StoryStore: Interactive Storytelling for Dashboard Onboarding

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Abstract

Onboarding a user to a visualization dashboard entails explaining the components in the dashboard. Authoring an onboarding experience is time-consuming, requires significant knowledge, and provides little guidance on best practices. Using the onboarding experience, on the other hand, can be either confusing and overwhelming, or tedious and unengaging, depending on the expertise of the user. We propose **interactive storytelling for onboarding** *to create semi-automated onboarding for varying user expertise while preserving the user's agency, interest, and engagement. We present a set of storytelling primitives inspired by open-world narrative design to blend guided and free-form narration. These primitives can be viewed at varying levels of detail depending on the expertise of the user. To validate the concept, we have implemented it in a tool called* STORYSTORE *that allows authors to craft custom onboarding stories using automatic storyboard templates or by starting from scratch. Even automatically generated onboarding stories can still be customized to use different media (such as video, audio, or highlighting) or new narratives to provide a tailored onboarding experience for individual users or groups. We demonstrate the usefulness of interactive story-based onboarding by means of use cases and expert interviews.*

CCS Concepts

• *Human-centered computing* → *Visualization theory, concepts and paradigms;*

1. Introduction

In the rapidly evolving landscape of data-driven decision-making, dashboards have emerged as pivotal tools, offering valuable insights through interactive data visualization [SCB*19]. However, understanding the different dashboard components and how they interact is challenging [WDSM23]. This leads to the importance of proper *onboarding* as a strategy to enhance the use and adoption of dashboard tools by filling the users' knowledge gaps [TLM16, CGM*17a, CAS*18]. Onboarding is typically conducted through user training, guided tutorials, and other support materials that often have to be crafted from scratch for each dashboard. For authors of such onboarding experiences, the creation of the material can be time-consuming and is often non-standardized in the absence of best practices. Similarly, for dashboard users, the onboarding experience might be tedious and unengaging or confusing and even overwhelming, depending on their expertise.

In this paper, we propose applying approaches drawn from storytelling, interactive narratives, and open-world video games to dashboard onboarding. We call this approach *interactive storytelling for dashboard onboarding*. The idea is to enable authors to craft interactive onboarding narratives that preserve the user's agency, thus increasing engagement and decreasing confusion. In fact, the inherent structure of dashboards naturally lends itself to a storytelling format with a narrative journey through visual explanation, data, and insights. Drawing parallels with the narrative visualization spectrum, which ranges from author-driven to reader-driven approaches, we position dashboard onboarding within this same continuum: from author-driven to reader-driven onboarding (Fig-

ure 1). In an author-driven approach, the author often creates a fixed sequence—essentially, a guided tour—that limits user agency. Conversely, a reader-driven approach allows users interactive control of the guidance [CYC*23], which reduces the author's narrative control. While data-driven storytelling has evolved to create more balanced narratives, dashboard onboarding has not yet fully exploited this potential. This often results in onboarding being confined to one of these two extreme approaches; most commonly a fixed tour.

We present STORYSTORE, an implementation of interactive storytelling for dashboard onboarding that supports a semi-automated
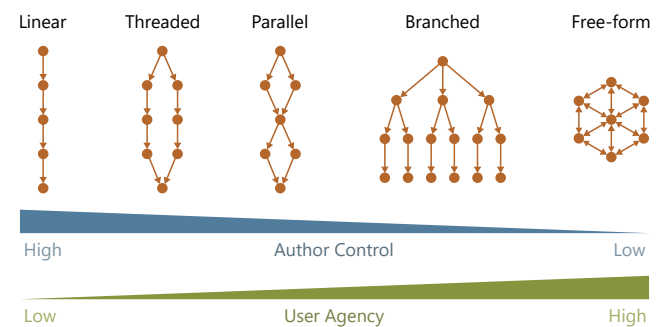

Figure 1: *Narrative structures inspired by storytelling. These structures, drawn from narrative visualization and open-world games [MCG10, Mun16] fall on different positions on the scales of author control and user agency.*
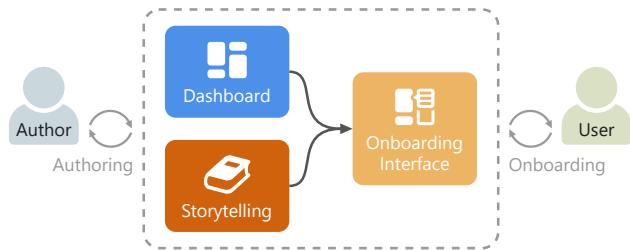
Figure 2: *Interactive Storytelling for Dashboard Onboarding. Authors build stories based on a dashboard's content. Users then navigates through the stories in an onboarding interface.*

authoring process. For authors, it offers automated authoring of onboarding narratives that can be tailored to create different kinds of stories, ranging from guided to free-form ones. For users, it enables them to engage with the created stories, offering the flexibility to choose their own path within the narrative and also have agency on the content. They can also perform a more free-form exploration to craft their own narrative. Our main contribution is (*i*) the concept of *interactive storytelling for dashboard onboarding* for creation and exploration of onboarding narratives using the power of storytelling to enhance user engagement and understanding, as shown in Figure 2. Our secondary contributions are (*ii*) the implementation of the concept in the StoryStore web application and (*iii*) the evaluation of StoryStore via usage scenarios and two expert interviews.

2. Related Work

In this section, we discuss existing research on onboarding for both single visualizations and dashboards. We also explore how classical data storytelling techniques can be adapted to create clear and engaging onboarding narratives. Additionally, we examine authoring tools in data storytelling, as their design significantly informed our approach to developing an onboarding solution.

2.1. Visualization and Dashboard Onboarding

Onboarding solutions, while common in areas like software tools and video games, are less prevalent for dashboards. Stoiber et al. [SGP*19] characterized the onboarding space for *single* visualizations. Means of onboarding include online guides [Rib20] and cheatsheets [WSMRB20]. More recently, approaches such as step-by-step guides and scrollytelling have become more prevalent [SWP*22]. A need for dedicated *dashboard* onboarding was emphasized by Walchshofer et al. [WDSM23], Brehmer et al. [BK22] and Sarikaya et al. [SCB*19]. Previous work on dashboard onboarding includes annotating dashboards [EB12] and helping users to learn public-access interactive tools [KPS03]. Recent work by Chundury et al. [CYC*23] offers data-driven, contextual, in situ help features for visual data interfaces. One of their contributions is a guided tour, however it is aimed at users seeking help or guidance rather than onboarding. We focus on onboarding as opposed to guidance [CGM*17b]. We previously characterized the space for dashboard onboarding and proposed a process model [DWH*22]. Commercial tools such as Tango [Tan23] and

Scribe [Col23] allow for the creation of annotations and guided experiences for websites and may also be used for dashboards. However, their approach is mainly static as they take screenshots to create these onboarding guides. While there are works on interactive onboarding for a single visualization, in the domain of dashboard onboarding, we still find mostly static approaches, such as tooltips and annotations in literature. This is surprising given the inherently interactive nature of dashboards. In real-life onboarding scenarios, we observed oral presentations [WDSM23] or static documentation to onboard an interactive dashboard.

2.2. Data-driven Storytelling

Visualizations are often used to present data facts through storytelling. Such data-driven stories can be delivered in the form of narrated videos or audio [KSM*23, SKH*23], plain text [SCC*23], or web pages [MBS23]. As dashboards also often tell a story with data, we propose to apply storytelling concepts to dashboard onboarding. Segel and Heer's 2010 framework [SH10] identified seven narrative genres in data visualization, balancing author-driven and reader-driven narratives. In this work, we adapt these narrative styles to create different styles of onboarding stories, where the dashboard user assumes the role of the reader. Zhao and Elmqvist [ZE23] proposed to integrate aspects such as audience size and interaction levels. Chen Q. et al. [CCWC23] surveyed the field of authoring tools in data-driven storytelling, with a focus on automation in narrative visualizations. While (semi-) automation is an aspect of our work, we do not plan to completely automate the narration. Instead, our work aims at keeping the author in the loop of onboarding story creation. To assist the onboarding author in narrative creation, we draw inspiration from work by Hullman et al. [HKL17] and Kim et al. [KWHH17], who explain the factors behind visualization sequencing for clarity in data presentations. In addition to the data-driven storytelling, our work is inspired by other areas that make use of narratives, such as movies and open-world games. Recent works from visualizing non-linear storytelling narratives in movies [KBI*18] list seven categories of the relationships between story order and narrative order. Unlike movies, dashboards do not have an inherent temporal order. Non-linear narratives are often employed in open-world games. McIntosh et al. [MCG10] discussed challenges of, and solutions for designing non-linear games. Specific types of non-linear narratives [RHDC18, Mun16], such as branching, parallel, and free-form narration, have been found to increase user engagement [BDF15] and have also been studied in the context of multi-user analyses [XBL*18]. We adapt these different narrative styles in our work to provide authors with control over the narrative structure of the onboarding in a way that allows a flexible level of user agency.

2.3. Authoring Tools for Storytelling

We reviewed authoring tools which support the creation of narratives in various domains. Green et al. [GHC20] introduced a design pipeline for interactive narrative authoring tools, with a focus on user experience. Meixner et al. [MMGK14] introduced an authoring tool for non-linear videos using a tree structure. In addition to video clips, annotations can be attached to scenes. In a follow-up work [Gre18], Green introduced *Novella*, an authoring

tool for interactive stories in games. Our workflow for creating dashboard onboarding stories draws inspiration from these works. In the field of scientific storytelling, ScrollyVis [MBS23] is related to our approach. ScrollyVis is an interactive authoring tool for guided dynamic narrations using scrollytelling. It allows for the integration of different resources such as images, text, videos, and maps to support the dynamic narration of scientific stories. Another storytelling work with a scientific target audience is Molecumentary [KSM*23], which allows for the creation of narrated documentaries about molecules. Molecumentary also supports various types of media, such as text, audio, and video to explain the molecule visualizations to the users. In the field of general-purpose data visualization, Roslingifier [SKH*23] offers a semi-automated approach for constructing data presentations using animated scatter plots. ChartStory by Zhao et al. [ZXC*23] offers a unique approach to crafting comic-style data narratives. A fully automated approach to video generation for storytelling from data facts is AutoClips [SSX*21]. Other notable authoring solutions include a slideshow-based tool for narrative visualization by Wang et al. [WLF*19], Temporal Summary Figures for annotated temporal visualizations [BMW17], and Erato [SCC*23] for data factsheets.

We implemented interactive storytelling for dashboard onboarding in the StoryStore application. StoryStore features an authoring mode that draws inspiration from several of the authoring tools mentioned above. However, our work focuses on allowing an author to create narratives based on a dashboard's content with the goal of onboarding new users to the dashboard.

3. Interactive Storytelling for Dashboard Onboarding

Recent studies on the use of visualizations [BK22, SCB*19] and dashboards [WDSM23] in larger organizations have shown that onboarding is currently primarily done through oral presentations at the time of a visualization's or dashboard's launch. This method involves a human going through a prepared, narrated script with limited to no user agency on behalf of the user. Additionally, the time and effort involved in creating elaborate onboarding material, such as a video or a guided tour, is high [BK22]. This also means that most organizations opt for a single onboarding experience that must work for all users, regardless of their expertise. Therefore, in most cases, documentation in the form of slides or a standard document may be provided as a supplementary aid with the dashboard to avoid repetitive onboarding scenarios. The apparent lack of interactivity and user agency in such fixed, "one-size-fits-all" onboarding can be particularly problematic for different users:

- **Novice:** Low visualization literacy [BRBF14] and lack of experience with a dashboard tool and workplace practices means that a novice user easily becomes *confused* or even *overwhelmed* by onboarding material not appropriate for their knowledge level.
- **Expert:** High visualization literacy and long experience with similar dashboards means that an expert can become *disengaged* or even *bored* by material not appropriate for their expertise.

This highlights the need for a more dynamic and adaptive onboarding solution for dashboards. Here we derive design goals for such an onboarding solution from (*i*) the characterization of the dashboard onboarding space in our previous work [DWH*22],

(*ii*) our experience with industrial collaborators [WDSM23], and (*iii*) studying existing authoring tools (cf. Section 2.3):

G1 *Allow Authors and Users to Access the Dashboard*— To create a dashboard onboarding experience, the author must have access to the visualizations in the dashboard and their interrelationships. This requires understanding how interactions with one visualization affect others, a key factor in determining *What* needs to be onboarded [DWH*22]. It is equally important for the onboarding *users* to have access to the dashboard, so that they can easily relate onboarding material to the visualizations in the dashboard. The onboarding is either integrated within the dashboard or presented externally, such as in a video [BK22].

G2 *Give Authors and Users Agency over the Onboarding Material*—The onboarding material is the subset of a dashboard's functionality that needs to be explained to the user. The author makes an initial selection of the material and then decides how much agency they want to leave for the user. The onboarding tool should support the author by providing ways to select this subset and provide or modify the information shown about it during the onboarding. For users, the tool should offer flexibility in selecting the level of detail at which they wish to engage with the onboarding material. Users should be able to choose which aspects of the dashboard to explore in more detail, customize the amount of information they receive, and potentially alter the path they take through the onboarding based on their interactions.

G3 *Allow Authors Create a Narrative*—To create an engaging and meaningful onboarding, a narrative must be created. This involves creating either fixed narratives for a specific use case or multiple narratives, which can branch or exist in parallel, to accommodate multiple storylines in the dashboard. Using the concept of storytelling, supporting various narrative structures [Mun16] can enhance onboarding comprehension and potentially cover more than one way of using the dashboard. The responsibility of crafting these narratives lies with the author, who must understand *Why* the onboarding is needed and *How* can it be best explained. The onboarding tool should provide ways of specifying or creating these narrative structures to support the author in the onboarding creation.

G4 *Enable Authors to Select the Means of Presentation*—The onboarding can be delivered in several ways, ranging from interactive guides, annotated walkthroughs, and video tutorials, to more dynamic, game-like exploratory modes. The onboarding tool should support the choice and selection of these means to allow the author to pick and choose from, based on their requirements.

G5 *Allow Authors and Users to Explore the Created Story*—The prepared onboarding story must be available to both the author and the user. The author can use this prepared story to evaluate its effectiveness in conveying the intended message and make necessary modifications. For the users, navigating through this narrative is essential to understand the dashboard. Based on the prepared narrative structure, the tool should facilitate varying degrees of user autonomy.

We propose the concept of *interactive storytelling for dashboard onboarding* which enables authors to create interactive onboarding experiences inspired by storytelling. The concept addresses all goals by integrating onboarding within the dashboard, granting ac-

cess to both the dashboard and the onboarding material. The author has the flexibility to select from a set of predefined narratives or craft them from scratch and attach appropriate onboarding means. The completed story is then made available for user exploration.

4. The StoryStore Application

We propose StoryStore, an implementation of our interactive storytelling for dashboard onboarding. StoryStore integrates onboarding into a dashboard that enables authoring and viewing of onboarding stories. The tool has two modes: the *authoring* mode, and the *onboarding* mode primarily aimed at users of a dashboard. The authoring mode consists of the *Shelf*, the *Builder*, and the *Preview*. Just like goods in a shop, StoryStore onboarding components are made available to authors in an organized manner via the Shelf to support the compilation of onboarding material in the Builder. Authors can preview and make the final product (i.e., the onboarding story) available to the users in the Preview. The StoryStore authoring mode is shown in Figure 3. In the following, we explain the design and working of StoryStore in more detail.

4.1. Shelf

The Shelf is an author's entry point into creating an onboarding story, organizing dashboard visualizations by type for easy access, similar to a store layout. It begins with 'Introduction' and 'Dashboard' levels, mirroring real-world onboarding steps that explain the dashboard's goals and data. Visualizations are then categorized by type at the same level, aiding authors in selecting and fulfilling **G1** and **G2**. Choosing a type reveals the specific visualization in the dashboard.

The content behind each visualization is broadly classified in three nodes based on Stoiber et al. [SGP*19]:

- **General**: This node contains general information about the visualization, which is based on the meta-model by Ingelmo et al. [VIGPT19] and a visualization grammar like Vega-Lite [SMWH17]. It stores information about the visualization such as its title, mark, axis, and legend.
- **Insight**: This node contains the insights that can be gained from the visualization. We derive this information from concepts such as data visualisation catalogue [Rib20] and Krist's visualization component grammar [Won20]. This can be, eg., trends in a line chart or the range of values in a bar chart.
- **Interaction**: This node contains the interactive aspects of a visualization. We use Krist's visualization component grammar [Won20] to specify this interactivity. Currently, we support basic operations such as self and cross filtering and highlighting. But by using this model, we can support more interactions.

However, not every visualization will encompass all three nodes. For instance, Key Performance Indicators (KPIs) typically lack interactivity and have overlapping general and insight information, so they are represented only by a *General* node. For visualizations which are only filters, such as drop-down lists, do not provide insights and hence lack an *Insight* node.

In our Shelf, these nodes can be *picked* for narrative construction,

by dragging and dropping them onto the Builder. Additionally, selecting them triggers two simultaneous actions: (*i*) highlighting the corresponding visualization in the Preview and (*ii*) displaying the default textual description for this node in the Builder. This dual-display functionality enables authors to easily correlate each type of information about a visualization with its location in the dashboard.

In early design iterations of the Shelf, we tried to show the complete structure of the dashboard, including all links between visualizations and detailed visual encoding specifications all the way down to the mark and channel level. While this approach would have ensured complete control over the finest details of the onboarding story, it overwhelmed authors. We thus opted for the hierarchical design based on visualization types and the substructure for each visualization based on the work by Stoiber et al [SGP*19].

4.2. Builder

The Builder enables the author to create stories from the nodes picked from the Shelf. Within StoryStore, authors can either utilize predefined narrative templates or create entirely new stories from scratch. Stories are represented by nodes with edges specifying the direction of the narrative. This section is further divided into subsections that explain the process of narrative crafting (Section 4.2.1), the selection of predefined templates (Section 4.2.2) and the choice of onboarding means (Section 4.2.3).

4.2.1. Narrative Crafting

We used a node-based story creation format, based on the guidelines of authoring tools for story creation, such as Novella [Gre18]. In this format, the author can construct narratives by simply dragging and dropping nodes from the Shelf. The authors can then establish connections between these nodes by adding edges, with each node possibly having multiple incoming and outgoing connections. The visual story creation is intuitive and easy to use as it requires no coding expertise, making it accessible to a broader audience.

To streamline the authoring process and improve the readability of the story, we introduced the concept of grouping nodes. A *group* is a collection of nodes bundled together with logical operations that determine how users can navigate through the story (**G2**). Authors have the flexibility to specify whether the user needs to visit all, only one, or at least one node in a group before being able to progress to the next node or group.

The choice of grouping option depends on the author's specific objectives. For instance, in scenarios where multiple visualizations of the same type are present, an author might prefer the 'Only one' or 'At least one' option to streamline the onboarding process. This way, the author can ensure that users grasp the key concepts without the need to tediously explore all similar visualizations.

For the narrative design itself, we did not use edges initially to avoid clutter in the Builder. However, this soon became cumbersome and authors during the pilot interviews found it hard to understand different narrative structures. Therefore, we introduced edges to mitigate this.
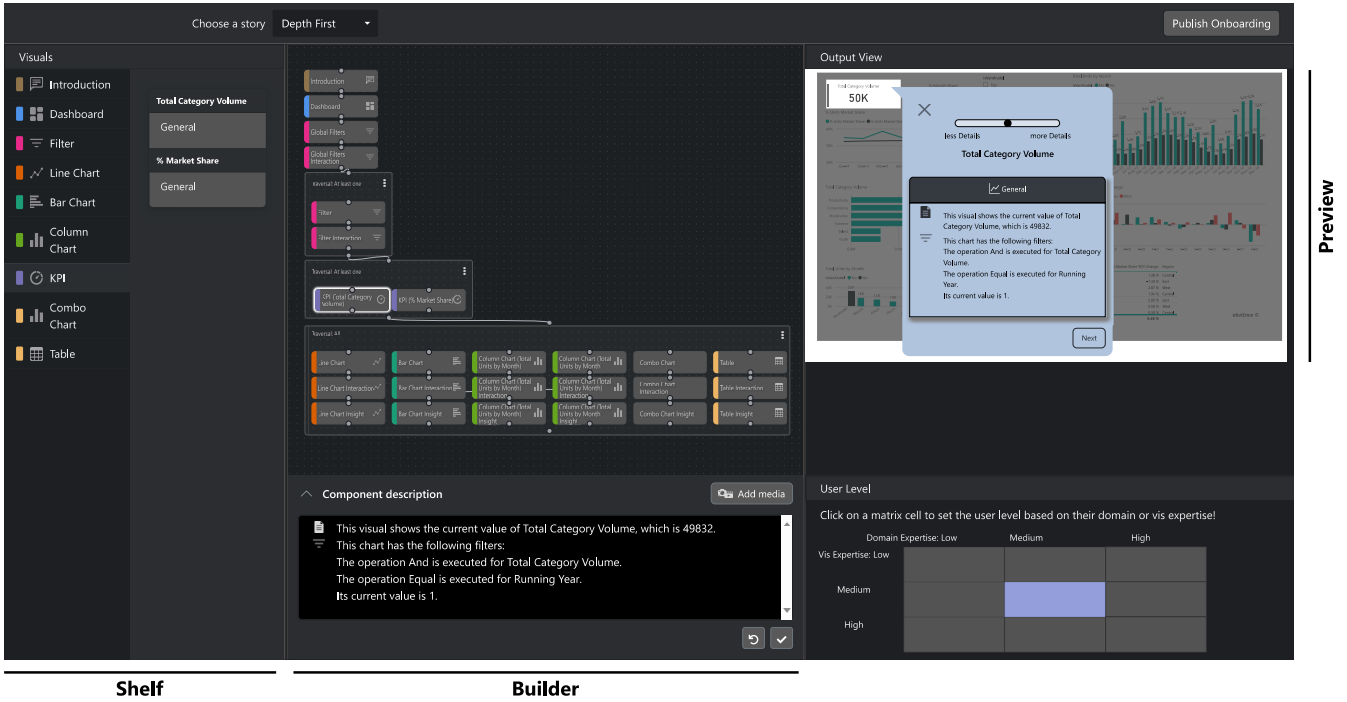
Figure 3: *StoryStore's Authoring Mode. Authors pick onboarding material from the Shelf and drag it to the Builder, where they create stories from it. The Preview in the upper right shows how the onboarding will appear to the user in the onboarding mode.*

4.2.2. Predefined Templates

In an attempt to automate the creation of narratives (**G3**), we implemented a few predefined story templates based on existing narrative structures. These templates can be easily customized by adding more nodes from the Shelf or by deleting existing ones. Currently, we support the following templates, which are also illustrated in Figure 4:

- **Deep-Dive Narrative:** This template guides users through each visualization of a dashboard in a detailed, sequential manner. The order of visualizations reflects their placement in the dashboard, traversing those visualizations that are placed at the top first. For instance, in a line chart, users would explore all nodes of its description (i.e., the general information, potential insights, and interactions) before proceeding to the next visualization. This template ensures a thorough onboarding experience for each individual visualization.
- **Similarity-based Narrative:** This template also provides a traversal of visualizations from top to bottom, however, by grouping visuals by type. The categorization criteria can extend beyond just the type of visualization to include aspects like data characteristics and insights, based on the work of Hullman et a. [HDR*13] and GraphScape [KWHH17].
- **General to Narrow:** This template is based on the Martini glass storytelling metaphor. It starts with a broad overview of the dashboard and gradually focuses on specific elements, mimicking the narrowing shape of a Martini glass.

Our supplementary material details various design considerations for nodes and these narrative structures [DHF*23d].

4.2.3. Onboarding Resources

In the StoryStory concept, each node represents a part of the narrative. The content that users will see for each node during the onboarding can be edited by the authors at the bottom of the Builder. Selecting a node shows its textual description, allowing authors to add, delete, or modify content as needed. The default description for each node depends on the expected visualization and domain expertise of the user, which the author can specify through the *user level matrix* at the bottom right of the Builder (Figure 3). If the author sets a high, visualization expertise, only little *General* information will be shown, as the user is expected to have a good understanding of what charts show in general. Likewise, if the author sets a high domain expertise, the default *Insight* description becomes concise. This supports the goal **G2**, by enabling authors to tailor the detail level for various user groups. All changes made in the text editor are immediately reflected in the Preview. Beyond textual descriptions, additional resources such as audio or video are also supported (**G4**). Authors can start screen recordings directly from StoryStore and attach them to a node's description. Attached audio and video resources are immediately visible in the Preview and accessible for the user in the onboarding mode.
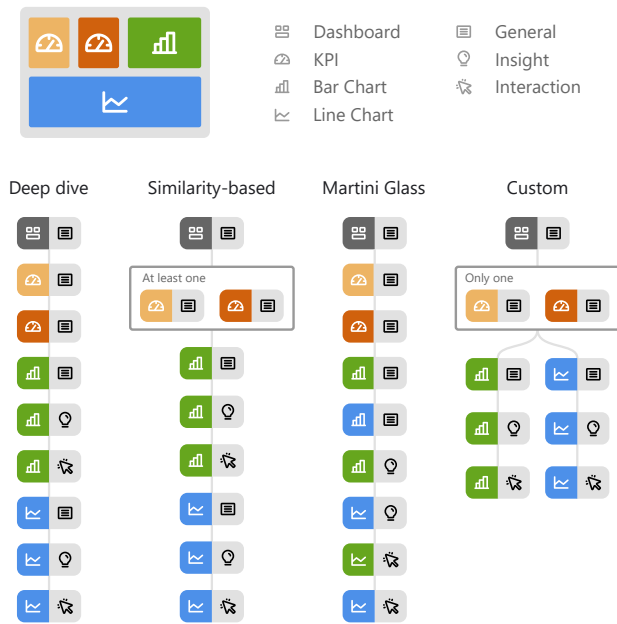
Figure 4: *Predefined Narrative Templates in StoryStore. The templates allow authors to quickly create stories based on established narrative structures, as indicated here for a simple example dashboard consisting of two KPIs, a bar chart, and a line chart. At all times, authors can move to a completely customized narrative.*

4.3. Preview

The Preview in our system acts as a miniature, real-time representation of the dashboard, incorporating interactions from the Shelf and Builder. As explained in Section 4.1, selections made in the Shelf are concurrently highlighted in the Preview (**G1**). Similarly, the Builder's active narrative elements and its means are reflected in real-time in the Preview. This helps in exploring (**G5**), testing, and refining the onboarding story without having to go back and forth between then authoring and onboarding modes.

The Preview emphasizes the selected dashboard element by overlaying gray boxes on the other elements, focusing the author's attention on the relevant part of the dashboard. Pop-up boxes adjacent to the emphasized element display the onboarding content. The boxes are positioned based on the visual's dimensions relative to the screen size. Each box includes 'Next' and 'Previous' buttons, facilitating a guided walkthrough of the narrative.

Once the author is satisfied with the onboarding narrative, they have the option to publish it, making the onboarding accessible to users. The authors can also edit and republish the onboarding story, if needed.

4.4. Onboarding mode

In the Onboarding mode, both authors and users can explore the onboarding story, allowing authors to experience the narrative from a user's perspective (**G5**). As the onboarding is integrated within the dashboard, the users have access to the dashboard content at all times (**G1**). They can interact with the visualizations and the content of the onboarding will update to reflect these changes.

Users can navigate through the onboarding in a guided manner. They either follow the predefined narrative crafted by the author, or choose a self-guided exploration mode. In the guided mode, the narrative unfolds through sequential pop-up boxes with 'next' and 'previous' buttons. For interactive elements in the narration designed by the author, a 'Try it out' option appears, encouraging active engagement with the dashboard. When the users encounter a branch in the narrative, they are prompted to select a path, indicated by green frames around specific visualizations. Their choice determines the continuation of the narrative journey. Users can also revisit and alter choices, leading to a different narrative path. They also have the option to adjust the detail of the content they receive during the onboarding, by setting it once for the rest of the onboarding. This choice can also be altered at any time to view a different level of detail. This agency over the content and the narrative enables the user to have a control over the onboarding (**G2**). The onboarding concludes with a close button, but users have the option to restart the tour.

In the free exploration mode, the narrative is solely driven by the user's choices. The onboarding content for each visualization is accessible upon clicking it. In this mode there is no 'next' and 'previous' navigation, as the user is in charge of the narrative.

5. Implementation

We implemented StoryStore using the Microsoft Power BI embedded report [Mic23c], which provides a practical solution for dashboard integration without the need for building one from scratch. This is a useful technical solution because of the comprehensive support offered by Power BI's REST API [SDl*23], which provides most of the information about the visualizations in a dashboard.

For the StoryStore front-end, we used the React framework [Met23]. We employed React-Bootstrap [Boo23] to structure the Shelf, allowing us to organize the nodes through user-friendly UI elements such as Navigation, Tabs, and Accordions. We ensure that the component graph we construct and update via the Power BI REST APIs always reflects the dashboard's current state.

The Builder uses React-Flow [CHJ*19], which offers support for building node-based editors. The Preview integrates the Power BI dashboard, and uses CSS and TypeScript to create dynamic pop-up elements. We use FastAPI [Ram18] and Python for the backend. This allows for the inclusion of multimedia content such as audio and video instructions.

The source code of the StoryStore implementation is available online [DHF*23e].

6. Use Cases

This section presents two concrete examples of dashboard onboarding with storytelling, authored with StoryStore. Both use cases are based on example dashboards available in Microsoft Power
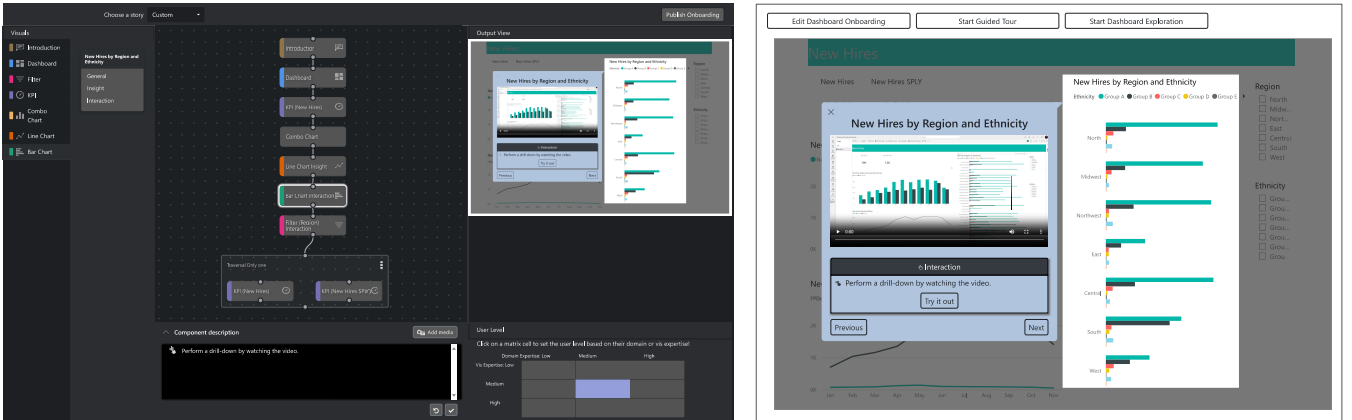
Figure 5: *StoryStore applied to the New Hires Dashboard. In the authoring mode (left), the author adds a video to explain the drill-down functionality of a bar chart. The user can later view the video at the respective point of the story in the onboarding mode (right).*

BI [Mic23b]: the New Hires Dashboard [SBI*23a] and the Sales and Marketing Dashboard [SBI*23b].

6.1. New Hires Dashboard

An author is asked to prepare an onboarding for a report that shows the new hires for a company (as shown in Figure 5). The onboarding should be created for team members of an internal department at the company who are well-versed with basic visualizations, such as line charts and bar charts, but do not have experience with interactive dashboards. The author decides to create a story from scratch. Before selecting the components from the Shelf, they think of a story they want to narrate. The plan is to first introduce the main insights from the dashboard and then explain interactions. They start looking for the needed components from the Shelf and drag them to the Builder. They then connect them linearly to craft the narrative. For each component, they read the generated content description and edit it as needed. For the given bar chart, the generated content does not show the drill-down functionality, which is a new feature of this chart. So, they decide to record a video in addition to the textual description. After this, they group the Key Performance Indicators (KPIs) to show their final values. However, they feel that explaining Only one KPI is enough for the onboarding, so they set the group option to 'Only one'. This will be reflected as a branch to the end user. The author tests the functionality multiple times to ensure the published version looks as intended (see the left part of Figure 5).

The published onboarding is given to the user who starts the onboarding by reading the introduction and clicking the next button. They gather the main insights regarding the new hires by reading the onboarding material and using tooltips to understand the data. They then watch the video for the bar chart to understand the drill-down functionality and try it out directly on their dashboard. The video embedded into the interactive onboarding journey allows them to view it without switching tools. Finally, to understand the effect of their previous interaction, they choose to view a KPI (as shown in the right part of Figure 5(b)). This onboarding can be repeated as many times as needed. The user always has the freedom

to do a self-guided exploration. A video that shows the authoring and usage of the onboarding for this use case is available in the supplementary material [DHF*23b].

6.2. Sales and Marketing Dashboard

In the second scenario, the author is asked to prepare an onboarding for both the managers and the employees (user groups) of a company keen on monitoring and analyzing, respectively its industry standing. The dashboard, in Figure 6, shows the market share of their company consists of two KPIs, a filter, a line chart, two column charts, one combo chart (combination of line and column), and a table.

The managers want see an overview of their sales and the most important insights from the dashboard. The employees, on the other hand, need a more thorough onboarding on all the visualizations.

The author starts the onboarding authoring process using our solution. An overview of all the visualization types in the Shelf helps them pick nodes for their onboarding stories. Instead of creating two different onboarding stories, the author decides to create a single adaptable onboarding story that can be used by both the user groups. To create this story, they start from scratch and add common nodes relevant to both the user groups, such as Introduction, Dashboard, and Filter *Interaction*. They also add a supporting video to enhance the textual description of the filter.

The narrative then branches as depicted in Figure 6. The left branch is tailored for the managers, featuring grouped KPIs with a 'Only one' selection option, allowing managers to focus on KPIs of their particular interest. In order to explain the most important insights from each visualization type, the author creates a linear sequence of *Insight* nodes for each unique visualization type. As there are two column charts, the author simply groups them with an 'At least one' option.

The right branch, specifically designed for employees, delves into a detailed explanation of the visualizations. Therefore, the author groups all the visualization *General* nodes together with an
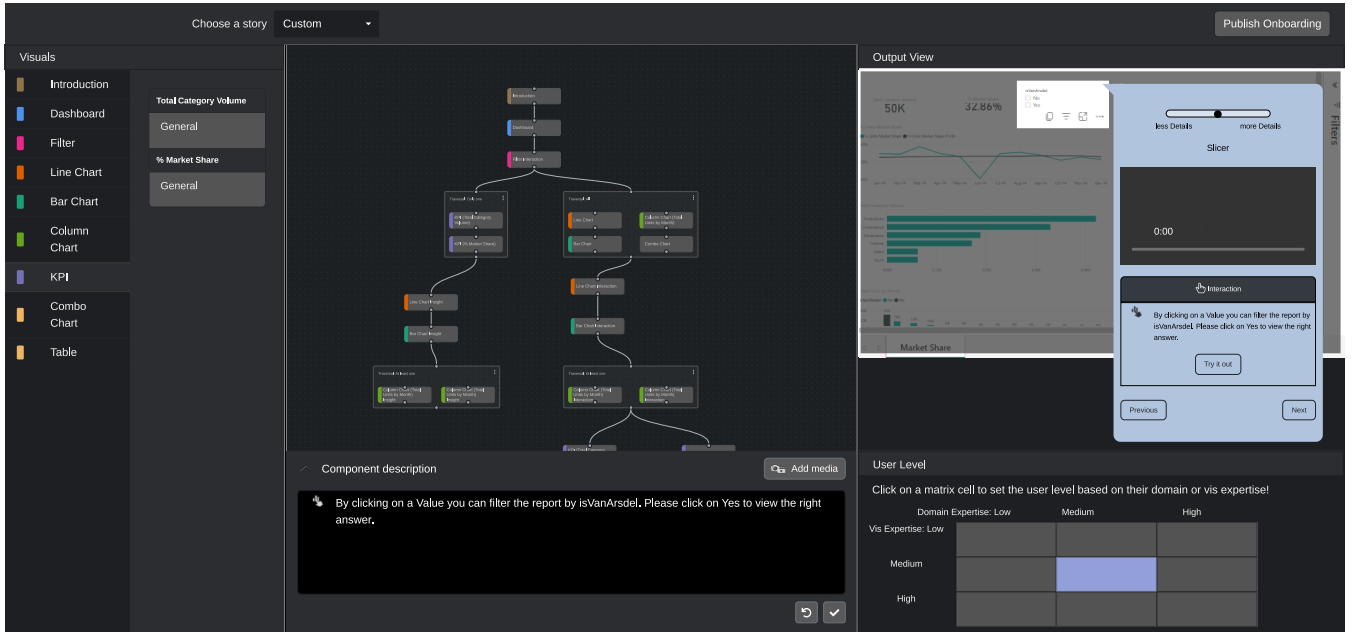
Figure 6: *StoryStore applied to the Sales and Marketing Dashboard. The author creates a branching narrative for the two user groups of managers and regular employees.*

'All' option to ensure that employees familiarize themselves with every visualization before they move on to interactions. To explain the interactions, the author creates a linear sequence of *Interaction* nodes for each unique visualization type. This mirrors the left branch but it is designed for the *Interaction* nodes. The story concludes with a branch on each KPI, providing users with a choice in their onboarding journey.

Both the user groups receive the onboarding and follow the prepared onboarding path. The managers gravitate towards the KPI-focused path, while employees' choices are influenced by their level of expertise. Most importantly, both paths are accessible to both the user groups, allowing for flexibility and adaptive onboarding. A supplementary video demonstrating the authoring and usage of this onboarding scenario is available in the supplementary material [DHF*23c].

7. Evaluation

We evaluated StoryStore with two onboarding authors (A1 and A2) and two users (U1 and U2) from our industrial collaborators, who are active in the production of steel and steel-based technologies worldwide. These authors, who are experts in their domain and knowledgeable in visualization, regularly create dashboards using Microsoft Power BI [Mic23b] and onboard the users, via personal or online meetings. Our choice regarding these authors was motivated by three main reasons: (i) their experience with real-world onboarding scenarios, (ii) their role as actual onboarding authors, and (iii) the use of the same technology stack as our solution. They further referred us to the users who they wanted to onboard, leading to a choice of U1 and U2. A qualitative approach and a thinking-aloud protocol has been adopted. We prepared separate question

sets [DHF*23a] for the onboarding authors and users to be answered before and after the evaluation.

The evaluation was done via scheduled in-person interviews. A1 shared their dashboard prior to the interview, while A2 provided it during the session. In both cases, they used real-world dashboards that they intended to use in their organizations. We conducted individual interviews with each author, followed by interviews with the respective onboarding users.

For the authors, the questions focused on their background in data analysis and domain knowledge with respect to the dashboard. We inquired about their typical onboarding processes and the challenges they encounter. After introducing StoryStore, we asked them to use it to create an onboarding narrative for their respective users. We describe details from each session and summarize the insights for both the authors and the users.

7.1. Onboarding Session 1

Before our first session, we embedded the A1's dashboard on our Microsoft Power BI account to test the settings. The dashboard consisted of eleven KPIs, two line charts, four tables, and two matrices. The main authoring goal was to onboard the new colleague on the workings of a manufacturing plant and explain indicators, thresholds, and system failures, if any. The evaluation started with the author sketching the desired onboarding story on paper, where they picked the most important points that should be made clear. For example, they picked one parameter, for which a value of zero indicates a production failure. After noting more of these points based on their domain knowledge, they switched to the StoryStore interface to craft their narrative. At first, they started by checking
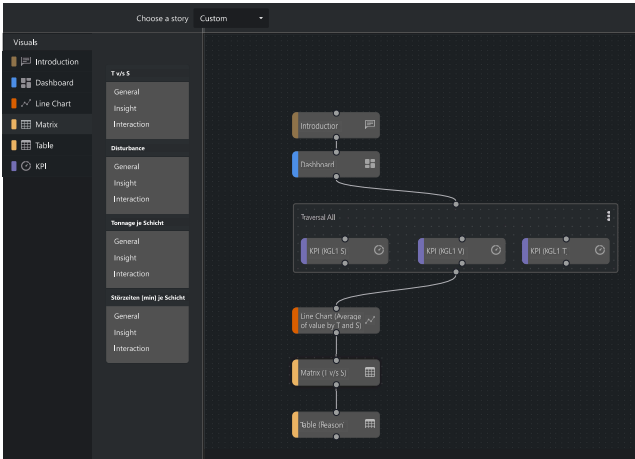
Figure 7: *Creation of an onboarding story using StoryStore in Onboarding Session 1. This figure shows the Shelf and the Builder at the time of story creation. The Preview is hidden as the dashboard includes proprietary information of our collaborators.*

which nodes belong to which visualizations and reading the corresponding textual descriptions. The already provided textual descriptions were well received as they mentioned that the description: *"shows additional information, that I don't think of"*. They started a new story by grouping the KPIs and then adding the corresponding nodes linearly in the story. They incorporated their domain knowledge, which they noted earlier, in the existing textual descriptions of the nodes. After testing the story, shown in Figure 7, the author published it for the user to access.

The user session started shortly after the author had finished creating their onboarding story. A1 was still present to witness how the session proceeded. The onboarding was perceived well by U1, who mentioned that *"the interaction with the dashboard"* alongside the onboarding was very convenient. At some stages, they pointed out *"missing contextual knowledge"* which A1 forgot to add. This also provided hints to A1 for their next onboarding session. U1 were engaged during the entire session and found the onboarding to be *"much better than previous sessions [in the company]"*. According to them, in the past onboarding was only carried out via *WebEx* calls, which *"was an overwhelming experience as it was too much information in a short a time"*. So, they clearly see an advantage in using the StoryStore approach as they can onboard themselves at their own pace.

7.2. Onboarding Session 2

In the second session, we received the dashboard after we introduced A2 to the StoryStore approach using a dummy dashboard. While integrating A2's dashboard into our solution, we had to replace some of their custom visualizations. For example, we replaced a custom KPI with the default Power BI implementation. This was necessary for our solution to detect the visualizations and supply proper default descriptions automatically. We explained these adaptations to A2.

Afterwards, A2 prepared a story about identifying and comparing the top ten disturbances of the past and current business years. Their intended onboarding user (U2) had expert visualization and domain knowledge. As the story required selecting and comparing the years, A2 started with selecting filters and then added the remaining nodes from the Shelf linearly. They also considered the existing textual description to be useful, however, in some cases a *"little bit too much"*. A2 found the story creation intuitive and liked the 'Try it out' option provided for the Interact node. They inquired about the difference between the *General* and *Insight* nodes before making a choice. Towards the end of the story creation process, A2 tested the story multiple times to ensure that the onboarding worked as planned.

The user session ended soon after, as the onboarding story was short. Similar to U1, U2 also mentioned that they would have wished for *"more descriptive text"* for some visualizations. They liked the 'Try it out' feature as well, which allowed them to interact with the dashboard alongside the onboarding. They also mentioned that one of the main advantages of our solution *"was definitely the less and more details option"*.

7.3. Summary of Insights

This section summarizes the combined insights from the two independent onboarding sessions.

Both authors said they currently onboard at the time of a dashboard's launch using oral presentations. In these presentations, the onboarding authors typically walk through each use case and show the users the visualizations. In the experience of A1, exposure to a new visualization type typically triggers questions that prompt the author to *"explain every detail about it"* (i.e., the new visualization). With StoryStore, A1 found that *"you can guess 90 % of the questions beforehand because of the automation and the flexibility of the message"*.

According to A2, they are sometimes *"asked to create a video"* to provide reusable onboarding material. However, they feel they are *"not a media person"*, so they instead *"end up doing personal meetings"* to perform the onboarding. StoryStore can possibly *"reduce the training time of the colleagues"* and save their own time as they *"don't need to be there all the time"*. For A2 the support of videos is valuable *"especially for the new users as it takes [away] their fear of clicking on something and accidentally 'breaking' things"*.

Both authors were able to implement their stories as planned, adapting quickly to the story creation process using the Shelf and the Builder. We asked both authors to rate the ease of learning, ease of use, efficiency, satisfaction with, and intuitiveness of StoryStore on 7-point Likert scales. We used questions such as "I find StoryStore to be intuitive to use." with answers ranging from "1: Strongly disagree" to "7: Strongly agree". Except for one score, both authors rated everything with 6 or 7.

Only for the intuitiveness, A1 gave a score of 5 as they felt that the implementation could be improved, especially in the case of group creation. To create a group, an author must select the nodes by using a combination of Shift and Click and then group them.

This was not obvious to A1, even though it was briefly explained before the evaluation. For the future, we plan to add a group icon that can be dragged on existing nodes to form a group.

The users found the onboarding informative. Both of them users would like to use such an onboarding solution in the future, with U1 saying that it is *"easy to use and self-explanatory"*. U2 said that they liked the *"simple styling of the onboarding as it is more effective"* the onboarding process they were used to.

8. Discussion

In this section, we reflect on conceptual limitations of our interactive storytelling approach for dashboard onboarding, and on technical limitations of the StoryStore implementation. Based on these considerations, we derived ideas for future work on the topic.

8.1. Limitations

The idea of using interactive storytelling for dashboard onboarding aims at enhancing the overall onboarding experience. We evaluated how well the solution works with real-world onboarding scenarios based on the StoryStore implementation. We found that independent of the specific stories, users liked the concept of being onboarded to a dashboard directly in-place. They appreciated the placement of onboarding information within the dashboard and found the option to switch from onboarding to actual usage at any time useful. While StoryStore significantly decreases the authoring effort necessary to create such reusable onboarding experiences, the effectiveness of the onboarding ultimately depends on the decisions made by the authors. It remains a challenge to make it even easier for authors to correctly choose the onboarding material and narrative style for a given use case.

We also received feedback through the pilot interviews and evaluation on a more detailed level. During one of the pilot interviews, an interviewee (an onboarding author) suggested a progress bar to convey where the user is situated in the onboarding story. However, progress bars are only directly applicable to completely linear stories and may be misleading when users navigate through branched or free-form narratives.

In the post-evaluation, A1 highlighted the need for more control over textual descriptions, specifically the ability to choose and use small icons. Currently, icons are automatically inserted in the default textual deceptions (e.g., horizontal axis icons for each mention of a chart's *x*-axis. We plan to allow authors to use icons more flexibly in the next version of StoryStore.

One of the technical limitations of StoryStore—but not of the general concept behind it—stems from the constraints of the Microsoft Power BI APIs. While the Microsoft Power BI REST API [SDl*23] provides extensive details about the visualizations on the dashboard, it has certain limitations. For instance, it lacks information on specific interaction types, such as whether a visualization was highlighted. We currently derive missing information by analyzing changes in a visualization's state, such as alteration in the displayed data and the opacity, to infer if parts of a visualization are highlighted or if the underlying data has been filtered. Another limitation arises with non-standard visualizations from Microsoft

AppSource [Mic23a], as the REST APIs do not provide information about their nodes. This makes it challenging to support custom visualizations in our solution.

Finally, even though our current StoryStore implementation uses Microsoft technology, the underlying concept and code are customizable to any dashboard system. The essential aspect is the ability to access the nodes of visualizations within these systems, as this basic information is required by StoryStore. Therefore, our solution can potentially be extended to other dashboard systems to enable a wider adoption.

8.2. Future Work

In the future, we plan to explore the integration of AI technology to improve both the authoring and the onboarding process of our solution. For the authoring process, we are considering using language models to enhance the generation of onboarding text. While this approach would allow us to move beyond predefined text templates for each chart, it will require substantial work on ensuring the factual correctness of the generated onboarding texts. Additionally, multi-model generative models could be used to analyze screenshots of a dashboard user interface to inform the creation of onboarding material. This idea could extend StoryStore's support of non-standard visualizations.

On the user end of the onboarding process, it might be beneficial to incorporate an AI-based chat assistant. This could allow users to interact with the dashboard in their natural language, simulating a traditional onboarding experience and providing them with even more agency over the onboarding material (**G2**).

9. Conclusion

We have interactive storytelling for dashboard onboarding. This concept allows authors to create narratives that enhance user engagement with dashboards in order to better understand them. We evaluated the StoryStore application, which implements this concept, through two use cases and expert sessions. The feedback from the authors was positive, as they were able to successfully create reusable onboarding experiences with little effort. The users also found the narrative onboarding engaging and indicated a preference for using StoryStore for their future onboarding needs. Our results suggest that interactive storytelling for dashboard onboarding improves the onboarding experience for both the authors and the users.

References

[BDF15] Boy J., Detienne F., Fekete J.-D.: Storytelling in Information Visualizations: Does it Engage Users to Explore Data? In *Proceedings of the ACM Conference on Human Factors in Computing Systems* (New York, NY, USA, Apr. 2015), ACM, pp. 1449–1458. doi:10.1145/2702123.2702452. 2

[BK22] Brehmer M., Kosara R.: From Jam Session to Recital: Synchronous Communication and Collaboration Around Data in Organizations. *IEEE Transactions on Visualization and Computer Graphics 28*, 1 (2022). doi:10.1109/TVCG.2021.3114760. 2, 3

[BMW17] Bryan C., Ma K.-L., Woodring J.: Temporal summary images: An approach to narrative visualization via interactive annotation

generation and placement. *IEEE Transactions on Visualization and Computer Graphics 23*, 1 (2017), 511–520. doi:10.1109/TVCG.2016.2598876. 3

[Boo23] BOOTSTRAP TEAM: Build fast, responsive sites with bootstrap, 2023. Last accessed on 2023/11/29. URL: https://getbootstrap.com/. 6

[BRBF14] BOY J., RENSINK R. A., BERTINI E., FEKETE J.: A principled way of assessing visualization literacy. *IEEE Transactions on Visualization and Computer Graphics 20*, 12 (2014), 1963–1972. doi:10.1109/TVCG.2014.2346984. 3

[CAS*18] COLLINS C., ANDRIENKO N., SCHRECK T., YANG J., CHOO J., ENGELKE U., JENA A., DWYER T.: Guidance in the human–machine analytics process. *Visual Informatics 2*, 3 (Sept. 2018), 166–180. doi:10.1016/j.visinf.2018.09.003. 1

[CCWC23] CHEN Q., CAO S., WANG J., CAO N.: How does automation shape the process of narrative visualization: A survey on tools. *IEEE Transactions on Visualization and Computer Graphics* (2023). doi:10.1109/TVCG.2023.3261320. 2

[CGM*17a] CENEDA D., GSCHWANDTNER T., MAY T., MIKSCH S., SCHULZ H.-J., STREIT M., TOMINSKI C.: Characterizing guidance in visual analytics. *IEEE Transactions on Visualization and Computer Graphics 23*, 1 (Jan. 2017), 111–120. doi:10.1109/TVCG.2016.2598468. 1

[CGM*17b] CENEDA D., GSCHWANDTNER T., MAY T., MIKSCH S., SCHULZ H.-J., STREIT M., TOMINSKI C.: Characterizing guidance in visual analytics. *IEEE Transactions on Visualization and Computer Graphics 23*, 1 (2017), 111–120. doi:10.1109/TVCG.2016.2598468. 2

[CHJ*19] CHRISTOPHER, HAYLEIGH, JOHN, MORITZ, PETER: React Flow, 2019. Last accessed on 2023/11/29. URL: https://reactflow.dev/. 6

[Col23] COLONY LABS, INC.: Scribe, 2023. Last accessed on 2023/11/29. URL: https://scribehow.com/. 2

[CYC*23] CHUNDURY P., YALÇIN M. A., CRABTREE J., MAHURKAR A., SHULMAN L. M., ELMQVIST N.: Contextual in situ help for visual data interfaces. *Information Visualization 22*, 1 (2023), 69–84. doi:10.1177/14738716221120064. 1, 2

[DHF*23a] DHANOA V., HINTERREITER A., FEDIUK V., ELMQVIST N., GROELLER E., STREIT M.: Evaluation questions for onboarding authors and users, 2023. URL: https://osf.io/cedzu. 8

[DHF*23b] DHANOA V., HINTERREITER A., FEDIUK V., ELMQVIST N., GROELLER E., STREIT M.: Onboarding for New Hires dashboard, 2023. URL: https://osf.io/yafuv. 7

[DHF*23c] DHANOA V., HINTERREITER A., FEDIUK V., ELMQVIST N., GROELLER E., STREIT M.: Onboarding for Sales and Marketing dashboard, 2023. URL: https://osf.io/u6pb7. 8

[DHF*23d] DHANOA V., HINTERREITER A., FEDIUK V., ELMQVIST N., GROELLER E., STREIT M.: Prototypes for StoryStore, 2023. URL: https://osf.io/uf8ew. 5

[DHF*23e] DHANOA V., HINTERREITER A., FEDIUK V., ELMQVIST N., GROELLER E., STREIT M.: StoryStore GitHub repository, 2023. URL: https://github.com/jku-vds-lab/dashboard-onboarding. 6

[DWH*22] DHANOA V., WALCHSHOFER C., HINTERREITER A., STITZ H., GROELLER E., STREIT M.: A process model for dashboard onboarding. *Computer Graphics Forum 41* (2022), 501–513. doi:10.1111/cgf.14558. 2, 3

[EB12] ELIAS M., BEZERIANOS A.: Annotating BI visualization dashboards: needs and challenges. *Proceedings of the ACM Conference on Human Factors in Computing Systems* (2012), 1641–1650. doi:10.1145/2207676.2208288. 2

[GHC20] GREEN D., HARGOOD C., CHARLES F.: A novel design pipeline for authoring tools. *Proceedings of the ICIDS International Conference on Interactive Digital Storytelling*, 12497 (2020), 102–110. doi:10.1007/978-3-030-62516-0_9. 2

[Gre18] GREEN D.: Novella: An authoring tool for interactive storytelling in games. In *Interactive Storytelling*, vol. 11318 of *Lecture Notes in Computer Science*. Springer Publishing, Cham, 2018, pp. 556–559. doi:10.1007/978-3-030-04028-4_66. 2, 4

[HDR*13] HULLMAN J., DRUCKER S., RICHE N. H., LEE B., FISHER D., ADAR E.: A Deeper Understanding of Sequence in Narrative Visualization. *IEEE Transactions on Visualization and Computer Graphics 19*, 12 (2013), 2406–2415. doi:10.1109/TVCG.2013.119. 5

[HKL17] HULLMAN J., KOSARA R., LAM H.: Finding a clear path: Structuring strategies for visualization sequences. *Computer Graphics Forum 36*, 3 (2017), 365–375. doi:10.1111/cgf.13194. 2

[KBI*18] KIM N. W., BACH B., IM H., SCHRIBER S., GROSS M. H., PFISTER H.: Visualizing nonlinear narratives with story curves. *IEEE Transactions on Visualization and Computer Graphics 24*, 1 (2018), 595–604. doi:10.1109/TVCG.2017.2744118. 2

[KPS03] KANG H., PLAISANT C., SHNEIDERMAN B.: New approaches to help users get started with visual interfaces: Multi-layered interfaces and integrated initial guidance. In *Proceedings of the 2003 Annual National Conference on Digital Government Research* (2003), dg.o '03, Digital Government Society of North America, p. 1–6. doi:10.5555/1123196.1123269. 2

[KSM*23] KOUŘIL D., STRNAD O., MINDEK P., HALLADJIAN S., ISENBERG T., GRÖLLER M. E., VIOLA I.: Molecumentary: Adaptable narrated documentaries using molecular visualization. *IEEE Transactions on Visualization and Computer Graphics 29*, 3 (2023), 1733–1747. doi:10.1109/TVCG.2021.3130670. 2, 3

[KWHH17] KIM Y., WONGSUPHASAWAT K., HULLMAN J., HEER J.: GraphScape: A model for automated reasoning about visualization similarity and sequencing. In *Proceedings of the ACM Conference on Human Factors in Computing Systems* (New York, NY, USA, 2017), ACM, pp. 2628–2638. doi:10.1145/3025453.3025866. 2, 5

[MBS23] MÖRTH E., BRUCKNER S., SMIT N. N.: ScrollyVis: Interactive visual authoring of guided dynamic narratives for scientific scrollytelling. *IEEE Transactions on Visualization and Computer Graphics 29*, 12 (2023), 5165–5177. doi:10.1109/TVCG.2022.3205769. 2, 3

[MCG10] MCINTOSH B., COHN R., GRACE L. D.: Nonlinear Narrative in Games: Theory and Practice. Game Careerguide, 2010. Last accessed via they Wayback machine at https://web.archive.org/web/20150406221523/http://www.gamecareerguide.com/features/882/features/882/nonlinear_narrative_in_games_.php on 2023/11/30. URL: http://www.gamecareerguide.com/features/882/features/882/nonlinear_narrative_in_games_.php. 1, 2

[Met23] META PLATFORMS, INC.: React: The library for web and native user interfaces, 2023. Last accessed on 2023/11/29. URL: https://react.dev/. 6

[Mic23a] MICROSOFT CORPORATION: Microsoft AppSource, 2023. Last accessed on 2023/11/29. URL: https://appsource.microsoft.com/en-us/. 10

[Mic23b] MICROSOFT CORPORATION: Microsoft Power BI, 2023. Last accessed on 2023/11/29. URL: https://powerbi.microsoft.com/. 7, 8

[Mic23c] MICROSOFT CORPORATION: Power BI Embedded, 2023. Last accessed on 2023/11/29. URL: https://azure.microsoft.com/en-us/products/power-bi-embedded/. 6

[MMGK14] MEIXNER B., MATUSIK K., GRILL C., KOSCH H.: Towards an easy to use authoring tool for interactive non-linear video. *Multimedia Tools and Applications* (2014), 1251–1276. doi:10.1007/s11042-012-1218-6. 2

[Mun16] MUNDAY R.: A guide to interactive documentary: Structure, tools & narrative, 2016. Last accessed on 2023/11/29. URL: https://directorsnotes.com/2016/08/08/interactive-documentary-guide/. 1, 2, 3

[Ram18] RAMÍREZ S.: Fast API, 2018. Last accessed on 2023/11/29. URL: https://fastapi.tiangolo.com/. 6

[RHDC18] RICHE N. H., HURTER C., DIAKOPOULOS N., CARPENDALE S. (Eds.): *Data-driven storytelling*. A K Peters visualization series. CRC Press, Taylor & Francis Group, Boca Raton London New York, 2018. 2

[Rib20] RIBECCA S.: The Data Visualisation Catalogue, 2020. Last accessed on 2023/11/29. URL: https://datavizcatalogue.com/. 2, 4

[SBI*23a] SPARKMAN M., BERDUGO M., INBAR P., SHERER T., HARVEY B., ISEMINGER D., SHARKEY K.: Human Resources sample for Power BI: Take a tour, 2023. Last accessed on 2023/11/29. URL: https://learn.microsoft.com/en-us/power-bi/create-reports/sample-human-resources. 7

[SBI*23b] SPARKMAN M., BERDUGO M., INBAR P., SHERER T., PIESCO J., ISEMINGER D., HART M., SHARKEY K.: Sales and Marketing sample for Power BI: Take a tour, 2023. Last accessed on 2023/11/29. URL: https://learn.microsoft.com/en-us/power-bi/create-reports/sample-sales-and-marketing. 7

[SCB*19] SARIKAYA A., CORRELL M., BARTRAM L., TORY M., FISHER D.: What do we talk about when we talk about dashboards? *IEEE Transactions on Visualization and Computer Graphics 25*, 1 (2019), 682–692. doi:10.1109/TVCG.2018.2864903. 1, 2, 3

[SCC*23] SUN M., CAI L., CUI W., WU Y., SHI Y., CAO N.: Erato: Cooperative data story editing via fact interpolation. *IEEE Transactions on Visualization and Computer Graphics 29*, 1 (2023), 983–993. doi:10.1109/TVCG.2022.3209428. 2, 3

[SDl*23] SHARABI K., DIAB M., LAURENT-MIC, DUNCAN O., DONG J., KUMAR S.: Using the Power BI REST APIs, 2023. Last accessed on 2023/11/29. URL: https://learn.microsoft.com/en-us/rest/api/power-bi/. 6, 10

[SGP*19] STOIBER C., GRASSINGER F., POHL M., STITZ H., STREIT M., AIGNER W.: Visualization onboarding: Learning how to read and use visualizations. In *Proceedings of the Visualization for Communication Workshop at IEEE VIS* (2019). doi:10.31219/osf.io/c38ab. 2, 4

[SH10] SEGEL E., HEER J.: Narrative visualization: Telling stories with data. *IEEE Transactions on Visualization and Computer Graphics 16*, 6 (2010), 1139–1148. doi:10.1109/TVCG.2010.179. 2

[SKH*23] SHIN M., KIM J., HAN Y., XIE L., WHITELAW M., KWON B. C., KO S., ELMQVIST N.: Roslingifier: Semi-Automated Storytelling for Animated Scatterplots. *IEEE Transactions on Visualization and Computer Graphics 29*, 6 (2023), 2980–2995. doi:10.1109/TVCG.2022.3146329. 2, 3

[SMWH17] SATYANARAYAN A., MORITZ D., WONGSUPHASAWAT K., HEER J.: Vega-Lite: A grammar of interactive graphics. *IEEE Transactions on Visualization and Computer Graphics 23*, 1 (2017), 341–350. doi:10.1109/TVCG.2016.2599030. 4

[SSX*21] SHI D., SUN F., XU X., LAN X., GOTZ D., CAO N.: Auto-Clips: An automatic approach to video generation from data facts. *Computer Graphics Forum 40*, 3 (2021), 495–505. doi:10.1111/cgf.14324. 3

[SWP*22] STOIBER C., WALCHSHOFER C., POHL M., POTZMANN B., GRASSINGER F., STITZ H., STREIT M., AIGNER W.: Comparative evaluations of visualization onboarding methods. *Visual Informatics 6*, 4 (Dec. 2022), 34–50. doi:10.1016/j.visinf.2022.07.001. 2

[Tan23] TANGO TECHNOLOGY, INC.: Tango, 2023. Last accessed on 2023/11/29. URL: https://www.tango.us/. 2

[TLM16] TANAHASHI Y., LEAF N., MA K.: A study on designing effective introductory materials for information visualization. *Computer*

Graphics Forum 35, 7 (Oct. 2016), 117–126. doi:10.1111/cgf.13009. 1

[VIGPT19] VÁZQUEZ-INGELMO A., GARCÍA-PEÑALVO F. J., THERÓN R.: Capturing high-level requirements of information dashboards' components through meta-modeling. In *Proceedings of the TEEM Conference on Technological Ecosystems for Enhancing Mulitculturality* (2019), ACM, pp. 815–821. doi:10.1145/3362789.3362837. 4

[WDSM23] WALCHSHOFER C., DHANOA V., STREIT M., MEYER M.: Transitioning to a Commercial Dashboarding System: Socio-technical Observations and Opportunities. *IEEE Transactions on Visualization and Computer Graphics* (2023), 1–11. doi:10.1109/TVCG.2023.3326525. 1, 2, 3

[WLF*19] WANG Q., LI Z., FU S., CUI W., QU H.: Narvis: Authoring narrative slideshows for introducing data visualization designs. *IEEE Transactions on Visualization and Computer Graphics 25*, 1 (2019), 779–788. doi:10.1109/TVCG.2018.2865232. 3

[Won20] WONGSUPHASAWAT K.: Encodable: Configurable grammar for visualization components. In *Proceedings of the IEEE Visualization Conference* (Los Alamitos, CA, USA, Oct. 2020), IEEE, pp. 131–135. doi:10.1109/VIS47514.2020.00033. 4

[WSMRB20] WANG Z., SUNDIN L., MURRAY-RUST D., BACH B.: Cheat sheets for data visualization techniques. In *Proceedings of the ACM Conference on Human Factors in Computing Systems* (New York, NY, USA, 2020), ACM, p. 1–13. doi:10.1145/3313831.3376271. 2

[XBL*18] XU S., BRYAN C., LI J. K., ZHAO J., MA K.-L.: Chart Constellations: Effective Chart Summarization for Collaborative and Multi-User Analyses. *Computer Graphics Forum 37*, 3 (2018), 75–86. doi:10.1111/cgf.13402. 2

[ZE23] ZHAO Z., ELMQVIST N.: The Stories We Tell About Data: Surveying data-driven storytelling using visualization. *IEEE Computer Graphics and Applications 43*, 4 (2023), 97–110. doi:10.1109/MCG.2023.3269850. 2

[ZXC*23] ZHAO J., XU S., CHANDRASEGARAN S., BRYAN C., DU F., MISHRA A., QIAN X., LI Y., MA K.-L.: ChartStory: Automated partitioning, layout, and captioning of charts into comic-style narratives. *IEEE Transactions on Visualization and Computer Graphics 29*, 2 (2023), 1384–1399. doi:10.1109/TVCG.2021.3114211. 3