Bridging Open Science and Data Visualization: Evaluating the Usability of dataWASHES Dashboard

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Abstract. *[Context] Open Science has gained traction in Software Engineering in recent years, driven by the growing need to promote transparency and collaboration. The dataWASHES initiative exemplifies this perspective by providing an API for accessing WASHES proceedings. [Problem] Despite its contributions, dataWASHES lacks an interactive data visualization tool, limiting its accessibility to a broader audience. [Objective] This paper presents and evaluates a dashboard for dataWASHES to enhance data analysis and usability. [Method] We conducted a qualitative inspection based on Tufte's principles and usability testing with 28 participants using the System Usability Scale (SUS). [Results] The dashboard adhered strongly to Tufte's principles, particularly minimizing non-essential elements. The SUS yielded a score of 91.25, with 96.4% of participants reporting high satisfaction and 100% willing to recommend the tool. [Contributions] This work contributes by (1) applying Tufte's principles in Open Science dashboards, (2) emphasizing the importance of user-centered design and data visualization in the engineering of Open Science tools, and (3) improving dataWASHES with a dashboard that turns data into actionable insights.*

1. Introduction

Open science has established itself as a fundamental pillar in advancing research in Software Engineering, nurturing transparency, scientific development, data sharing, and collaboration among different stakeholders. According to Mendez et al. (2020), open science encompasses the dissemination of software source code (open source), data (open data), analysis scripts (open materials), and study manuscripts (open access). In this landscape of advancements in open science, open infrastructure also stands out for its role in operationalizing these principles, providing tools and platforms that facilitate data access and the reuse of produced knowledge [UNESCO 2021].

Aiming to strengthen open science initiatives within the Workshop on Social, Human, and Economic Aspects of Software (WASHES), dataWASHES[1] was introduced as a public, academic, and open-source Application Programming Interface (API) designed to provide the community with a convenient tool for systematically and programmatically querying the WASHES proceedings data [Araújo et al. 2024]. However, despite its initial contribution, there is a relevant opportunity for the evolution of dataWASHES: the development of a dashboard, leveraging the existing API, to enable the community to visualize and explore WASHES proceedings data in a more accessible and interactive manner.

In particular, when assessing the current landscape of open science, it becomes evident that data visualization techniques, including dashboards, have a large potential by enabling researchers, professionals, and students to interact with information in an intuitive and efficient manner [Wang et al. 2015]. Essentially, dashboards are visual tools that present data in a clear and organized manner, facilitating analysis, monitoring, and decision-making [Laubheimer 2017]. Building on this potential, the primary objective of this work is to present and evaluate a dashboard for dataWASHES, with a focus on usability and data visualization, both of which are fundamental when discussing the social and human aspects of software.

To evaluate the proposed dashboard, this work adopted a qualitative-quantitative approach. First, a qualitative and observational inspection was conducted to assess the dashboard's adherence to Tufte's principles [Tufte 2001]. Tufte's principles emphasize the primacy of simplicity and clarity in data visualization, aligning with the evaluative context designed for this study. Additionally, an empirical evaluation was made to understand user perceptions through an user testing with 28 students. Data were collected using a semi-structured questionnaire based on the Systems Usability Scale (SUS) [Brooke et al. 1996]. The choice of SUS is justified by its wide adoption and reliability in usability evaluations, offering a comprehensive perspective in complement to the previously mentioned qualitative inspection.

This work presents contributions both to academia and to practice within the context of the social and human aspects of software. Concerning the academic perspective, it provides a systematic analysis of the application of Tufte's data visualization principles in the context of a tool for open science, thus expanding the understanding of how these guidelines can be explored in the design of dashboards for Open Science. Moreover, by employing the SUS to assess the usability perception of the dashboard among students, the study emphasizes the importance of discussions on user-centered design practices in engineering solutions for Open Science. From a practical perspective, dataWASHES is enhanced by offering a visual and interactive solution that facilitates access to and analysis of strategic WASHES data. This evolution strengthens the proposed solution and could eventually serve as inspiration for similar initiatives in other scientific communities.

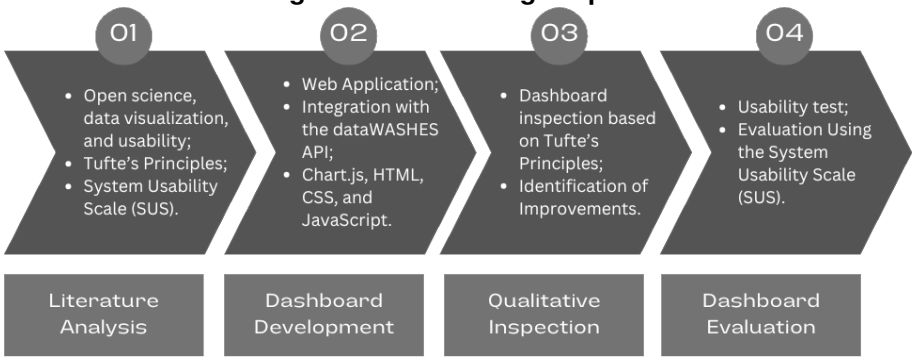
This paper is structured as follows: Section 2 presents the method, while Section 3 discusses the scope and demonstration of the dashboard. The results (Section 4) are followed by the discussion (Section 5) and final remarks (Section 6).

[1] `https://gesid.github.io/datawashes`

2. Methodological Procedures

This study is characterized as applied research, with both qualitative and quantitative nature, focused on the development and evaluation of the dataWASHES dashboard. As illustrated in Figure 1, the research process was divided into four main stages: (1) literature analysis, (2) development of the dashboard, (3) qualitative inspection based on Tufte's data visualization principles [Tufte 2001], and (4) usability testing with users based on the Systems Usability Scale (SUS) [Brooke et al. 1996].

Figure 1. Methodological plan.



The **first stage** involved a literature analysis on the concepts of open science, open infrastructure, data visualization, and usability evaluation of dashboards. This analysis aimed to identify best practices and gaps in the literature that could guide the development and evaluation of the dataWASHES dashboard. As a result of this stage, the relevance of Tufte's principles [Tufte 2001], such as graphic integrity and minimization of non-essential or decorative elements, was identified. The analysis also highlighted the role of the SUS as a widely used scale for the empirical evaluation of the usability of digital interfaces [Grier et al. 2013].

The **second stage** consisted of the development of the dashboard using HTML, CSS, and JavaScript. Using the Chart.js library, which is specific for data visualization, the dashboard aimed to integrate the functionalities of the dataWASHES API with a set of interactive visualizations, such as charts and dynamic tables. The dashboard included key features to facilitate the visualization and analysis of data from WASHES publications, such as author rankings, publication distribution by Brazilian states, award-winning WASHES papers, and more.

The **third stage** consisted of a qualitative inspection of the dashboard to assess its adherence to Tufte's data visualization principles [Tufte 2001]. To ensure the rigor of this inspection, one co-author independently conducted the qualitative analysis, and later, another co-author validated the obtained results. This evaluation was based on a detailed analysis of the following aspects: (1) the principles of graphical integrity (six in total) which directly impact the dashboard's ability to convey accurate and complex information while avoiding cognitive overload, misinterpretations, as well as promoting accessible and efficient visualization; and (2) the minimization of non-essential or decorative elements, such as gridlines and borders, to ensure that the design prioritized the clear presentation of data without unnecessary graphical elements (chartjunk). This stage was critical for identifying potential improvements to the prototype before submitting it for user testing.

Finally, the **fourth stage** involved evaluating the dashboard with a group of students from the Systems and Analysis Development course of the Federal University of Cariri. The test was conducted online on February 4, 2025, between 8:30 PM and 9:40 PM, with the participation of 28 students. Before starting the test, participants read and accepted an informed consent form. Following this step, an overview of the dataWASHES dashboard was presented, highlighting its main features. After this explanation, participants interacted freely with the dashboard, with the goal of exploring its functionalities without additional instructions, allowing for a more autonomous experience.

After the interaction time with the dashboard, which lasted at least three minutes, participants filled out a questionnaire with three main sections: 1) Characterization and Initial Perceptions, 2) SUS, and 3) Overall Satisfaction and Final Considerations. The interaction time was defined to ensure that participants had enough time to explore the dashboard's functionalities. The analysis of quantitative data was performed using descriptive statistics, including mean and median, with the results presented in stacked bar charts. Qualitative data were analyzed using open coding, organizing the responses into categories and recurring themes. It is worth noting that, prior to the user test, a pilot test was conducted with one volunteer to validate the test script and the questionnaire. Although the data from this pilot were not used in the final analysis, the adjustments made during this phase ensured greater clarity in the instructions and testing procedure with the participants. No major issues were identified. All the instruments and data used in the study are openly available in the supporting repository for this paper [Gonçalves et al. 2024].

Regarding the general characterization of the participants, information was extracted concerning age, education level, and familiarity with the use of dashboards. The participants' ages ranged from 20 to 51 years, with an average age of approximately 31 years and a median of 30. In terms of education, the majority of participants (60.7%) were pursuing their undergraduate degree. Those with a completed high school education accounted for 17.9%, while 10.7% had technical or technological training. In addition, 7.1% of participants had a completed undergraduate degree, and only 3.6% were pursuing a postgraduate degree. Regarding familiarity with dashboards, 67.9% of participants had some prior exposure to the technology. Of this total, half reported having used dashboards a few times, while 17.9% stated they used them frequently. In contrast, 32.2% had never used a dashboard, although, among these, 55.6% had heard of the topic.

3. Scope and Demonstration of the dataWASHES Dashboard

The dataWASHES dashboard[2] was developed to provide an interactive interface that facilitates access, visualization, and interpretation of data from WASHES publications. Its scope includes presenting data in a clear and accessible manner, allowing researchers, students, and professionals in the field to interact with publication data without the need for manual queries or complex data processing. Based on data visualization principles, such as those proposed by Tufte (2001), the dashboard aims to offer an intuitive and informative user experience.

The dashboard was designed to integrate directly with the dataWASHES API [Araújo et al. 2024], ensuring programmatic access to the latest WASHES data. This integration allows the dashboard to present data dynamically and in real-time, continuously

[2]`https://gesid.github.io/datawashes/dashboard`

reflecting the most recent publications and research findings in the field. The interface design was structured to provide a seamless navigation experience, featuring filters and interactive charts that enable users to explore various aspects of the publications. Notable aspects include the ranking of authors, the geographical distribution of publications across Brazilian states, and the award-winning papers from past WASHES editions. The goal is to make the interface intuitive enough that even users with no prior experience in data visualization can navigate and utilize its features easily and effectively.

As illustrated in Figure 2, the dashboard encompasses features for interactive and visual analysis. In contrast to the API's output, e.g., json files or spreedsheets, the dashboard focuses on data visualization, enabling users to view and compare retrieved data in a clear and objective manner. Through dynamic charts and tables, users can access information on the number of publications, author count, relevant research topics, and trends over the years. Finally, interactive analysis is a key feature of the dashboard, enabling users to hover over charts and tables to access more detailed information. It is important to emphasize that the dashboard does not replace the API, nor does the API render the dashboard unnecessary. Each solution has its own purpose and specific use case, depending on the user's needs.

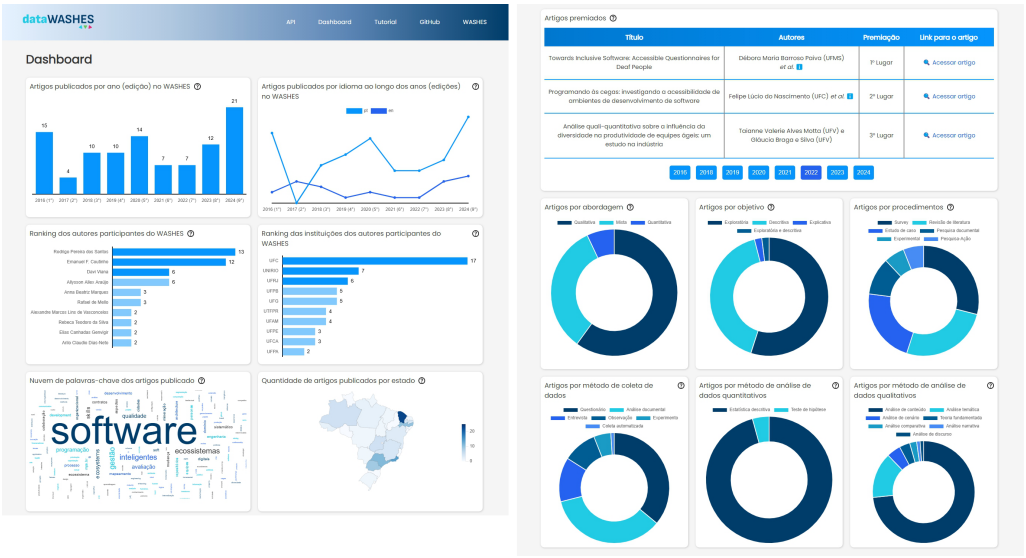


Figure 2. Overview of the dataWASHES *dashboard*.

4. Results and Analysis

To evaluate the proposed dashboard, two complementary approaches were employed: (1) a qualitative inspection to assess the dashboard's adherence to Tufte's principles, and (2) an evaluation based on the System Usability Scale (SUS), conducted through user testing.

4.1. Qualitative Inspection following Tufte's Principles

The qualitative and observational inspection of the dashboard was carried out with the objective of assessing its adherence to six graphical integrity principles and minimization of non-essential or decorative elements proposed by Tufte (2001). Each principle was evaluated through an individual analysis of each graph, using a checklist to measure adherence. For each case, a justification was provided indicating whether the graph aligned

with the corresponding principle. These principles emphasize the importance of clarity, simplicity, and efficiency in the presentation of data, with the aim of minimizing the use of unnecessary graphical elements.

Regarding the achievement of graphical integrity, Tufte outlines six principles aimed at ensuring an accurate graphical representation of the data [Tufte 2001]. The first principle requires faithfully and proportionally representing data without distortion or ambiguity. Our analysis revealed that Chart.js maintains accurate proportions in numerical values, ensuring that visual differences in charts correspond to actual data variations. Furthermore, the use of labels and explanatory text allows for clear identification of information, contributing to the accuracy and comprehension of the charts, and aiming to achieve adherence to the second principle, which defends the use of these elements to defeat graphical distortion and ambiguity. The third principle advocates for prioritizing data variation over design variation. In this regard, an effort was made to minimize the use of chart variants, focusing on common designs (bars, lines, etc.) and introducing other variants only when they enhanced contextual understanding and comprehension. The fourth principle, related to time series displays, was not applicable, as these representations were not part of this study. The fifth principle states that a graph should not have more dimensions than the data it represents. This principle was followed in all representations, except for the word cloud. It could be argued that representing the frequency of words by scaling it in two dimensions may contradict this principle. Finally, with regard to the sixth principle, not quoting data out of context, all visualizations are free from any omission of data representation or temporal references that could create ambiguiety or misinterpretation, thereby adhering to this guideline.

Moreover, the concept of data-ink ratio, proposed by Tufte, represents the proportion of "ink" (or pixels) dedicated to displaying the data in relation to the total used in constructing the graph. In particular, Tufte advocates for maximizing this metric in order to minimize the use of non-data-ink, which is "ink" used to represent unnecessary elements, those that do not contribute to understanding the data and are often chartjunk. The dashboard design was observed to be aligned with the principle of maximizing the data-ink ratio. The interface was designed to display graphical representations with minimal use of visual elements, keeping the focus on essential information and removing chartjunk (decorative visual elements), such as borders, grids, and lines that provided no informational value.

In conclusion, the qualitative inspection in light of Tufte's principles revealed that the dataWASHES dashboard generally adheres to clarity and efficiency in data visualization. Due to space constraints, we could not include illustrative screenshots for each analysis. However, we have provided a supplementary file in our repository [Gonçalves et al. 2024] with these examples to enhance clarity. The evaluation indicated that the interface is well-structured, with a focus on minimizing non-essential elements and presenting information in an objective manner, as suggested by Tufte (2001).

4.2. User Testing

This section presents an analysis of the questionnaire results obtained during user testing. The findings are structured into three perspectives: perceived usefulness and relevance, system usability as measured by the System Usability Scale (SUS), and overall satisfaction, including findings from open-ended responses.

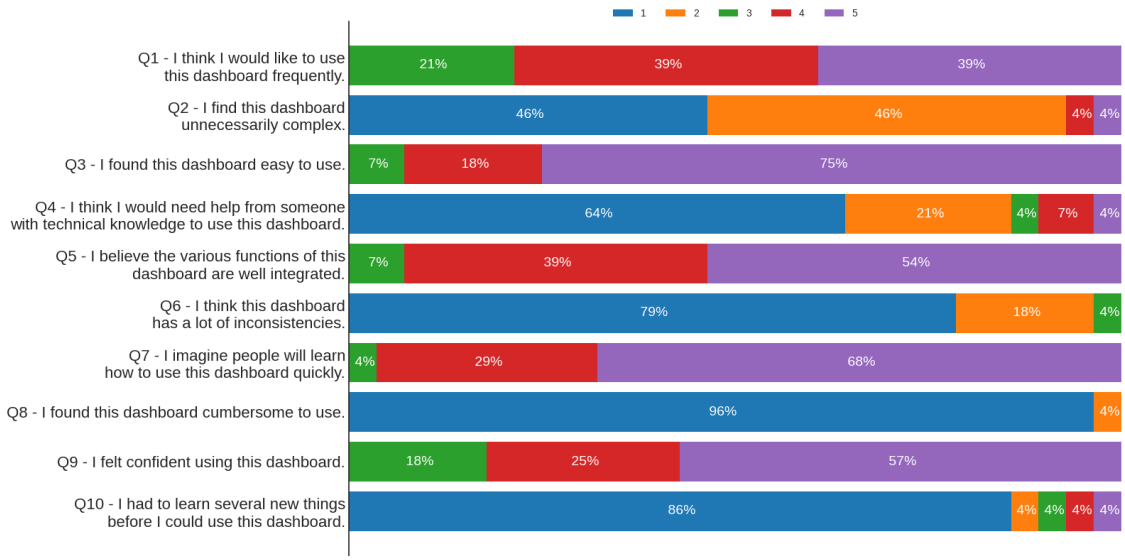
4.2.1. Analysis of Perceived Usefulness and Relevance

After filling out the profile characterization questions, the students answered two questions (on a scale from 0 to 5, where 0 means "Totally Disagree" and 5 means "Totally Agree"), one regarding the perceived usefulness of dashboards in research activities and the other regarding the relevance of the information displayed on the dashboard, both within the context of the WASHES research. When asked, "Do you believe that using dashboards would be useful for your research activities (if they involved the WASHES context)?", 26 students (92.9%) responded positively (4 and 5), meaning they agreed that dashboards are useful for research activities. Only one student strongly disagreed (1), and another gave a neutral response (3). Regarding the relevance of the information, all participants, when answering the question "Do you believe the information displayed on the dataWASHES dashboard is relevant for research involving the WASHES context?", indicated agreement (ratings of 4 or 5) with the relevance of the data presented.

4.2.2. Analysis of the System Usability Scale

After answering the questions in Section 1 (Characterization and Initial Perceptions), the participants proceeded with the 10 SUS questions, rated on a Likert scale from 1 to 5, where 1 represents "Totally Disagree" and 5 represents "Totally Agree." Figure 3 provides an overview of the results obtained, which will be discussed below.

Figure 3. Results based on SUS.



The results indicate a high level of satisfaction among the participants with the dashboard. In Q1, approximately 78% totally agreed with the statement that they would like to use it frequently, while 21% adopted a neutral stance. Q9 reinforces this positive perception, with 82% of respondents feeling confident using it, and no participants reported any disagreement. In turn, Q4 revealed that 85% of participants did not feel the need for technical support to use the dashboard, suggesting that the interface is intuitive and easy to learn.

Ease of use also stands out positively in the perception of the participants. Q2 showed that 92% of participants disagreed with the idea that the dashboard is unnecessarily complex, pointing to an intuitive design. Regarding reliability, Q6 revealed that nearly 97% of participants did not perceive the dashboard as inconsistent, reinforcing its cohesion. In terms of learning, the results from Q3, Q7, and Q10 indicate a smooth learning curve. Three out of four participants stated that the dashboard is easy to use (Q3), and approximately 97% believe that others will quickly learn to use it (Q7). Nearly 90% did not think it was necessary to learn something new to operate the dashboard (Q10), highlighting its intuitiveness. Furthermore, the efficiency of the dashboard was also well-rated. In Q5, 93% of participants agreed that its functions are well-integrated, and in Q8, 96% disagreed with the statement that their experience was hindered, thus demonstrating a smooth, obstacle-free interaction with the dashboard.

Finally, the SUS score for the dashboard reached 91.25, a value classified as "Excellent" according to the adjective scale by Bangor et al. (2009). This result confirms that the tool effectively meets the users' expectations, being highly satisfactory and usable.

4.2.3. Analysis of Overall Satisfaction and Open-Ended Answers

After completing the SUS questions, participants moved on to the third and final section of the questionnaire, which addressed overall satisfaction and final considerations. When evaluating their overall satisfaction (using a Likert scale from 1 to 5), 96.4% indicated being satisfied with the application, with 50% selecting option 5, expressing high satisfaction. Regarding the clarity and usefulness of the information presented on the dashboard, all participants rated it positively (options 4 or 5), with 60.7% expressing total satisfaction with this issue.

Regarding recommending the dashboard to other researchers or students, 100% of participants expressed agreement (4 or 5), reflecting a positive perception from the users. In this sense, when asked about what they liked most about the dashboard, participants highlighted the clarity, usability, and interactivity of the tool. P9 described the dashboard as "*An application that is very intuitive and interactive, with easy access and a clear understanding of the information*". P23 noted that the interface had "*Simplicity and a clean visual*" while P4 mentioned that the aspect they liked most was its "*Ease of use*". Some components of the dashboard were highlighted as differentiators, making navigation more efficient and adding value to the experience. P21 remarked that "*The option to go directly to the published papers is very interesting*", while P26 pointed out that "*The informative icons that explain in detail the purpose of the presented graph were also very useful, eliminating the need to search for external tutorials*".

Finally, when asked to suggest improvements, participants primarily recommended enhancing the responsiveness of components such as the word cloud, the publication map by state, and the donut charts, which displayed inconsistencies on certain screens. They also suggested improving table readability, with P27 mentioning that they "*Experienced some difficulty reading the titles due to their central alignment*," as well as refining charts, particularly the font used in the word cloud. Design-related suggestions included adjustments to the donut charts to improve color differentiation, as P23 noted: "*Despite the clean visual design, some colors seem similar*", along with displaying values

directly rather than requiring user interaction. Participants also mentioned the inclusion of a dark mode and customization options, as well as the addition of new search and filtering options, enabling more precise refinements across all WASHES papers.

5. Discussion

This study addressed the presentation and evaluation of the dataWASHES dashboard, a tool for visualizing data related to WASHES. This work fits within the growing need for tools that facilitate access to and understanding of scientific information, aligning with the principles of Open Science. In this regard, Wilkinson (2005) argues that the "grammar of graphics" should serve not only aesthetics but, most importantly, the effective communication of scientific data, a principle that guided the development of dataWASHES.

In general, the results obtained revealed a strong alignment of the dashboard with Tufte's (2001) principles of data visualization, with an emphasis on graphic integrity and minimizing non-essential elements. This perspective finds parallels in the work of Few (2009), who also advocates for "visual eloquence" through simplicity and clarity. In addition, the user evaluation showed positive results, with a SUS score of 91.25 (classified as "Excellent" [Bangor et al. 2009]), as well as high levels of overall satisfaction (96.4%) and willingness to recommend dataWASHES. Participants also highlighted clarity, usability, and interactivity as strengths, while improvement opportunities were focused on aspects of responsiveness, readability, and refinements in the design of specific graphs. As emphasized by Nielsen (2012), successful interfaces combine ease of learning and efficiency, characteristics evident in the participants' responses, with 85% not feeling the need for technical support and 97% not perceiving inconsistencies.

The contributions of this work are multifaceted, providing academia with a practical case of applying Tufte's principles with empirical validation in the context of open science tools, as well as a hybrid evaluation methodology that combines theoretical inspection and user testing. For practice, dataWASHES exemplifies how the systematic application of information design principles, combined with a user-centered approach, can result in tools that are valuable to the scientific community, making a tangible contribution to Open Science. As noted by Fekete et al. (2008), well-designed visualizations transform data into actionable knowledge, a function that the dashboard serves by offering multiple perspectives on the scientific production of WASHES.

Despite the methodological rigor adopted, this study faces some threats to validity that were considered and mitigated as much as possible. Regarding internal validity, a potential bias lies in the qualitative observational inspection, as the evaluation of adherence to Tufte's data visualization principles was conducted by the researchers themselves. To mitigate this threat, an independent validation process was implemented, where a second researcher critically reviewed the findings of the initial inspection. Moreover, Tufte's principles were applied systematically and documented, reducing the subjectivity of the analysis. As for external validity, the sample of participants consisted exclusively of students, which may limit the generalizability of the results to other audiences, such as experienced researchers or industry professionals. To minimize this limitation, it is emphasized that a reasonable number of students with varying levels of familiarity with dashboards participated. Studies suggest that 5-15 participants can identify most critical issues in usability testing [Bevan et al. 2003].

Regarding construct validity, the use of SUS as an evaluation tool may not capture all dimensions of usability, especially aspects related to the perception of utility or relevance and overall satisfaction. However, to address this limitation, a complementary qualitative analysis was incorporated, including open-ended questions to capture more detailed insights from participants. Furthermore, conducting a pilot test before the main study ensured that the evaluation script was clear and well-structured, reducing potential errors in data collection. Regarding conclusion validity, the main threat lies in the possibility of misinterpretation of results due to the sample size and the subjective nature of the participants' perceptions. It is also worth noting that the participation of students was anonymized to minimize potential biases. Finally, the availability of the tools used and the collected data in an open repository contributes to the transparency of the study, allowing for future replications and further exploration. While there are threats to validity, the strategies adopted minimized their impact and strengthened the reliability of the findings.

6. Final Remarks

Open Science has become a fundamental element for the advancement of research in Software Engineering. In this context, the dataWASHES dashboard emerges as a tool aligned with the principles of Open Science, providing an interactive and visual interface to explore data from papers published in the Workshop on Socioeconomic, Human, and Software Aspects (WASHES). The objective of this study was to present and evaluate the dashboard through a qualitative inspection based on Tufte's data visualization principles, followed by a usability test with 28 students. For this empirical test, data was collected through a semi-structured questionnaire covering the perceived usefulness and relevance, the System Usability Scale (SUS), and overall satisfaction.

The results indicated that the dashboard satisfactorily adheres to Tufte's data visualization principles, featuring a clear and efficient interface, with an emphasis on minimizing non-essential elements and directly communicating the data. In terms of usability, user perceptions were highly positive based on the SUS, with high satisfaction regarding ease of use, confidence, and clarity of information. However, qualitative feedback highlighted some areas for improvement, including the responsiveness of certain components, such as the word cloud and interactive charts, as well as the need for adjustments in the colors of some charts and suggestions for new functionalities, such as personalized viewing modes and refined filters.

This study contributes both to academia and practice by expanding the understanding of applying Tufte's data visualization principles in the design of dashboards for open science. Furthermore, the usability evaluation through the SUS emphasizes the importance of user-centered design for solutions aimed at open science. From a practical perspective, the enhancement of the dataWASHES provides a more interactive and accessible tool for the community, facilitating the analysis of strategic data related to WASHES.

Future work includes implementing the improvement suggestions provided by users and expanding research on the intersection of data visualization, usability, and open science tools within Software Engineering. In addition, further exploration of heuristic evaluation techniques to enhance user experience and accessibility in this domain could be approached. Moreover, we propose reassessing a new version of the dashboard with a larger and more diverse target audience, aiming to gather more generalizable feedback.

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