Educational Data Comics: What can Comics do for Education in Visualization?

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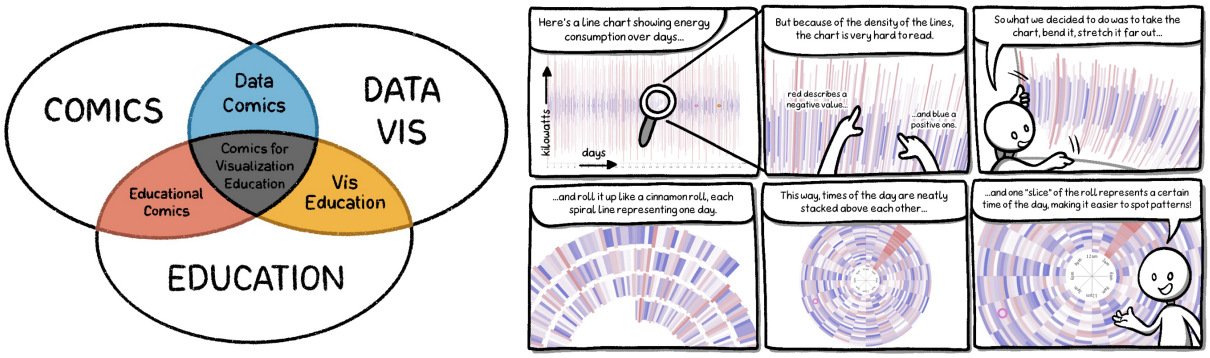

Fig. 1: *Left:* The related research areas and their overlaps form the research landscape we scoped in our initial literature research. *Right:* An example of a data comic explaining the visual mapping of a spiral chart based on a line graph.

Abstract—This paper discusses the potential of comics for explaining concepts with and around data visualization. With the increasing spread of visualizations and the democratization of access to visualization tools, we see a growing need for easily approachable resources for learning visualization techniques, applications, design processes, etc. Comics are a promising medium for such explanation as they concisely combine graphical and textual content in a sequential manner and they provide fast visual access to specific parts of the explanations. Based on a first literature review and our extensive experience with the subject, we survey works at the respective intersections of comics, visualization and education: data comics, educational comics, and visualization education. We report on five potentials of comics to create and share educational material, to engage wide and potentially diverse audiences, and to support educational activities. For each potential we list, we describe open questions for future research. Our discussion aims to inform both the application of comics by educators and their extension and study by researchers.

Index Terms—data comics, educational comics, visualization education, visualization literacy

1 Introduction

With the increasing spread of visualizations and the democratization of data visualization tools, we need better ways to teach and learn about visualization techniques, concepts, and correct applications. For example, the general public was recently introduced to various data visualizations presenting medical data such as reproduction numbers, Covid-19 cases, hospitalization, etc. [41]. However, visualization beyond simple bar- and line charts is rarely taught in the course of general education, which results in a low visualization literacy among the public [10]. This can be a problem considering that a lot of data can only be thoroughly explored through less widely known, possibly even interactive visualization techniques, even though the interpretation of such data is vital to decision-making. While there is a growing literature on education methods, including workshops [53], evaluation methods [11], onboarding [45, 46], visualization literacy assessment tests [35], and teaching approaches [9, 24], we need to focus on providing efficient and effective resources to learn visualizations outside traditional classroom settings and in situations of *informal learning* that occur away from a structured, formal classroom environment: self-learning, online learning, and professional development.

In this paper, we discuss educational data comics, i.e., comics used in the context of education in data visualizations. Comics combine graphical and textual content into concise representations, they provide sequential explanations, they rely on familiar visual languages and reading conventions, they can appeal to a diverse audience due to a wide variety of styles, they can be easily shared and read, and they provide quick access to graphical content across a page, as compared to, for example, a video which has to be played in order to access all the content. In the past, comics have been successfully used to explain and disseminate concepts in science [12] and medicine [1], have found their way into the classroom [19, 42, 43], and have been used to explore visualization design through creating data comics [53]. For these reasons, we think it is timely to ask: *What can comics do for education in visualization?*

2 Method

Work related to our question is found in the overlaps of three large areas: *comics*, *data visualization*, and *education* (see Figure 1). Since each of the overlaps is a topic large enough to warrant multiple structured literature reviews, which is out of scope for this paper, our approach is based on triangulating scientific literature from these areas. We first surveyed publications for each overlap in Google Scholar, using the keywords *data comics*, *teaching with comics*, *visualization teaching*, and *comic visualization*. Then, we surveyed the first 10 result pages of the digital libraries of ACM, SpringerLink, IEEE Xplore, and Sage Journals with the same keywords. We included or excluded papers in our starting sets for each overlap based on their titles, and when in doubt, the abstracts, based on the following criteria: *Data comics:* Does the paper use comics to present or reflect on data through vi-

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sualizations? *Educational comics:* Does the paper report on the use of comics to educate the readers or creators on specific topics? *Visualization education:* Does the paper report on theories, methods, or activities for teaching data visualization? Additionally, we preferred papers published after 2015 for the starting sets. To further identify important and possibly older work in the respective areas, we used the reference snowballing method described by Wohlin [58], including and excluding papers according to the same aforementioned criteria. This process led us to a total of 50 papers. Our team regularly met over multiple weeks to discuss **methods** and **open challenges** with respect to comics for education in visualization for each overlap area that we could identify through the initial literature research and our extensive experience in these areas.

We discuss five potentials of comics for visualization education (section 4), such as sequentiality of visual and textual explanations, easy creation, enhanced engagement, media independence and flexibility for class activities.

3 Scoping the Research Landscape

3.1 Education in Visualization (*Education+Visualization*)

State-of-the-Art—Visualization literacy and teaching visualization gained special attention in the last few years (see recent formats such as the 2021 IEEE Special Issue [4], the 2021 IEEE VIS Panel Discussion [2] and the 2022 Dagstuhl Seminar [18] on the topic) and led to a plethora of methods and techniques. These include textbooks, online tutorials, graph libraries, tool libraries [38], interactive tools [14], and more. A wide range of materials and activities are good to cover a wide variety of education scenarios, people, and tasks associated with learning and education. Textbooks are great for theoretical and holistic overviews and provide very curated lenses by authorities in the field, and online tutorials can provide step-by-step illustrations of visualization programming or explanations of visual mapping. Graph and tool libraries provide entry points to larger collections of items and might come with criteria for filtering and browsing. Interactive tools have been used to help students learn visualizations more effectively than through slides [13]. Attempts to help users in taking full advantage of complex visualization tools have been made in visualization onboarding research [46] as well as in user assistance and guidance in visual analytics contexts [44]. Efforts have also been made to teach visualization skills early in elementary schools using tablet applications, e.g., [3, 9]. Both papers report on the capability of elementary school pupils to create meaningful visualizations and the critical engagement with the visualization process which leads to productive discussions. Alongside resources for education, a series of recent workshops on VisActivities [21] is stressing the importance of hands-on activities over sole instructional learning. At the same time, activities always either require some sort of material, such as cards [53] or dedicated instructions, and the incorporation of such activities has only recently received attention in research [24].

Open Questions—Most of the actual learning in visualization is still happening in traditional classrooms with an instructor and students. However, there is a need to address scenarios of informal learning such as self-learning, online learning, asynchronous learning, professional development, playful learning, or hands-on activities. There are many scenarios where practitioners require knowledge in-situ, e.g., while they engage in visual analysis. This can happen as part of active visual analysis, the communication of results, a collaboration with visualization creators, or a specific visualization design exercise. The added value in learning in such scenarios has been pointed out in a study by Kwon and Lee [27]. However, we also need to reach diverse audiences, such as children, disabled people, or people without access to the internet and media. Specific learning disabilities such as dyslexia might have to be considered when designing such learning materials. Future resources (and activities) must provide effective means to explain visual concepts and strategies such as visualization techniques, construction and interaction processes, design thinking and design tradeoffs, user interfaces for tools, visualization algorithms, illustrating examples of good and bad (deceptive) visualization designs, and many more. Addressing these questions requires the creation and employment of novel educational resources and media for education. In analogy to the *Seven Genres* in narrative visualization [40], we think of comics as one possible genre for visualization education with potentials especially in supporting self-paced reading, easy sharing, visual accessibility, or suitability for low-literacy readers (see section 4).

3.2 Educational Comics (*Comics+Education*)

State-of-the-Art—Educational comics have a long history and usually aim to educate the reader about different non-fictional scientific concepts. Their effectiveness in educational contexts has been examined in many studies across various disciplines. A result that all these studies share is that they are very effective for improving the audience's motivation and engagement, most notably through their multimodal nature, accessibility, as well as through using characters that enable emotional attachment and form a basis for self-reflection [12, 52]. A lot of educational comics have been designed for classroom use with children (e.g., English [22], Science [30], or Programming [48]), and efforts have been made to facilitate their integration into class [51]. Moreover, the popularity of non-fiction comics for adults is also seen in the rise of a book genre called *Graphic Guides*, which aims to explain different topics commonly discoursed in textbooks in an easily accessible format. Such guides have existed for longer (e.g., for statistics [50]), but the term has especially been coined by the publisher Icon Books, whose Graphic Guides series contains, as of 2023, almost 100 books[1]. Specific tools for the creation of educational comics are also emerging, e.g., on the topics of programming [49] or privacy concepts [47]).

Comics have also found their way into science communication, where they are valued for their ability to "humanize data" [1], and to promote public engagement with scientific topics [34]. For example, xkcd comics [33] explain various scientific concepts to the general public in a humorous way. They are frequently shared online, and their popularity lead to multiple related best-selling books. Another example of comics in science communication is *Graphic Medicine*,[2] a community dedicated to comics in the healthcare domain, from educational comics for students and patients to graphic memoirs of illness. Since 2010, there has even been an annual conference on the topic.[3]

Open Questions—Educational comics cover a wide range of topics and sometimes use visualizations to support explanations of scientific phenomena. However, the respective visualizations themselves and the knowledge required to properly read and apply them are not the focus of educational comics yet. For example, visual representations of concrete subjects (e.g., how a machine works) can be designed in a way that does not require any specific visualization literacy to be read. Often, these concepts are explained through analogies and metaphors, especially when the concepts are very theoretical or hard to grasp, such as math or programming [48, 49]. In contrast, data (e.g., statistics of vaccine effectiveness) needs to be effectively visualized before a comic can explain visualization types, their forms and shapes, the visual patterns we can identify and what they mean, etc. Hence, these educational comics do not face the same challenges as comics communicating data.

3.3 Data Comics (*Comics+Visualization*)

State-of-the-Art—Data comics communicate insights in data by deliberately using aspects of the comic medium (e.g., juxtaposition, captions, or panel layout) in the presentation or even as a part of a data visualization. Data Comics were first mentioned by Segel and Heer [40] in 2010, highlighting comics' potential benefits for communicative data visualization. Zhao et al. [61] were the first to describe the genre in detail, using characters to guide a reader through panels, presenting visualizations step-by-step, while Bach et al. [6] describe specific characteristics of data comics as four components: *i)* layout (ranging from open to sequential), *ii)* text and picture (ranging from rather text-heavy to image-heavy), *iii)* visualization (ranging from realistic renderings to

[1] https://www.introducingbooks.com/graphic-guides (Accessed June 26, 2023)

[2] https://www.graphicmedicine.org/why-graphic-medicine (Accessed June 26, 2023)

[3] https://www.graphicmedicine.org/comics-and-medicine-conferences (Accessed June 26, 2023)

very abstract sketches), and *iv)* narration (ranging from fully narrated comics with characters and stories explaining the respective context of the data to very factual comics reduced to the visualizations themselves). Study results comparing data comics to infographics and illustrated texts show that data comics are most engaging as well as effective in helping readers to understand [57], and might lead to a better memorability of content [60].

Since then, a range of applications and studies followed, investigating the genre in greater detail. This includes data comics to explain changes in temporal networks [5] or processes of setup, data collection, and analysis during controlled user studies [54]. The authors note that they can aid studies as support material or even act as an alternative to common reporting approaches. Unlike the character-driven approach by Zhao et al. [61], these examples use a more abstract style, focusing on the elements' visual consistency between individual panels and using the panels' innate narrative to convey insights about the visualization.

Considering the fact that a lot of data visualizations require interactive ways of exploration due to the density of underlying datasets, the potential of interactive data comics has also recently been examined [23, 55]. Adding interactivity to data comics allows for new ways of exploration, such as goal-driven navigation, displaying details on demand, changing story perspectives, incorporating branching storylines, or adding (personal) data. While studies show promising results, they also highlight great challenges especially in authoring interactive data comics, both on the technical and the conceptional side [55].

To support the creation of data comics, Bach et al. propose design patterns [7] which they successfully used in design workshops [53]. However, in these scenarios, the focus was on creating comics for data-driven storytelling, rather than teaching visualization. In such cases, or in the cases of data comics including very complex visualizations or explaining their underlying data in more detail, sketching them by hand can be cumbersome, which is why digital creation support in the form of authoring tools has been proposed as well [25, 60].

Open Questions—Similar to educational comics, most of the existing examples and studies have focused on explaining data *through* visualization, rather than explaining visualization techniques and concepts. More research is required about how to integrate words and visualizations into the narratives and visual styles in the comic layouts to teach different aspects of visualization, such as visualization literacy, usage, and creation.

Additionally, multidimensional, live, or very large amounts of data are likely to raise additional needs in data comic authoring. Making data comics for different audiences also raises questions, such as audiences with various literacy to data and visualizations. Although interactive data comics enable exploration, finding a balance between free exploration and guided narrative can be a challenge.

4 What Comics can do for Visualization Education

Considering the three topic spaces in our research landscape, we looked for work that sits at the intersection of education, comics, and visualization, by C1) *...using a comic representation*, C2) *...talking about or using visualizations of data as per our definition*, and C3) *...having an educational purpose for visualization*.

To the best of our knowledge, the only work that fulfills all of the aforementioned criteria is the visualization cheat sheets by Wang et al. [56] and the data comics workshops by Wang et al. [53]. Visualization cheatsheets use comic strips to explain how different visualizations (parallel coordinates, adjacency matrices, time curves, boxplots, confluence graphs, and treemaps) are constructed in a way that is understandable for novices (see Figure 2). This approach is similar to our example in Figure 1. Data comic workshops use data comics as a "hands-on" exercise for students to learn data visualization and storytelling. In a series of workshop sessions, participants collected data and designed visualizations to be used in their data comics (see Figure 5).

In an attempt to fill this gap in data comics research, we list potentials we identified through regular discussions among the authors who have extensive collective experience in teaching several visualization courses for both students and professionals over several years; running workshops on data comics (e.g., [53]), visualization, and sketching; as well as our extensive research on data comics [5–7, 54–57] and previous professional experience in comic illustration. The list is further informed by the literature review in the previous section and the open questions we identified. The potentials are mainly based on the specific characteristics of the comic medium, and each points to a range of possible scenarios in using comics in visualization education.

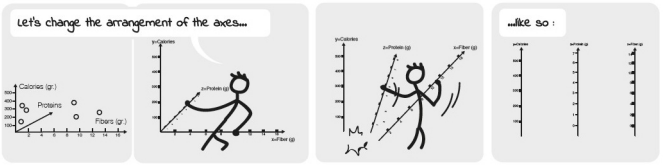

Fig. 2: A comic in the visualization cheatsheets [56] explaining the construction of a parallel coordinate plot.

P1. Foster learning through sequences of visual and textual explanations Many traits of comics naturally satisfy the requirements for effective learning. For example, Petterson [36] reports on how written teaching material is best presented. He notes that the content should be:

- ***parallel in structure*** *(i.e., parts of a sentence parallel in meaning should also be parallel in structure).* Comics employ parallelism by nature, not only through the connection of text and image, but also because previous panels are always easily accessible—either because they are on the same page/screen, or they can quickly be retrieved interactively.
- *conveyed through* ***repeated words and ideas****, and tied to prior knowledge.* This harmonizes well with the aforementioned ability of comics to refer to earlier panels through "flashbacks" and compare them to new content.
- *presented as* ***main ideas rather than details***. Data comics in particular have been successful in presenting the main idea along a narrative, with optional details being available when studying individual panels [5].

Due to the inherent visual nature of visualization, explanations about them naturally benefit from descriptions that are also visual. **Visual elements in combination with text** can lead to higher learning performance [36, 62] and most other explanation formats (videos, animated explanations, or life demonstrations) apply this combination of visuals and text. Applying visualization rhetoric [20] can also enhance memorability and learning. Another requirement of almost all explanations is a sequence of steps, especially in the case of complex concepts (e.g., the visual mapping of a more complex visualization technique) or a process (a design rationale). The technique of adapting the visual presentation of visualizations depending on users' level of familiarity has been proven promising [39] and is something that can easily be adopted by comics (e.g., in sequential panels). **Sequentiality also breaks down the complexity** of explanations and follows a specific process or logic. Our traditional explanation formats do follow this schema of sequence; however, they can restrict the learner as they take full control of the pace at which information is presented. This requires the learner to listen through the whole narration, take notes, and wait until the end to know whether their questions are answered in the course of the presentation. Comics have a more **open narration** instead of a strictly linear one and can allow the reader to skim the content first, see which points are addressed, and then proceed with more detailed reading, quickly jumping between panels whenever the narrative prompts them to revisit a previous step [7] (see Figure 3), or when they need to clarify something for themselves.

Comic explanations are also immediately visible and visually accessible. Readers can **quickly access the relevant parts** without, for example, having to manually scrub through a video timeline. Visual anchors in specific panels can help with this process. Similar to a video player showing preview images as the user hovers over the timeline, this can help navigate back and forth, only without having to actually

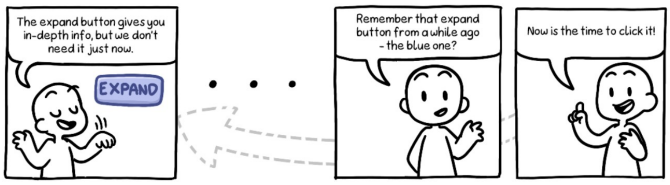

Fig. 3: Comics can prompt the reader to go back to a previous panel.

rewind. For example, the first panel of a comic could introduce an explanation (like showing a visualization system before it has been interacted with), while the last panel naturally shows the result (after such an interaction), which can help decide whether to read the full comic or not.

We imagine this potential being leveraged to explain concepts that require visual representations, including visual patterns and visualization techniques, showing and discussing examples of "good" and "bad" visualization design, and describing fallacies in interpreting visualizations as well as potential deceptions (as also experimented with in visualization cheat sheets [56]). Comics could also explain elements in the interface of an interactive visualization tool and describe interaction capabilities (see Figure 4), or encourage interaction for exploration (e.g., view change) [46]. Textual explanations can be provided as part of captions or annotations in each panel, explaining concepts that are hard to express with visual content alone.

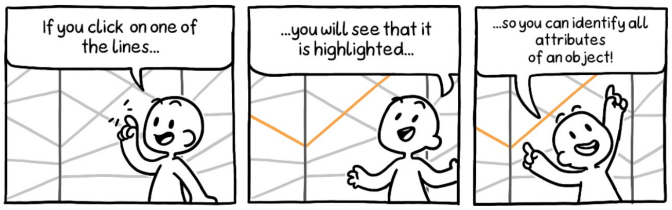

Fig. 4: A character explaining the highlighting of a line in an interactive parallel coordinate chart.

Apart from preliminary results [56], we have no recorded empirical evidence about the effectiveness of comics for visualization education yet. Future studies can compare educational data comics to e.g., videos and animated explanations, and should also investigate metaphors for explaining visualization concepts as well as ways to convey complex explanations. Eventually, we hope this will inspire explanations inside scientific papers and posters.

P2. Support creation and prototyping of learning resources Beginners often describe comic creation as effortful and requiring many diverse skills. While this might be true for professionally rendered and polished comics, comics are easy to storyboard by using just a pen and paper, helping to express ideas about visual explanations. Comics can be effective with even just stick figures (see *xkcd* [33]) and simple graphic explanations (see Figure 2). Through tools and libraries, comics can also be created without drawing at all: Apps like Comic Life[4] and Pixton[5], for example, offer comic templates and assets to mix and match and were designed with classroom use cases in mind. Other tools tailored specifically to more data-driven comics also exist [28, 61]. Additionally, the rise of text-to-image generation technology, such as OpenAI's Dall-E[6] and Midjourney[7], opens up possibilities of enhancing the creation of scenes and characters even more. In any case, creating comics is easier than video production and can be achieved by every instructor, from researchers providing explanations to their novel techniques [57] or teachers creating materials for their classes [51], to students drawing comics to explain their ideas to peers (see Figure 5).

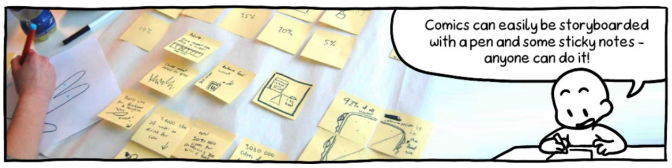

Fig. 5: Comics can be easily created by anyone. Visible in the background is a student's comic storyboard from a data comic workshop [7].

P3. Appeal to a variety of different audiences Comics can employ a variety of visual and narrative styles [29]. For example, comic **characters** can lead the way through a narrative, explaining topics almost on a person-to-person level, which creates room for self-reflection [12, 52]. Other comics completely refrain from using any characters. This way, they can be adapted to specific audiences, or hint towards a target group the comic explanations are intended for. Comics can be designed in **either playful and neutral** ways, depending on the presented topic and the target audience. For example, younger audiences might find comic characters more appealing, and visual embellishments on charts can enhance memorability [8] (see Figure 6). Students with learning disabilities could also benefit from the easy-to-access format [51]. At the same time, tools such as cheatsheets might favor a **more abstract style** akin to assembly instructions.

Comics appeal to a wide range of people, possibly enticing learners who are less acquainted with traditional instructional techniques or not attracted to commonly used learning media such as videos and textbooks. While they have different histories, comics share many traits with the highly related visual narrative medium of *"Zines"*. Especially the latter have flourished in marginalized communities as a medium to voice perspectives because they are easy to create, and at the same time engaging and memorable for readers. The potentials of zines in visualization pedagogy have been explored by McNutt [32]. Similarly, we suggest that comics can not only contribute to learning as a curated learning material, but that their **creation process constitutes a learning activity** in itself, offering an alternative way for learners to engage with the material on a personal level and stimulate critical thinking.

Comics **can also be short**, sometimes only a few panels for a single explanation, which can reduce the barriers to engage in reading. Additionally, studies have shown that **hand-drawn content can lower the participation barrier** to discussions on visualizations, as opposed to clearly rendered graphics [59]. Different from screenshots of visualizations and applications, drawings and abstract illustrations can also help focus on the most important concepts in an explanation. Other studies suggest that comics' engaging way of presenting content along a narrative can also increase the likelihood of readers memorizing the content [57, 60].

Fig. 6: Different styles of comics can appeal to different target groups: Left is a neutral style, right a more playful approach.

Some comics, for example popular Korean webtoons, employ unusual storytelling mechanics like automatic transitions between certain panels, or temporarily taking control of the browser's scroll function to

[4] https://apps.apple.com/de/app/comic-life-3/id891378056, (Accessed August 14, 2023)

[5] https://www.pixton.com/student-comic-builder, (Accessed August 14, 2023)

[6] https://openai.com/dall-e-2/, (Accessed June 26, 2023)

[7] https://www.midjourney.com/app/, (Accessed June 26, 2023)

scroll through a series of cleverly positioned panels with high speed, creating flipbook-like animations (e.g., Bongcheon-Dong Ghost[8]). Some digital comics have experimented with adding sound [16], and even experiments on comic-game hybrids have been made [17]. Depending on the requirements of a visualization that is to be taught through a comic, similar digital enhancements could be used to, for example, interactively manipulate a visualization in one panel to change what the next panels display.

Comics are a versatile medium which can be used as an engaging "add-on" to traditional learning, but they can also support alternative or informal learning spaces. Through their visual narrative, they can support democratizing learning experiences and offer different entry points to the topic of data visualization. This can broaden the scope of current visualization teaching efforts and bridge the gap that exists between conventional educational methods and learners from diverse backgrounds and various social contexts.

P4. Widely shareable and reusable material Comics are "un-demanding" when it comes to the medium they are presented in. Print and paper can easily be used in physical classroom settings (group work, wall posters, slideshows, textbooks, handouts) and as **low-tech** ways to reach people with restricted access to video devices and internet streaming. Printed copies can also carry **additional "value" when holding a real physical booklet** and flipping through the pages, discovering content like in coffee-table books and overcoming digital fatigue [37]. Efforts have also been made to offer finished comics with curated content on different topics (e.g., "Reading With Pictures"[9]), which can be edited by instructors to tailor them to their needs (e.g., "Comixplain"[10]). On the other hand, digital versions can be shared easily, e.g., on social media, blogs, and websites. Generally, comics adapt well to the individual constraints of different media (e.g., scrolling through digital panels or navigating on an infinite canvas as opposed to turning a page [31]). Eventually, educational data comics could be made interactive for exploration, personalization, and interaction [55].

P5. Support visualization activities Comics can be used not only as instructional material but also as a supporting medium for learning activities [21]. Educational theories effectively used to teach visualizations in other media [45] could inform ways of using comics both as material for autonomous learning (see P1) and as a "learning-by-teaching"-approach, when **learners create educational comics** for others, reflecting on the content along the way and thus strengthen their own understanding about it [26] (see P3 and Figure 7). For example, comics could be used as a method for collecting and tracking data, similar to Galman's approach of comics-based data analysis [15]. Writing and drawing can support making sense of data, acting as a multimodal way of scaffolding the analyst's cognition. Galman describes the process as similar to making mind maps to explore emerging ideas, only that comics give access to empathy, offering possible new insights and acting as a common ground for discussion with fellow researchers. Building on this notion, educational data comics could be used by students as a **participatory design approach** to document visualization design options, decisions, differences, evolution, etc. as part of "design journals". The layout and visual depiction would help with discussing and reviewing these alternatives with other learners. These comics could even be reused by other educators, handed out to groups, or put up in classrooms to support instruction.

5 Conclusion

We started this research by asking ourselves what comics can do for education in visualization. We scouted literature in the research landscape of visualization education, educational comics, and data comics, discussed 50 related papers, and list open questions in these areas. Our description of five potentials, possible application scenarios, and future work reveals great potential for creative exploration in *i)* the creation of educational data comics *ii)* the application of educational comics in learning scenarios, beyond the traditional classroom and into visualization activities, and *iii)* research into effectiveness, best practices, and promising application scenarios.

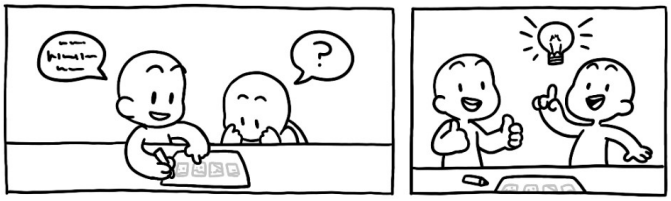

Fig. 7: Comics can support participatory design approaches as a part of, for example, a visualization class.

[8] https://comic.naver.com/webtoon/detail?titleId=350217&no=31, (Accessed June 26, 2023)

[9] https://www.readingwithpictures.org/, (Accessed August 14, 2023)

[10] https://fhstp.github.io/comixplain/, (Accessed August 14, 2023)

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