VISUALIZATION ONBOARDING DESIGNED BY USERS: AN EMPIRICAL STUDY

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ABSTRACT

Visualizations have become more complex in recent years so that users need to learn how to use these systems. Onboarding systems can help users to learn how to interact with a visualization efficiently. Simple tutorials are often not sufficient. There are still open questions on how to design such onboarding systems. So far, a few usability studies have been conducted to clarify this issue. We decided to adopt an approach using sketching. We conducted a study with 29 participants. Possible users of onboarding systems were asked to develop prototypes of an onboarding system based on sketches. The process of developing these prototypes and the results were analyzed in a qualitative study. We can show that onboarding systems should follow a step-by-step approach and be integrated into the visualization. In addition, it seems that questions, tasks, and examples should be part of an onboarding system, so that users can try out how to use the system on their own.

KEYWORDS

Visualization Onboarding, Qualitative Evaluation, Prototyping, Sketching

1. INTRODUCTION

Information visualization (InfoVis) is becoming mainstream, especially since the COVID pandemic (Grammel et al., 2010). The general audience got in touch with diverse data visualizations presenting medical data such as reproduction numbers, COVID-19 cases, hospitalizations, etc. Using data visualization effectively can be demanding for first-time and inexperienced users (Börner et al., 2016). Having a low level of visualization literacy (Boy et al., 2014; Börner et al., 2016; Galesic and Garcia-Retamero, 2010) leads to incorrect conclusions and to frustration or rejection of otherwise powerful data visualizations (Börner et al., 2016). Onboarding systems can assist users to interact with visualizations more efficiently. Approaches from educational psychology can help to create successful onboarding systems.

While there is some research on how to design onboarding systems (Stoiber et al., 2022a,c, 2021; Chundury et al., 2023), there are still some open questions. Some empirical evidence indicates that onboarding systems integrated into the visualization (in-situ onboarding) are more acceptable to users than external onboarding systems, and step-by-step approaches also seem advantageous (Stoiber et al., 2022c). On the other hand, it is not yet clear whether users would, for example, appreciate videos for onboarding or whether an abstract approach that explains only the functionality of the system without any concrete examples is better than an approach using a concrete data set. To clarify the open questions and get additional support for the existing results, we conducted a study inspired by constructive visualization (Huron et al., 2014a; Huron, 2014; Grammel et al., 2010). We developed a concept for an investigation based on the observation of study participants explaining a visualization to other study participants. The idea was that one group of participants (group A) should learn a visualization called Netflower (Stoiber et al., 2019) by themselves and then explain Netflower to participants from another group (group B). Participants from group B were supposed to sketch a prototype for an onboarding system based on their experience in a Zoom meeting.

Netflower (Stoiber et al., 2019) is a visual analytics tool in the form of a web application that was developed primarily for data journalists. It visualizes network flows, such as the number of asylum seekers between countries, using a Sankey diagram and multiple bar charts, shown in Figure 1. It provides various filtering

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options and interactive features, including hovering and click-for-detail interactions, which may not be immediately obvious to users.

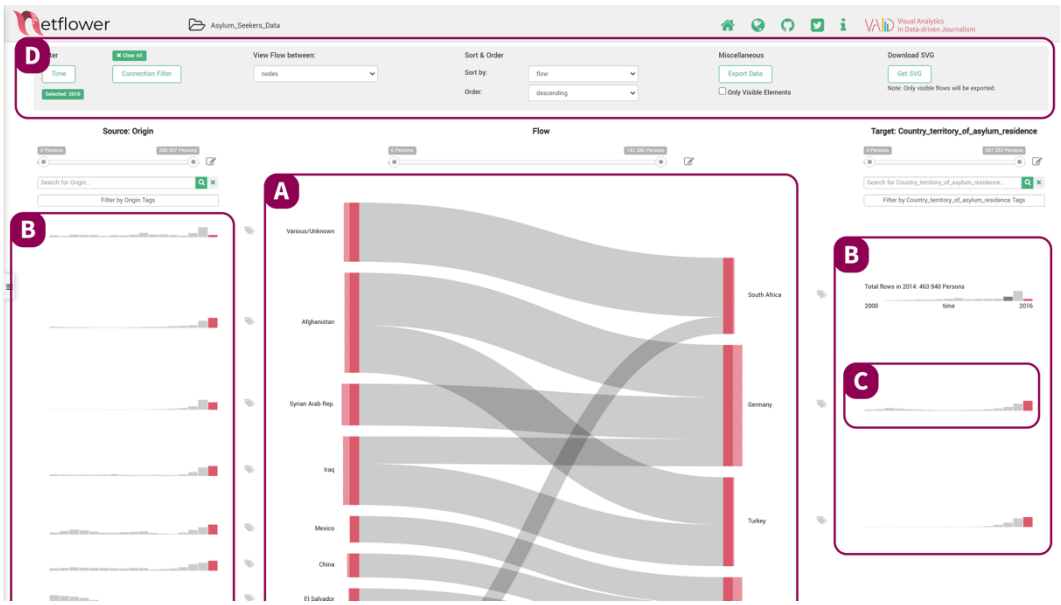

Figure 1. Key Features of Netflower. The main visualization consists of a Sankey diagram **A**, showing the flows between nodes. It is read from left to right, as the left nodes represent the origins of the flows, and the right nodes represent the targets. It is supported by bar charts **B** to the left and right, showing the development of all flows to or from one node along the time axis. Hovering over a bar **C** in this chart reveals the labeling of the time axis, as well as the exact value for the sum of flows for this node at that time. The global filtering and sorting options, as well as the export features, are concentrated in the grey section **D** at the top. Not pictured are the buttons to show more flows in the Sankey diagram.

2. RELATED WORK

2.1 Educational Approaches for Visualization Onboarding

Visualization onboarding methods (Stoiber et al., 2022c) aim to support end users in comprehending data visualizations and taking full advantage of the tools at hand. In this context, different educational approaches have been suggested (e.g., constructivism, and especially scaffolding).

In the current literature, Tanahashi et al. (2016) investigated *top-down* and *bottom-up teaching methods* and *active* or *passive learning types*. The bottom-up teaching method ("textbook approach") (Zeid et al., 2011) focuses on small, detailed pieces of information that students then combine to get a better understanding. Conversely, a top-down teaching method is given when a broad overview first helps to understand the abstract, high-level parts of an idea/topic, which then provide context for understanding its components in detail (Tanahashi et al., 2016). Furthermore, a distinction can be made between active and passive learning types. Passive learning means that students only receive the information without participatory dialog. In contrast, active learning describes an active participation (Tanahashi et al., 2016).

In their comparative study, Kwon and Lee (2016) explored the effectiveness of *active learning* strategies. Three tutorial types—static, video-based, and interactive —were used to support the learning of parallel coordinates plot visualizations. They observed that participants who used interactive and video tutorials outperformed those who used static or no tutorials. Their analysis indicates that top-down exercises were more effective than bottom-up and active learning types, with top-down tasks being the most effective.

Ruchikachorn and Mueller (2015) found out that the *learning by analogy* concept is helpful as participants in their study could entirely or at least significantly understand the unfamiliar visualization methods better after they observed the transitions from the familiar counterpart. The authors also describe another advantage of learning-by-analogy over other forms of demonstrations, such as textual or oral descriptions: the power of visuals, as they bridge any language barriers.

Stoiber et al. (2022c) developed four onboarding concepts (a step-by-step guide, scrollytelling, a video tutorial, and an in-situ scrollytelling). They conducted two quantitative comparative user studies with MTurk workers and a qualitative comparative user study with students. The main aim of these studies was to investigate the effect of onboarding on user performance and evaluate the subjective user experience. They proposed guidelines for the design of visualization onboarding methods, in particular, (1) onboarding systems should be integrated into the visualization tool; (2) use of an easy-to-understand data set and concrete examples on how to read the charts is vital, they support and increase comprehension; (3) to-the-point descriptions make it easier to absorb information (step-by-step); (4) Some users tend to ignore onboarding systems, even if they struggle. These users have to be motivated to use onboarding. Additionally, the authors explored abstract and concrete onboarding instructions and assessed them in a quantitative comparative user study with students (Stoiber et al., 2022a).

2.2 Involving Users in Visualization Creation

There is increasing research on how non-expert users create information visualizations. This kind of research has been inspired to some extent by the work of Seymour Papert (2020). Papert assumes that learners should interact with concrete objects to discover their properties (discovery learning) rather than learn in a more abstract way. One approach has been to investigate the sketching processes of non-expert users (Grammel et al., 2013). The authors argue that, while novices might be reluctant to express their ideas using a software product, they had fewer problems producing a sketch of a visualization. Sketching also yields interesting results because it may reveal the users' thought processes. Roberts et al. (2015) use sketching as a method to teach visualization design to students. They aim to enable students to study a large range of different solutions and, in that way, encourage their creativity.

Another approach that is better able to represent dynamic visualizations is constructive visualization (Huron et al., 2014a). Constructive visualization states that users should engage in the construction of their own visualizations by using familiar objects. Huron (2014) argues that non-expert users often have difficulties creating appropriate visualizations when they use off-the-shelf software. A possibility to overcome this problem is to use tangible tokens (e.g., Lego bricks or beads), that is, physicalization. This is the main idea of the constructive visualization approach. Huron et al. (2014b) observed users develop their own visualizations. This kind of research clarifies how the visual mapping process of non-expert users works. Their research indicates that this process deviates significantly from the processes suggested by commercial software to develop visualizations.

The idea of constructive visualization inspired our own approach. However, it should be pointed out that adopting physicalization for developing an onboarding system would be difficult. Therefore, we decided to use sketching (in combination with written explanations) to develop prototypes of onboarding systems. Despite the criticism, sketching can provide interesting insights into potential users' ideas about how to design such systems. From prototypes developed by our study participants, we aim to derive design recommendations for onboarding systems.

3. INVESTIGATION

3.1 Study Design

There were two groups of participants. Group A participants had to explain Netflower to group B participants. First, participants from group A had to fill out a questionnaire with open-ended questions. This questionnaire mainly contained questions about how they intended to convey information to participants from group B. It provided us with information about the educational theory they wanted to adopt. Basically, there are two

different approaches: a cognitivist approach (Ertmer and Newby, 2013) based on an expository teaching style or a constructivist approach (Sawyer and Greeno, 2009; Duffy et al., 1993) based on solving examples or gamification. We wanted to know which approach the participants wanted to use.

Second, we conducted Zoom meetings where group A participants explained Netflower to group B participants, and we recorded these Zoom meetings. We assume that the analysis of the recordings of these meetings can provide us with insights into how participants would go about conveying information about visualization in a face-to-face setting.

Third, participants from group B had to fill out a questionnaire with open-ended questions and develop a prototype for an onboarding system. The prototypes consisted of sketches with explanations of the functionality of the system. In previous studies, participants tested existing onboarding systems. It might be argued that this is restrictive because participants can only decide about these existing systems. When they design the onboarding system, they can express their ideas and preferences without constraints.

This is a report about ongoing research. We will present results from the questionnaires completed by group A and the prototypes developed by group B. We will not present the results from the analysis of the recordings of the Zoom meetings. We used qualitative content analysis (Schreier, 2012) to analyze the data from these two sources.

We will address the following two research questions:

RQ1: What kind of educational approach do participants adopt to teach Netflower to another participant?

RQ2: What kind of prototypes do participants develop for onboarding purposes?

The answers to these two research questions should enable us to get more detailed information about designing efficient onboarding systems.

3.2 Participants

The persons participating in this investigation were students of computer science who were enrolled in a master's program. This means they had some previous knowledge about various diagram types and that they had experience using visualizations.

21 participants identified as male, and 8 identified as female. Of 29 subjects, we randomly assigned 15 subjects to group A and 14 to group B. However, we excluded one participant from group A and one from group B, as they did not submit reasonable input. After removing their answers from the data set, we have 14 documents from group A and 13 documents from group B. We base our results on the analysis of these documents.

4. RESULTS

The following results are based on the developed prototypes and the answers to the questionnaires. We used qualitative content analysis (Schreier, 2012) to interpret the results. Two of the authors conducted this analysis. We primarily used codes based on previous research (Stoiber et al., 2022a,b), but a few additional codes were developed during the coding process. The analysis was pursued until an agreement between the two authors was reached. The results of the most interesting topics will be discussed in the following. The main issues addressed by the participants are highlighted in the discussion of the results.

4.1 Results Group A

Group A had to learn Netflower themselves and then teach it to participants from group B. They had to fill in a questionnaire with open-ended questions on how they learned Netflower and how they planned to teach it to the participants from the other group. We wanted to know what educational approach they would use to teach Netflower.

How did you proceed with learning the tool Netflower? Eight participants started with the tutorial and then solved the tasks. Four participants ignored the tutorial and just explored, and two participants ignored the tutorial and just solved the tasks. In general, participants from group A learned about Netflower in a very interactive and explorative manner. P12 said about the tutorial, *"I first tried to read the tutorial, but I found it*

a bit tedious and dull without having the visualisation directly in front of me. Therefore, I eventually skipped the tutorial, opened the visualisation and started by trying to solve the tasks right away."

Will you start your explanation with the visualized data or with features of the tool? Starting with the data implied that a concrete dataset was used as an example (e.g., the asylum seeker dataset in our example), in contrast to a procedure where the functionality was explained without referring to a concrete dataset and on a more abstract level. An abstract explanation would just state, for example, that a Sankey diagram shows flows from an origin to a destination without reference to any concrete data. Ten participants said they would start with examples using domain data. Four said they would start with a brief abstract introduction about the tool and then talk about the application examples using domain data. Participants apparently preferred to use the dataset provided by Netflower to explain its functionality. Nobody wanted to adopt a completely abstract approach.

What approach do you want to adopt when you teach Netflower to the participants from the other group? Nine participants said they would present information and then answer questions. Four participants said they would instead work through tasks together. However, all participants planned to present examples from the currently loaded data set during their explanation. The participants' ideas about how to teach Netflower to other participants rather follow a cognitivist approach, mainly consisting of presenting the system and answering questions.

4.2 Results Group B

Group B participants had to develop prototypes for visualization onboarding systems. Again, we were especially interested in what kind of educational approach participants would choose for their prototype and whether they would rather suggest tutorials or more interactive kinds of prototypes.

What are the main ideas for an onboarding system of the participants? Most of the participants described onboarding systems based on a step-by-step system (mentioned six times). As a motivation for this, P3 explained, *"If I had to follow a tutorial instead of having it explained to me by someone else, I would like it to have a similar structure. That is, showing different parts of the visualization one by one, explaining what they represent and how they can be interacted with"*. This step-by-step system was usually opened within the Netflower system (in-situ). This approach was often combined with a feature providing hints to the users when they needed advice (mentioned seven times). Only three participants described an onboarding system that was primarily a video tutorial. One of these solutions was a video tutorial integrated into Netflower (in-situ). The other two solutions suggested having first a short video tutorial before using Netflower and then solving interactive examples. It should be mentioned, however, that some of the other prototypes also contained videos, but only as supplementary material.

Two participants suggested tutorials. One of these solutions is not in-situ but suggests that users open Netflower simultaneously and solve an example. The other tutorial consists of a brief introduction to the system before starting Netflower, and then users should solve an example. One participant suggested using gamification to teach Netflower. It is an open question whether gamification is an efficient approach for onboarding.

It is obvious from this overview that participants are skeptical about classical tutorials that should be read before using the system. This does not seem to be a solution that the users appreciate. Most of the systems are integrated into the Netflower system (in-situ), use a step-by-step approach, and use some form of interactive examples. Most of the prototypes rather follow a constructivist educational approach, so users have to develop their own mental model about the system Netflower actively.

Did they integrate elements of the explanations they got in the Zoom meetings? The answers concerning this question are very heterogeneous. Three participants mentioned that the step-by-step approach in the Zoom meetings inspired them also to adopt a step-by-step approach. Three other participants said they did not make use of their experience in the Zoom meetings. All other ideas originating from the Zoom meetings were only mentioned once (e.g., explaining through examples, focusing on hard-to-understand areas, and videos with explanations instead of text).

Did the participants use data-oriented (with examples) or abstract onboarding instructions? It is still not clear whether explanations in onboarding systems should rather be abstract or use examples with specific data. The participants of our study predominantly developed systems that are data-oriented and not abstract. There is only one person who used an abstract approach.

Was onboarding provided before or during interaction with Netflower? All participants stated that onboarding should take place while users work with Netflower. There are two special cases where the participants planned to have a short video tutorial before the users started to work with the system. In one case, the tutorial and Netflower were supposed to be open simultaneously.

Did participants design in-situ or external onboarding? Participants also found that onboarding should take place within the system (in-situ) and not be offered as a stand-alone system (external). Only one participant suggested an external system, and two suggested a combination of both approaches. These are the same exceptions as the one described in the previous paragraph.

Did onboarding support defined steps or free-to-browse options? Several participants planned for a step-by-step onboarding system. The idea is to follow steps in a pre-defined order. Eight participants adopted this approach. Three participants suggested a hybrid approach where it is possible to skip some of the steps. One participant suggested that users should be completely free to browse the system, and another did not specify whether to use defined steps.

Explanation of "reading the chart," "interacting with the chart," and "using the chart". The structure of onboarding explanations is based on work by Stoiber et al. (2022c, 2021). The onboarding stage "Reading the chart" explains the visual encoding (e.g., size, color); "Interacting with the chart" helps the user to understand the interaction concept. "Using the chart" guides the user towards further insights (e.g., making comparisons, identifying value, etc.). The analysis of our data shows that participants planned for explanations concerning "reading the chart" (12), interacting with the chart (12), and using the chart (7).

How did onboarding support interaction (Tasks/Questions; Worked Examples)? We wanted to know whether participants included tasks, questions, or examples in their prototype. A specific case would be worked examples, that is, examples where a path to a solution and the solution are provided. This category also included cases where the onboarding system gave hints to the users on how to solve a task. Nine users included questions or tasks in their onboarding system, seven included worked examples. Only two users did not use any kind of tasks or examples. P10 explained why s/he appreciated examples *"Following along an example does not only explain what you can do but also why you should do it"*. P14 explained why it was so important to use examples: *"I think that these tasks greatly impacted my decision on how to present Netflower. Because I worked through these tasks in exactly that order I had already a strategy for "learning" Netflower which is very similar to the tasks and the tutorial."*

Features: (multimedia, possibility to skip, possibility to repeat later, pop-ups, progress bar) Multimedia: We defined the category multimedia broadly. Everything apart from the text was coded as multimedia. Eight participants wanted to use multimedia in their system (mainly video or animation), and five only wanted to use text. Possibility to skip: We wanted to know whether the planned onboarding systems would force the user to study the whole system or provide the possibility to look at just the material that interested them. It is a bit surprising that many of the participants intended to force users to work through the whole material (8), and only a minority (4) allowed the users to skip material they did not need. It might be argued that it makes sense for users to access only the information they need in an onboarding system.

Discard previous prototypes: We wanted to know whether participants explored possible solutions. Six of the participants stated that they had discarded previous solutions. The first drafts were generally less sophisticated and contained less interaction than the final drafts. One user started with a pre-recorded tutorial but mentioned that s/he wanted to involve the user more. Another one first developed a system with a step-by-step wizard that was not integrated into Netflower and was not interactive. Again, this was modified so that the final version was interactive and integrated.

5. DISCUSSION: LESSONS LEARNED AND LIMITATIONS

The current investigation provides some possible recommendations for the design of onboarding systems. It suggests that a step-by-step system integrated into the visualization is the most appropriate solution. Traditional tutorials or videos are not seen as an attractive possibility. Furthermore, the investigation indicates that questions, tasks, and examples should be introduced into onboarding systems to help users familiarize themselves with the visualization if needed. Participants also favored a more concrete approach, using concrete datasets as examples. For an overview of the results see Table 1.

Based on our investigation, we can answer our proposed research question presented in Section 3.1.

Table 1. Summary of the results of our analysis of the responses of the questionnaire

Group A	
Learn Netflower	tutorial, solve tasks
Teach Netflower to Group B	primarily domain data (concrete) Didactic approach: present information, answer questions, examples
Group B	
Main Ideas	step-by-step system, in-situ, interactive
	data-oriented, referring to data visualized
	defined steps
	use tasks or worked examples

RQ1: What kind of educational approach do participants adopt to teach Netflower to another participant? Participants suggest a cognitivist approach to teaching Netflower: presentation, questions, and answers. Besides, they would use concrete onboarding instructions to refer to the data visualized.

RQ2: What kind of prototypes do participants develop for onboarding purposes? In contrast, the prototypes for visualization onboarding developed by group B participants follow a rather constructivist approach. They would integrate interactive step-by-step (defined steps) onboarding instructions, which are integrated into the onboarding system (in-situ). Additionally, concrete onboarding instructions are preferred.

We present ongoing research in this paper. We have not yet analyzed the recordings of the Zoom meetings. It is possible that this analysis may clarify some of these open issues. There are other limitations, that we would like to point out. So far, we have only analyzed the results of participants with some prior knowledge about visualizations. It would be interesting to investigate whether participants with more domain knowledge and less knowledge about visualizations behave differently.

6. CONCLUSION

We conducted an investigation to clarify how onboarding systems for visualizations should be designed. This investigation was inspired by constructive visualization approaches and used sketching for the development of prototypes for onboarding systems. The investigation yields some interesting new results. This indicates that the approach using sketching is able to clarify issues that were not previously identified.

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