Diving in the story: exploring tailoring in narrative data visualizations

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ABSTRACT

End-User Development is a research topic aimed at empowering end-users to tailor their daily applications. With time, many researchers proposed methods, tools, taxonomies, and other approaches to enable the users and the applications to deal with unpredicted demands within software development. As the research developed, researchers started investigating the application of EUD concepts in other fields, such as data visualization. In this context, this study draws attention to the intersection of End-User Development concepts with exploratory narrative data visualization. To drive our investigation, we performed a focus group with data visualization professionals to understand how designers could employ narrative concepts and exploratory resources to allow readers to customize their story experience within the narrative. To analyze our findings, we use the semiotic engineering for End-User Development. As a result, we present this analysis and drive design implications for narrative data visualizations with customizable facilities.

CCS CONCEPTS

• **Human-centered computing** → **Interaction design theory, concepts and paradigms**.

KEYWORDS

data visualization, narrative visualization, storytelling, semiotic engineering, customization, end-user development

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1 INTRODUCTION

End-User Development (EUD) is a research topic focused on investigating approaches to allow end-users to tailor their daily applications. By tailoring, we mean activities of modifying an application to meet some user's context [17].

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EUD is formally defined as a set of methods, techniques, and tools to allow users that are not technically skilled to create, modify, or extend software [20]. These activities may encompass simple customization such as changing the color or font size or more sophisticated ones such as creating new features during software usage.

Over time, the goals posed by EUD have attracted many researchers interested in evolving software to cope with novel users' demands and empower them to act as designers of their applications. Researches such as Capiello and colleagues [5], Desolda et al. [10], Fischer [11], and Fischer and colleagues [13] developed mashup applications and frameworks to support developers in building EUD-like applications. Santos and Villela [24] characterized the EUD recent research in five dimensions: the context of use, platform, interaction style, quality of use, and limitations. More recently, EUD research has advanced to Artificial Intelligence (AI) [12], Smart Environments [3], and the Internet of Things (IoT) [7] proposals.

Another topic that has been attracting researchers' attention is data visualization. It is widely acknowledged that a good data visualization may engage and take viewers to novel insights [15]. Segel and Heer [25] introduced the concept of narrative data visualization, a.k.a. storytelling or data-driven storytelling [23], as a means of data visualization. Advancing the topic, Hullmann and Diakopoulos [16] described techniques involved in narrative visualizations.

Considering this perspective, researchers have explored the intersection of EUD activities and data visualization development. For example, Pantazos and colleagues [22] investigate how data visualization tools address EUD resources for visualization designers. On the other hand, Castelli and colleagues [6] reported the results that allow non-skilled users to develop visualizations for smart home data visualization.

In this work, we present our emerging research results to address the EUD perspective for designers and end-users while they are planning and interacting with narrative data visualizations. We envisioned a research opportunity to investigate how designers could employ narrative elements and customizable features to convey a narrative regarding their intents. We followed the concepts of narratives poised by Segel and Heer [25] and concepts of exploration delimited by Thudt and colleagues [28].

To support our investigation we also adopted the Semiotic Engineering perspective over EUD activities [27]. This perspective classifies in *intent reencoding* and *scope expansion* the modifications users may perform while interacting with the application. Hence, we analyzed part of our results to identify what type of modifications users may achieve in the narrative planned by designers.

As part of our results, we ran a focus group session to understand how designers could plan narrative visualization assembled with interactive techniques to allow end-users to explore the narrative while reading it. This contribution is a step forward in designing narratives covering the entire data visualization pipeline.

To present the research done, we organized the remainder of this papers as follows. Section 2 briefly presents the concepts that anchor our research. Section 3 shows the focus group protocol. Section 4 presents the focus group findings. In the Section 5 we discuss our findings in the light of Semiotic Engineering and point out some design implications for narrative visualizations. Finally, in Section 6 we address our final remarks, and point out three future works.

2 BACKGROUND

In this section, we present the concepts that underscore our research. First, we address End-User Development (EUD) and some essential ideas within this topic. We then proceed to narrative data visualizations and exploratory narratives. Finally, we present the semiotic theory and summarize the relations between the topics of this section.

EUD is a topic within the Human-Computer Interaction (HCI) field defined as a set of methods, techniques, and tools to allow non-technically skilled software users, at some point to create, customize, modify, or extend the software [20]. Nardi [21] presented in a seminal work findings to describe a set of advanced activities that software users can get involved with.

Regarding the end-users activities, Lieberman [20] distinguished customization from software modification as follows. The former encompasses activities, such as changing the color font, type, or other properties, that allow users to choose predefined system behavior. On the other hand, software modification involves more sophisticated actions that imply creating or modifying the software. Visual programming, programming by demonstration, macros, and script languages are examples of approaches in this category.

Cabitza et al. [4] specialized public EUD into *inward* EUD and *outward* EUD. *Inward* and *outward* specializations encompass situations in which the users tailor artifacts for a community they also belong to, or external communities, respectively.

The topic has strong worldwide peer research collaborations. Correa and Silveira [8] showed that Italy and United States have a highlighted contribution to the field. In addition, they also showed collaboration clusters addressing subjects such as the quality of the systems and EUD frameworks.

Narrative data visualization emerged to enhance the reader's comprehension of data visualization. Indeed, blending narrative with data visualization has been an effective way of giving meaning to the data [19]. Segel and Heer [25] characterized the components involved in narrative visualization. Throughout the analysis of case studies from online journalism, blogs, videos, and visualization research, the authors organized the design space of narrative visualization into three dimensions: genres, visual narrative tactics, and narrative structure tactics. Each dimension comprises resources that together aid the storytellers[1] in conveying a message.

[1]The term storyteller in this work means a designer building a narrative visualization

Regarding the first dimension, Segel and Heer [25] identified seven genres for narrative visualization: magazine style, annotated chart, partitioned poster, flow chart, comic strip, slide show, and film/video/animation. Essentially, they hold ways to organize and present information to viewers. They primarily vary in terms of the number of frames, i.e., the number of different scenes, how they can be applied to represent time and space, and the ordering of visual elements. By organizing the information differently in the space, these genres also influence how a user can explore a narrative. For instance, whereas a slide show follows a linear path, a partitioned poster tends to present a loose reading ordering. An essential aspect of the genres is that they are not mutually exclusive; thus, they can be combined to convey more complex narratives.

The second dimension, visual narrative tactics, contains resources that facilitate the narrative. Facilities such as highlighting, progress bar, timeline slider, and transition guidance are examples of this dimension. These resources support the designer in orienting the viewer by augmenting specific points in a narrative.

The third dimension, narrative structure, comprises tactics used by each visualization and non-visual mechanisms to assist the narrative. The facilities in this dimension help the viewer explore a narrative by letting them select, filter, navigate, etc.

Taking steps toward empowering the readers in customizing the narratives, Thudt and colleagues [28] investigate a significant feature of data-driven storytelling, the **exploration**. Exploration provides readers with access to additional data, functionalities, or forms of representation. Moreover, it facets authors to create stories that can be personalized according to reader knowledge, interests, and experiences [28]. These authors[28] distinguish three dimensions in which exploration can be provided: *view*, *focus*, and *sequence*. The view dimension addresses ways in which data is shown to readers. The focus relates to the story's subject, i.e., the particular set or subset of data shown. Finally, the sequence addresses the order in which the information in the story can be viewed. Designers can employ techniques to integrate exploration to different degrees in each dimension.

The **Semiotic Engineering** [9] is a theory of HCI that considers the interaction happening as a metacommunication between designers and users in the application's interface. In other words, the designer sends a message to users (carrying out some intent) through the interface.

The Semiotic Engineering perspective of customizable applications comprises two classes of modifications that users may perform when interacting with such applications: the one that conserves the same scope of intent accounted by the designer, and the other one that introduces new intentional elements. These modifications are characterized by the combination of dimensions of intent, expression, and content.

We are interested in the semiotics applied to End-User Development in our work. De Souza and Barbosa [27] stressed this topic by characterizing designers' and users' activities and intentions from such a perspective. They presented a matrix with the semiotic manipulation possibilities based on combining three characteristics from computer processing and human communication. The former addressed a perspective that is applied to computers. Whereas the latter refers to the human communication perspective. Due to our

research purpose, our focus is to investigate the human perspective. Figure 1 shows these manipulations possibilities.

The human communication perspective presents seven possibilities that are reached by combining three dimensions: expression, content, and intent. By varying one or more dimensions, the user can interact in ways that can change the content, intention, expression, or even all by interacting with an interactive system.

Manipulations of types A, B, and C are intent-preserving changes. For example, type A manipulations introduce new expressions without changing the content and intent. It can be reached by changing the label or name of some interface element. On the other hand, manipulations of types D to G are intent-changing. For example, type D represents a situation where a table structure in HTML is used to design a webpage; it represents a new intent to an existing element once tables are not associated with webpage designs.

3 METHODOLOGY

In this section, we present the approach adopted to conduct our research. Initially, we approach the general aspects of our study. Then, we present the tasks and questions made.

We decided to run a focus group method[2] to investigate how designers could leverage exploratory facilities while designing a narrative data visualization. The method's usefulness is that it allows diverse issues to be raised and enables people to put forward their perspectives [26]. In addition, the focus group is suited to obtaining initial feedback on new concepts and generating ideas [18].

We held the session remotely because in-person activities were not reestablished on the scheduled date. Besides allowing us to invite participants from other cities and states, the remote study allowed us to reach a more diverse participants profile. This aspect would be more challenging if we conducted the study in person once it may require participants' dislocations to the place of the study. We used Zoom for the remote meeting and Figma for the activities to conduct the session. A total of six participants attended the focus group. Table 1 shows the participants' identification, genre, position, and the experience in years they have with data visualization. We labeled each participant with the letter *P* followed by a number. In the next section, we use this identification to describe each participant's comments.

Table 1: Focus group participants

Participant	Gender	Position	Experience
P1	M	Software Developer	5
P2	M	Researcher	5
P3	M	Software Developer	2
P4	F	Researcher	2
P5	F	Data Analyst	5
P6	M	Researcher	4

We organized the focus group' session in rounds of activities and discussions. The first round consisted of questions to map the participants' profiles. Following, we presented the significant concepts regarding exploratory narrative visualizations. Then, we proceeded to the round in which we explained the tasks proposed. The participants had about 50 minutes to perform the group activity. Finally, they discussed four questions regarding their perception of the exploratory narrative concepts and how they could provide readers with customizable resources during the interaction.

The audio and video interaction of the session was recorded for analysis purposes. All the participants were required to read and sign the consent form before the session started. To analyze the results, we employed content analysis techniques, such as thematic analysis, which is a suitable approach to identify, analyze, and find data patterns [2].

The focus group comprised five tasks and three questions concerning the tasks plus two closure questions. The data used in the activities were retrieved from Our World in Data[3]. In addition, due to research purposes, we retrieve data about education.

We adopted the perspective of *inward* EUD [4]. Hence, the designers are planning a narrative data visualization for members of their community. By planning this narrative, the designers provide end-users, i.e., the readers, with exploratory resources to allow them to customize to their needs the story presented. Thus, they could experience their story to some extent.

To support participants in this activity of planning a narrative, we organized the Figma into five layers. Four of five contained resources to plan the narrative. We named them as *visual structure*, *visualization techniques*, *exploratory dimensions*, and *dataset*. The fifth layer was the *narrative' design*, in which we put the participants choices for the narrative' design. Following, we present the tasks performed by participants.

> *T1*: Define an intention for the narrative considering the dataset presented.
> *T2*: Pick up one or more narrative data visualization genres.
> *T3*: Pick up visualization techniques to show the data selected.
> *T4*: Considering the narrative built and the exploratory dimensions and techniques, define what resources will be employed to provide readers with forms to experience the narrative from other perspectives.
> *T5*: Justify the choices.

During the session, the participants solved the tasks aloud together and said which options they chose. Then, the researcher set the layers in Figma according to their choices. In addition, the researcher was responsible for mediating situations of disagreement. After achieving the above tasks, the participants were asked to talk about the following topics:

- perceptions about data visualization and narrative data visualization;
- perceptions concerning exploratory narrative visualizations;
- how the narrative genres could provide users with different perspectives of a narrative;
- interactions techniques that can be used by designers to create exploratory narratives.

The closure questions addressed the participants' opinions of the readers' skills required to interact with a narrative data visualization

[2]Project approved by the Institution's Ethics Committee (number 54348321.1.0000.5336)

[3]https://ourworldindata.org/

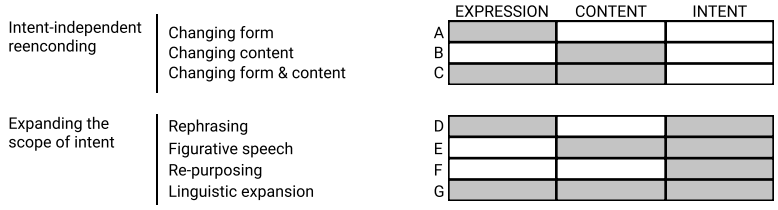

Figure 1: Semiotic manipulation possibilities. Adapted from de Souza and Barbosa [27]

and if they had any additional contributions to the topic. In the next section, we present our results.

4 RESULTS

In this section, we stressed the focus group results. We categorized our findings into four topics: the use of exploratory dimensions, providing readers with explicability facilities, the relation between narrative genres and exploratory dimensions, and the narrative's target public. The topics summarize the participants' comments during the focus group.

Figure 2 shows the process of planning an exploratory narrative data visualization. As the visualization designer, the domain user follows five steps to define how the narrative should appear. At each step, the designer can select from a bundle of resources which ones he or she wants to use. On the other hand, the end-users take advantage of the exploratory options placed in the narrative to customize their experience.

Table 2 presents what the participants chose at each process step shown in Figure 2. For example, to convey the narrative they selected the partitioned poster and annotated chart genres.

Table 2: Focus group participants choices

Task	Choice
Select a dataset	Worldwide Education Expenditure
Define the intention	Budget per capita and childhood education per country relation
Select the genres	Partitioned poster and annotated chart
Select the visualization techniques	Bar chart and drill-down
Select the exploratory dimensions	Focus and view

The **use of exploratory dimensions** addresses participants' opinions about how they could use the three dimensions (focus, view, and sequence) to tell a narrative. From the three dimensions presented, P3 and P6 choose the *focus* and *view*. In addition, P6 enhanced that the dimensions can be combined once they complement one another. In this wake, P3 said that using two or more dimensions is more appropriate, in her opinion. According to her, it provides the end-users with more information. On the other hand, P5 commented that even though the dimensions can be combined, there are situations in which they cannot be used. For example, regarding the narrative built (see Figure 2), they chose the partitioned poster and annotated chart genres. In her opinion, these genres could not be used with the sequence dimension. In addition, these genres can be combined with more broad ones, such as the slideshow genre.

P2 added that the sequence dimension could be used for the cases in which the designer realizes that it is better to split the narrative into separated points. Moreover, for P2, the dimension focus is the foremost opportunity to dive the end-user into the narrative.

Concerning the conceptual meaning of the dimensions, P1 asked the other session participants what they understood as the sequence in a narrative. He asked whether a slider allowing the readers to explore data evolution over time could be considered to belong to the sequence's exploratory dimension. P5 replied, commenting that the sequence fits the situations in which the slideshow genre is employed, i.e., the story is organized as a sequence of separated points. P2 reinforced that the interacting technique mentioned by P1 belongs to the exploratory dimension of focus.

The topic of **providing readers with explicability facilities** encompasses participants' remarks on the need to aid the end-users while interacting with the narrative. For example, during the narrative design planning, P5 observed that although they have picked up visualization techniques, genres, and other narrative techniques to tell a story, they should consider providing users with explicative facilities. According to P5, these explanations should be placed in specific narrative points or moments. Otherwise, the narrative would become a group of visualizations without relations within a partitioned poster. In addition, P5 added that these explanations should state the initial perspective of the narrative and its intent. Then, while interacting with the exploratory resources, the readers would be able to compare the initial narrative state with the one he/she reached after the exploration.

Following the debate, P3 inquired how these explanations would be shown within the narrative, i.e., whether they form an initial introductory page before the partitioned poster or placed in the partitioned poster themselves. P5 replied that these explanations should appear altogether the other information in the visualization. The idea behind it is to provide end-users with the narrative context. Therefore, these explanations should be fixed in the partitioned poster to maintain the narrative context and intent. In other words, it means that the remaining partitioned poster information will be updated by readers, except the explanatory ones. P6 agreed that these explanations should contain generic information to instigate the readers' inferences.

The **relation between narrative genres and exploratory dimensions** contains some participants' reasoning about how the

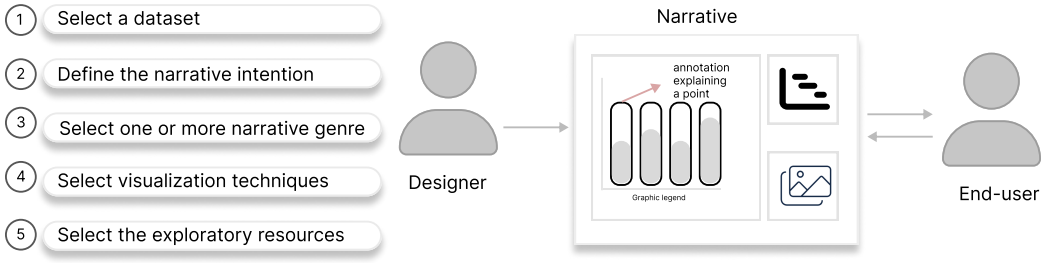

Figure 2: Process of designing narrative data visualizations with exploratory techniques

genres could be matched to exploratory dimensions. In this sense, P6 commented that the dimensions of focus and view were more suitable to the genre (partitioned poster) they chose. In addition, P6 provided a counterexample explaining that the dimension focus would hardly be combined with a comic strip once this genre does not allow filtering, for example. P3 agreed that each genre could contain resources from one or more dimensions or even could not contain any.

The **narrative's target public** concerns about for whom the narrative is being developed. By arguing the importance of the three exploratory dimensions, P2 highlighted that as essential to define what exploratory resources will be provided is to identify the narrative's target public. Hence, P2 argued that the exploratory dimension of the sequence is the most suitable to cover a broader target public once it allows the designer to decouple the narrative into different parts that support the story. By adopting this strategy, the designer can provide initial information that explains meaningful points, which is interesting for layman readers on the topic.

P5 mentioned users' data literacy area, a topic aimed at investigating how users understand data visualization. She said that, to her knowledge, no research seeks to investigate the users' literacy regarding narrative techniques. In addition, such research would provide the designer with information to assist the decision-making process of planning and designing a narrative. P2 complemented P5 speech adding that the designer is responsible for guiding the reader through the story. Due to this, the designer should not expect any reader's training on the topic but interest. P3 highlighted the study required to identify such required training. Because even whether the visualization is made as simple as possible, it is impossible to infer that it will reach users' expectations.

Regarding this subject, it is significant to mention that four of six participants also teach data visualization to learners, which makes them able to reason about such requirements. In addition, we plan to conduct studies with end-users to investigate this topic further.

5 DISCUSSION

In this section, we discuss the results obtained from our focus group regarding the theoretical concepts that anchor our study. Before proceeding to the discussion, we must enhance how we organized the discussion. Therefore, to improve comprehension, we organized the section into two topics. In the Subsection 5.1, we analyze the participants' choices regarding the narrative techniques, whether they are related to Segel and Heer [25] outcomes or Thudt and colleagues [28]. In addition, we take a step forward in the concern for whom the narratives are made that were raised during the activity. Following, in the Subsection 5.2 we present the second topic, in which we address the choices made by participants in the light of Semiotic Engineering. Therefore, we take the exploratory dimensions picked up and the resources they could provide to discuss the exploration planned in the focus group regarding the semiotic dimensions of *expression*, *content*, and *intent*.

5.1 Participants' choices

While performing the tasks they analyzed the possibilities that each genre may provide. Initially, they considered employing the slideshow to build a narrative with the progression of the information shown. The participants' intention was first to introduce some concepts to readers, then let them proceed with the exploration. This approach resembles the martini glass structure [25] in which the information is gradually presented to readers. However, after a round of arguments, they decided to plan the narrative using the partitioned poster.

The primary reason for this choice is that the participants realized that the partitioned poster is versatile, i.e., it can accomplish one or more visualizations, images, or texts that aid the narrative. Hence, the participants also decided to use an annotated chart to provide users with a visualization containing the explanation of the data exhibit. Nevertheless, the participants lack a structure that informs the readers about the visualization context and the designer's intentions.

Considering this situation, the participants decided to customize the partitioned poster with explainable resources. They assumed that these parts of the narrative should not be updated whether the readers change some visualization parameter. By deciding on this characteristic, the participants shed light on the importance of keeping readers aware of the context of the narrative. In this scenario, it may be worth investigating whether aid systems could be employed associated with a partitioned poster to inform readers of the context.

Following the activities, we identified another research opportunity. While defining which dimension they would employ to provide narrative flexibility and consequently allow the users to explore the story, the participants justified the choice. They opted for focus and view. Although they recognized the significance of the three dimensions, they commented that focus and view dimensions best fit a partitioned poster.

According to the participants, the former is essential to provide users with the feeling they are controlling the pace of the narrative; the latter is essential to provide some interesting interactive resources, such as drill-down. Hence, considering the choices taken, one perspective is to address studies investigating how the exploratory dimensions could be combined with the narrative genres.

One significant point raised during the sessions was the end-user profile. As a general assumption, they stated that the designer should not expect technical skills from readers. At this point, we agree with them once one of the primary goals of EUD is to allow users non-skilled to perform advanced tasks. In addition, we can assume that the participants were planning a visualization for users belonging to the same community (inward). Although we cannot take it for granted, this assumption may reduce the cognitive burden required to interact with the visualization.

5.2 Semiotic characterization

As mentioned before in this work, Figure 1 shows the combinatorial possibilities of semiotic engineering. It was proposed to analyze the modifications users may introduce while interacting with EUD environments [9, 27]. There are seven types of combinations. Types A to C keep the intent, whereas types D to G expand the scope of the intent. Each gray area represents the dimension(s) that change(s) in each possible interaction.

While planning the narrative in their EUD environment, we can observe that the narrative planned contains flexibility characteristics that place it within the types A to C, i.e., intent reencoding. Therefore, it can be explained that the participants desired to provide users with exploratory resources without letting them change the narrative freely.

By choosing a dataset and defining an intention, the designer can reason about which dimension best approaches the flexibility in the narrative she or he wants to make available. Our participants chose two exploratory dimensions: focus and view.

The focus dimension provides designers with resources to plan the story to let readers access a particular set or subset of the data shown and the aspects of data that are shown, such as aggregation. In addition, this dimension encompasses interacting techniques such as filtering, selecting, and drill-down.

Look at the choices made by our study participants (Table 2). Therefore, considering the manipulation possibilities, the participants planned a narrative in which readers may perform type B or C modifications. For example, we may assume that the B type happens when the reader applies a filter or selection and maintains the same graphic type showing the data.

In this sense, one may claim that all content changes will always imply changing the expression, i.e., C-type. It sounds true if we consider the values shown in the graphic as the expression, so filtering will modify the values within a chart without affecting its type. However, we may contrast this interpretation by replacing it with a more abstract one. Imagine that after applying some filtering, the reader keeps showing the data employing the same technique, such as a bar chart. The way readers understand a bar chart will keep the same independently of its values. That is why we claim that this is a B-type.

Regarding the above, the C-type will happen when the user modifies the graphic type in addition to filtering, for example, from bar chart to line chart. It may happen by user action or by recommendation of the system, in the case of algorithms that recommend visualization techniques according to the data type.

The second exploratory dimension picked up was the view one. According to Thudt et al. [28], the flexibility in the view could be reached by providing views that show separately the same data side by side. We can argue that the partitioned poster planned during the focus group naturally accommodates this flexibility once it allows the designer to place visualizations side by side.

Finally, as posed by Thudt et al. [28], the designers of the narratives must carefully evaluate whether the readers will engage with an exploratory visualization. It leads us to consider Visual Analytics (VA) methods [1, 14] to evaluate the user interaction with narratives.

6 FINAL CONSIDERATIONS

EUD and narrative data visualizations are trend topics within the HCI community. These topics have attracted researchers due to their potential to empower end-users to achieve meaningful activities and allow them to explore data within a context.

In this work, we show the results of a research project to support designers and end-users in data exploration. While the designers can create a narrative and assemble it with exploratory techniques to bound readers in their intent, the readers could experience their own story by customizing what is shown. From our results, we could realize how designers perceive the use of narrative genres in practice. In addition, they provide valuable insights regarding how to add explainable resources to keep readers aware of the narrative's intent.

The results represent our interpretation of the information obtained from the focus group analysis. To reduce the interpretation bias, we held meetings among the authors to discuss the analysis produced. Moreover, from our analysis we envision a set of future works that we believe will help us to refine our research on understanding narrative visualizations with tailoring resources. Following we list them.

- Regarding the user's literacy in narrative data visualizations and their resources, it may be helpful to investigate it in the light of Visual Analytics methods. The methods can provide many insights about VA workflow and can be used in behavioral and provenance analysis [1, 14].
- Investigate how the narrative genres could contain resources from one or more exploratory dimensions. This research could enhance the process of decision-making related to how the narrative will be shown to readers.
- Investigate how help systems could be used to assist the designers in the task of maintain users aware of the visualization's context.

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