



A SYSTEMATIC REVIEW OF DATA VISUALIZATION TECHNIQUES AND STORYTELLING WITH DATA

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ABSTRACT

In today's data-driven environment, organizations produce vast amounts of data every day. However, without effective analysis and clear communication, this information does not translate into meaningful insights. Data visualization and data storytelling play a crucial role in converting complex datasets into clear, actionable knowledge. This paper examines the core principles, methods, tools, and practical applications of data visualization and storytelling. It highlights how combining strong analytical insights with well-structured narratives enhances decision-making across sectors such as business, healthcare, education, and public policy.

1. Introduction

The rise of digital innovations has led to an extraordinary increase in data generation across various industries. Although analytical techniques can extract valuable insights from this data, effectively communicating these findings remains a challenge. Conventional reports dominated by tables and figures often fall short in guiding decisions. Data visualization, which presents information in graphical or visual formats, enables clearer understanding and promotes more informed decision-making[1].

Visual analytics transforms numerical data into graphical forms—like charts, plots, and dashboards—making it easier to identify patterns and relationships. Tools such as Excel, Power BI, and Tableau are commonly used to create interactive dashboards and analytical visualizations. Data storytelling takes this a step further by embedding these visuals within a structured narrative, guiding audiences toward meaningful insights and actionable decisions. Some methods for interactive visualization are implemented through web-based visual analytics platforms that utilize WebGL, enabling data processing and rendering directly on the GPU for enhanced performance[2].

This study examines the connection between data visualization and storytelling, showing how their combined use improves the clarity, effectiveness, and overall impact of communication.

2. Objectives

2.1 Concepts of Data Visualization

Data visualization involves presenting information in graphical formats to enhance comprehension. Representing data visually is a crucial aspect of data science and analytics, as it converts raw data into structured, meaningful forms that support insight generation and informed decision-making[3].

Data visualization simplifies complex datasets, reveals hidden patterns and relationships, supports data-driven decision-making, increases audience engagement, and enables faster comprehension of information. Effective data visualization emphasizes clarity, accuracy, simplicity, consistency, and a design focused on the audience. Table I presents various types of charts and plots commonly used for this purpose.

Table 1. various types of charts and plots

Types of Data Visualizations	
Type	Purpose
Bar Charts	Compare categories
Line Charts	Show trends over time
Pie Charts	Display proportions
Scatter Plots	Show relationships between variables
Heat Maps	Display intensity or density
Dashboards	Provide interactive overview

Improper or poorly designed graphs can lead to misinterpretation of data.

2.2 Concepts of Data storytelling

Data storytelling combines factual data and analysis, visual elements such as charts and graphics, and a narrative that provides context and explanation. It acts as a bridge between analytical findings and managerial decision-making.

There are four key components of data storytelling: Context, which explains why the data is important; Insight, which uncovers what the data reveals; Narrative Flow, which guides how the story unfolds; and Call to Action, which indicates what decisions should be taken based on the data.

2.3 Narrative Structures in Data Storytelling

Common narrative frameworks in data storytelling include the problem–solution approach, before-and-after comparisons, trend analysis over time, and cause-and-effect analysis, all of which help communicate insights and relationships in a clear and structured manner.

3. Methods

This study employs a systematic literature review methodology. Relevant articles were gathered from multiple sources using keywords such as “data storytelling,” “interactive dashboards,” “visual analytics,” along with other related terms from the keyword list. Recent publications were reviewed and synthesized, with a focus on analyzing a case study in the field of education.

A variety of tools are commonly employed for data visualization and storytelling. Widely used visualization software includes Tableau, Microsoft Power BI, Google Data Studio, and Microsoft Excel. Additionally, programming environments such as Python—with libraries like Matplotlib, Seaborn, and Plotly and R using ggplot2 are extensively used to create detailed analytical visualizations.

For narrative-focused communication, tools such as interactive dashboards, infographic design platforms, data-driven presentation systems, and web-based visual reporting frameworks are commonly used to convey insights effectively.

Tableau is a robust data visualization platform that allows users to build interactive dashboards, supports a wide range of visual formats, and enhances storytelling by clearly communicating insights and trends. Microsoft Power BI integrates smoothly with Microsoft applications such as Excel, enables real-time data monitoring, and provides customizable visualizations to improve the analysis and interpretation of complex datasets[3].

Other tools that facilitate effective data visualization include Gantt charts, GIMP, Privacy Rating, and WAVE, which help present information clearly while also assessing design quality, privacy considerations, and accessibility features[4].

4. A Case Study on Education Analytics with Student Performance Dataset (200 students)

The dataset for this analysis was sourced from the UCI Machine Learning Repository – Student Performance Dataset. The main aim of this study is to investigate the factors that affect students’ academic achievement and overall performance.

The dataset contains important variables including study time, attendance, family background, internet access, and final grades. These attributes provide insights into both the academic and socio-economic factors that impact student performance.

This dataset can be directly imported into tools like Microsoft Excel, Power BI, and Tableau for further analysis and visualization.

To analyze the data effectively, various visualization techniques were employed, including correlation heat maps, box plots, scatter plots, and distribution histograms. These graphical methods allowed for clear identification of relationships, trends, and variations in student performance.

4.1 Excel Implementation

A. To create a Scatter Plot showing Study Time versus Final Grade in Microsoft Excel, first open the dataset in Excel. Next, select the columns labeled `Study_Time_Hours_per_Week` and `Final_Grade`. Then, navigate to the Insert tab on the ribbon and choose the Scatter Plot chart option. Once the chart is generated, right-click on any data point and select Add Trendline to display the relationship between study time and final grades more clearly.

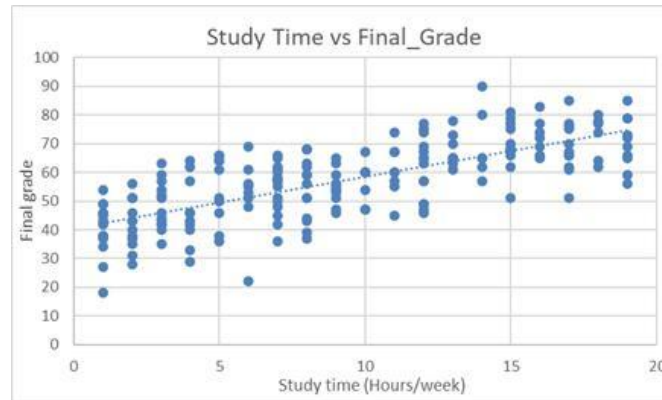


Figure 1. Scatter plot

Story Insight:

Students who spend more than 12 hours per week studying tend to consistently attain above-average grades.

B. To create a Scatter Plot showing Attendance vs Final Grade in Microsoft Excel, go to the Insert tab, select Scatter from the Charts section to create the plot, and then choose Add Trendline to display the overall pattern and relationship between the variables.

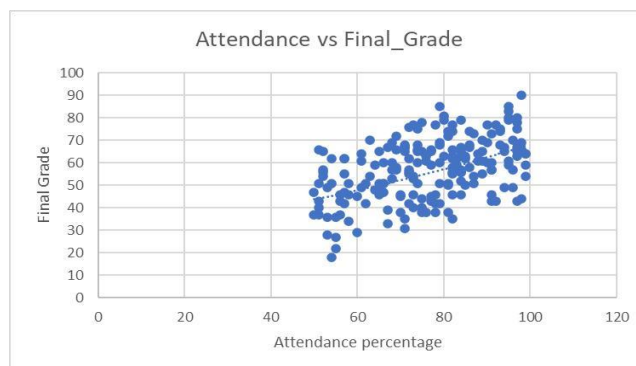


Figure 2. Scatter plot

Story Insight:

An attendance rate above 80% significantly contributes to more consistent and reliable academic performance.

C. To create a bar chart showing the relationship between Internet access and average grade in Microsoft Excel, first generate a Pivot Table to summarize the average scores based on Internet availability, and then insert a Bar Chart to visually compare the performance differences between the groups.

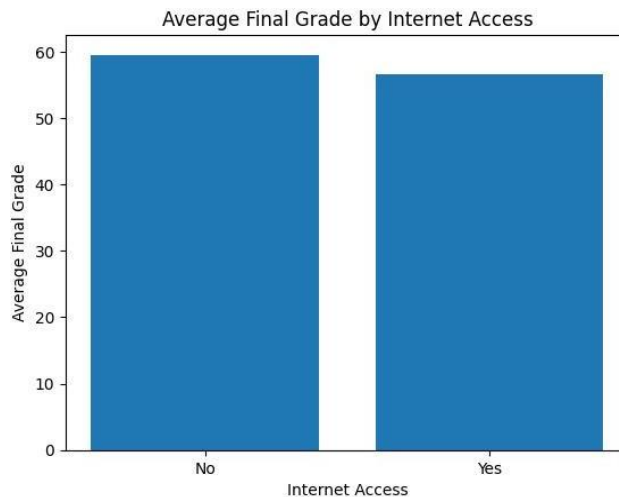


Figure 3. Bar chart

Story Insight:

Students without internet access generally exhibit slightly lower average academic performance, underscoring the impact of the digital divide on learning outcomes.

The storytelling framework starts by addressing the central question: why do some students perform below expectations? Through detailed analysis, patterns emerged across socio-economic factors and academic behaviors. The results indicate that students who invest more time in studying generally achieve higher grades. Attendance exhibits a strong positive correlation with final exam scores, while internet access shows a moderate impact on overall academic performance.

From an educational standpoint, this visual data narrative helps institutions identify students who may be at academic risk. It also aids schools in designing targeted intervention strategies and optimizing the allocation of resources to enhance overall student performance.

4.2 Power BI Dashboard Design

To create a dashboard in Power BI Desktop, start by launching the application and clicking on Get Data, then select Excel to import your dataset. Once the data is loaded, define relationships between tables as needed to ensure accurate data modeling. After that, build and organize visual components like charts, slicers, and cards to design an interactive and dynamic dashboard for effective analysis.

4.3 Tableau Implementation

To implement the visualization in Tableau, start by opening the Tableau application and selecting Connect, then choose Microsoft Excel and select the required dataset file. After loading the data, drag the relevant fields into the Sheets area to create visualizations and we can start building analysis.

5. Storytelling Platforms Implementation

Data storytelling (DS) is increasingly acknowledged as a technique that integrates data, visual components, and narrative strategies to create engaging stories, helping target audiences grasp key

insights and messages more clearly and efficiently[5]. For instance, as shown in Figure 1[5], this approach is illustrated by emphasizing the strawberry revenue data series with a bold, colored line, including annotations on important data points (A), and maintaining consistent use of the same color across text, lines, and other visual elements to reference these points (B).

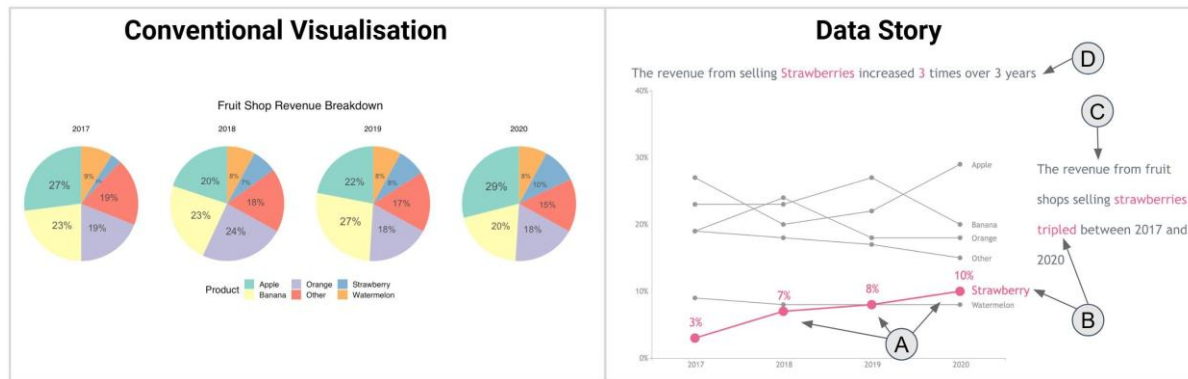


Figure 4. An example illustrating how a traditional data visualization (left) can be transformed into a data story (right). The updated version integrates essential data storytelling features: (A) annotated data points, (B) consistent color coding in both text and lines, (C) informative textual annotations, and (D) a clear, descriptive title that conveys the main insights.

5.1 Interactive Dashboard

An interactive dashboard is a dynamic visual interface that allows users to explore, manipulate, and analyze data in real time. As a business intelligence (BI) tool, it displays key performance indicators (KPIs) and critical metrics while enabling active interaction with data visualizations. Unlike static reports, which offer a fixed view, interactive dashboards let users filter, organize, and drill down into information on the fly, empowering them to uncover insights and answer specific questions independently[6].

Platform:

A. Microsoft Excel

An interactive dashboard in Microsoft Excel can be created by following these steps: first, structure the dataset in a clean table with appropriate headers; next, insert PivotTables via Insert → PivotTable to summarize key variables; then, create Pivot Charts from these PivotTables to visualize patterns and comparisons; after that, add slicers using Insert → Slicer to enable interactive filtering; and finally, organize all charts and slicers on a separate worksheet to build a clear, dynamic, and user-friendly dashboard. PivotTables are powerful analytical tools that help condense large datasets, categorize information meaningfully, and calculate essential metrics such as totals, averages, and counts[7].

B. Power BI / Tableau

On platforms like Power BI and Tableau, interactive dashboards provide a range of advanced features designed to enhance data exploration and analysis.

Cross-filtering enables users to select a data element in one chart, which then automatically updates and highlights the related data across other visuals within the dashboard.

Drill-down filters let users navigate from aggregated, high-level data to more detailed levels. For example, moving from yearly performance to quarterly and then to monthly breakdowns.

Hover tooltips provide additional information when the cursor hovers over a data point, offering extra context and relevant metrics.

Dynamic slicers act as real-time filtering controls that immediately update all connected visualizations.

KPI cards present key performance indicators in a clear, concise format, highlighting important metrics such as averages, totals, or growth rates at a glance.

In the context of the case study, these features enable school administrators to sort and filter data by student categories, allowing them to quickly identify groups that may be academically at risk.

5.2 Infographic Design

The infographic, created using platforms like Canva or Piktochart, is titled “What Drives Student Success?” and emphasizes three key findings: students studying over 12 hours per week show roughly a 15% grade improvement, maintaining at least 80% attendance is essential for strong performance, and internet access affects academic consistency. The design features icons representing study materials, attendance, and internet connectivity, along with simple bar comparisons and prominently displayed percentage indicators, presenting insights in a clear, concise, and visually engaging way. Fig. 5 shows an example for infographic design.

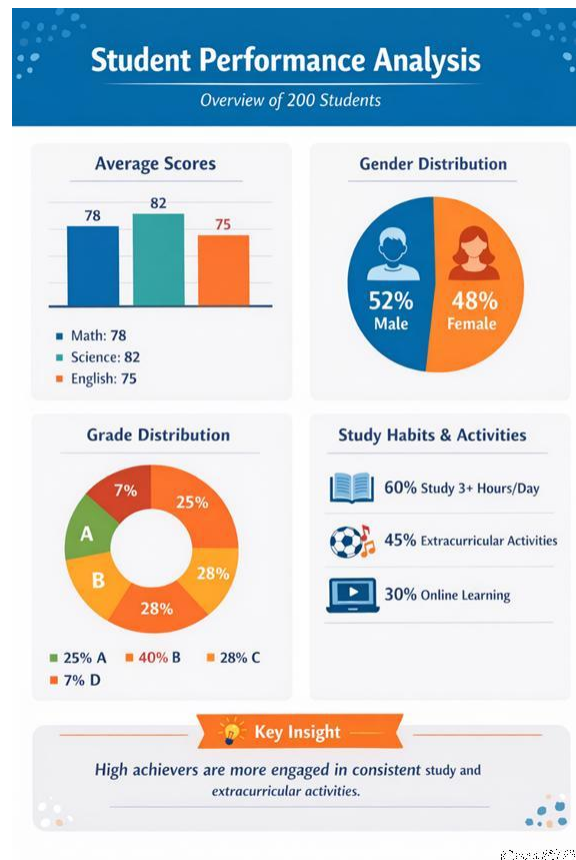


Figure 5. Infographic design

5.3 Data-Driven Presentation

A data-driven presentation in Microsoft PowerPoint should follow a clear and logical slide sequence: start with the problem statement, then provide an overview of the dataset. For the case study, include an

analysis of study time supported by relevant charts, an examination of attendance impact, and an exploration of the digital divide concerning internet access. Conclude the presentation with strategic recommendations for improvement.

An effective data-driven presentation begins by defining a clear objective, understanding the target audience, focusing on the most significant insights, and applying storytelling techniques to provide context and direction. When using data visuals, it is essential to keep them simple, choose relevant chart types, avoid overloading the audience with too much information, and present the data within a coherent narrative that guides viewers through the key findings.

An Information and Communication Technology (ICT)-enabled presentation relies on infrastructure such as computers, internet connectivity, telecommunications networks, and digital devices like smartphones and tablets, along with software applications for processing, managing, and presenting information[8].

5.4 Web-Based Visual Report

A web-based visual report is an interactive online document that presents data insights through charts, graphs, dashboards, maps, and other graphical elements accessible via a web browser. It combines data visualization, web technologies, and narrative techniques to communicate analytical findings clearly and engagingly.

These reports typically involve several key components. Data sources may include databases like MySQL or MongoDB, CSV or Excel files, APIs, or JSON datasets. The front-end layer is usually built with HTML5, CSS, and JavaScript, utilizing visualization libraries such as D3.js, Chart.js, or Power BI. An optional back-end layer can use technologies like Node.js, Python frameworks (Flask or Django), or PHP to handle data processing and server-side operations. Various visualization formats—including bar charts, line graphs, pie charts, heatmaps, dashboards, and infographics—can be incorporated to enhance understanding.

Web-based visual reports can also be created using platforms such as Tableau Public, Power BI Service, or Google Looker Studio. A well-structured report typically includes an executive summary, interactive charts, highlighted key insights, strategic recommendations, and an option to download the complete report.

The case study demonstrates that this integrated, multi-platform visualization approach—using Excel for initial data exploration, Power BI and Tableau for interactive dashboards, and storytelling tools such as infographics and web-based reports—significantly enhances educational decision-making. By embedding a structured narrative into visual analytics, stakeholders can move beyond raw academic performance data and translate insights into actionable, evidence-based educational interventions.

6. RESULTS

Data stories can convey insights more effectively than traditional visualizations. However, users with higher data literacy are generally able to extract insights regardless of whether the information is presented as a narrative-driven data story or a conventional visualization. While all domains—such as education, medicine, and finance—share the core components of data, narrative, and visualization, their approaches differ in terms of analytical methods, structural models, and strategies for engaging their specific audiences[9].

7. Applications

A. Business Intelligence: Organizations use dashboards to monitor sales metrics, analyze customer behavior, and assess market trends.

B. Healthcare: Data visualization supports tracking disease spread, identifying patterns in patient records, and managing healthcare resource allocation.

C. Education: Academic performance analytics enables the design of personalized and adaptive learning strategies.

D. Public Policy: Government and public institutions apply data storytelling to effectively communicate demographic statistics, economic indicators, and environmental data to stakeholders.

8. Challenges

Key challenges in data visualization and storytelling include information overload, misleading or misrepresentative visual designs, lack of storytelling expertise, cognitive biases affecting interpretation, and ethical concerns in data presentation. To address these issues, it is crucial to maintain transparency and follow responsible visualization practices to uphold credibility and retain stakeholder trust.

9. Future Trends

Emerging trends in this field include AI-powered automated storytelling, dynamic real-time interactive dashboards, immersive visual analytics using augmented and virtual reality technologies, and the increasing use of predictive and prescriptive visualization methods.

10. Conclusion

Data visualization and storytelling are powerful tools for transforming raw data into actionable insights. Visualization enhances the clarity and accessibility of information, while storytelling provides context and strategic guidance. Together, they improve communication effectiveness, facilitate informed decision-making, and foster a data-driven culture. As data volumes continue to grow rapidly, the importance of clear and impactful visual communication is expected to increase even further.

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