrete representations, which positively impacts students' learning motivation and conceptual understanding. Overall, mastery of data visualization strategies and web-based system development emerges as a fundamental competency for students of Information Technology Education in realizing more accountable, effective, and sustainable educational governance within the era of data-driven education.

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