Playing games through interactive data comics to explore water quality in a lake

A case study exploring the use of a data-driven storytelling method in Co-design

Md Tanvir Hasan
Software Engineering & Digital Transformation, Lappeenranta Lahti University of Technology, Lappeenranta Finland
Md.Tanvir.Hasan@lut.fi

Annika Wolff
Software Engineering & Digital Transformation, Lappeenranta Lahti University of Technology, Lappeenranta Finland
annika.wolff@lut.fi

Antti Knutas
Software Engineering & Digital Transformation, Lappeenranta Lahti University of Technology, Lappeenranta Finland
antti.knutas@lut.fi

Anne Pässilä
LUT School of Engineering Science, Lappeenranta Lahti University of Technology, Lahti, Finland
anne.passila@lut.fi

Lasse Kantola
Theatrum Olga, Diakonia College of Finland, Finland
lasse.kantola@sdo.fi

ABSTRACT

This case study explores the use of an existing data-driven storytelling method, called data comic, within a co-design process, to improve the sense-making of data. Data can often support a co-design process by providing additional insight towards a problem that is being solved. A large number of methods are available to facilitate different aspects of a co-design process, but when it comes to embedding curated data, alternatives are limited. Not everyone has the expertise to understand raw data and co-design scenarios are typically time-limited meaning that learning new data skills is not the focus. Therefore, appropriate data curation can help to bring data into a design process while reducing time spent on data manipulation or upskilling. At the same time, it is important that participants are encouraged to think critically about the data and not simply accept a pre-determined viewpoint. We have adapted an existing technique called Data Comic for curating data for use in a co-design situation by turning the comic panels into a card game so that they can be used interactively and collaboratively. In this paper, we describe and reflect on its use within a workshop with participants who were mostly teenagers. We led them through a process of engaging with curated data to make sense of water pollution in a Finnish lake since the 1970s and raise awareness towards environmental pollution. We present our results from the participant's feedback and workshop to reflect on how data comics played a role in sense-making.

CCS CONCEPTS

• **Human-centered computing** → Human computer interaction (HCI); Interaction paradigms; Collaborative interaction.

KEYWORDS

Data Comic, Co-design, Data driven storytelling, Data visualization, Data curation

1 INTRODUCTION

A comic is an appealing medium of sequential art. While often considered as lightweight entertainment, comic forms have also been used to tackle serious subjects. For example, documentary graphic novels are, according to [19], "examples of the utilization of the comics medium to create documentary works that deal head-on with serious issues such as war, culture, and identity". Visualization of a subject matter into a comic strip form can help readers to transport into the story and travel through a fictional world. For this reason, HCI has accepted comics in various research contexts [16] such as explaining ongoing work with technology and research through design [8], data-driven storytelling [3], and provocation [15]. But the area is still underexplored. Comic visualization has also been used in co-design in many different aspects. For example, [2] used comic visualization as a fiction approach where they used comic and character cutouts for co-designing fiction. A participatory design technique comic boarding has been demonstrated as a productive approach in co-designing with children [12]. This technique provides comic structure and incomplete content to support individuals in coming up with ideas. Comic boarding has also been used as a participatory design method for productive brainstorming sessions with children [14].

There is no shortage of approaches for using comic visualization in co-design but when it comes to embedding curated data, options are limited. Data collected through activities such as citizen science,

or open data sets, can act as a useful resource in co-design to support problem-solving. The interest in involving general people in scientific research activities is increasing day by day in citizen science projects. Extensive research has been done to find the outcomes of citizen involvement but the road to ensure adequate participant engagement is still narrow. Human computer interaction (HCI) research can facilitate citizen participation and how it is done as the principles of HCI highlight design elements to attract and engage users [1]. But most often this data is difficult to understand for people who lack data literacy skills. This process of engaging with and making sense of the data should be fun, interesting, and straightforward in order to be engaging and to lower barriers to participation. The goal is not just to learn about the data but it's essential to perform further workshop activities.

One possible solution is to make this data simpler so that people can learn and interact with it. HCI has developed and designed techniques for visualizing data for behavior change such as encouraging physical activity [6], monitoring health issues such as diabetes [13], and in sustainability where sensors can monitor water activity [11]. Recently the HCI community got interested in the human experience of data [9] considering how this data reflects on regular social encounters and characterizes the past and future in new ways [10].

Data comics combine the visual language and storytelling concept from traditional comics with data visualization. They are intended to help to explain the insight about the data and make the visualization process simple [18]. Given that the comic form has been demonstrated to be useful within co-design, we propose that Data Comics may provide an answer to overcome barriers to embedding data into co-design. However, in its existing static form, a data comic may not lend itself very well to collaborative activities. We, therefore, propose that an interactive form of a data comic may lend itself better to this scenario and have designed such a comic in the form of card games which we have tested in a co-design workshop performed with teenagers.

In this paper, we focus on one research question:

What role do data curation and data visualization play to support sense-making within a time-limited situation, such as co-design?

2 CARD GAME

Two interactive card games were designed and used in this research a) Speed data-ing and b) Hauki Byte. Both games were designed based on the concept of data comics to help participants to understand two different elements in water: phosphorous and chlorophyll. In Speed data-ing key information on the cards were a) basic introduction of the element as a comic character; b) their levels and impacts in lake water; and c) causes of fluctuations in their level. Hauki Byte is based on a US television show card game where they start playing the game with a random card and the player has to guess if the next card (facing downwards) will be higher or lower. We used the same strategy here focusing on water data about a Finnish lake and using the phosphorous level as the value to guess. The Hauki is a freshwater pike that is common in Finnish lakes.

Both games have different rules. Speed data-ing has two cards containing data comics regarding two water elements (Phosphorous and Chlorophyll) (see Figure 1). Participants get a certain amount of time to read the data comic and learn about the elements. In

Hauki Byte there are 5 cards in total. The timeline of each card is a decade, meaning that each card contains information of 10 years. We had data about the lake water from 1970-2020. So, five card timelines were divided as 1970-1979, 1980-1989, 1990-1999, 2000-2009, 2010-2019. Each card contains the level of Phosphorous and Chlorophyll in the water, the state of the lake during that decade, actions taken by the authority to improve the condition, and a visual representation of the phosphorous level (Graph). (see Figure 1). By this time students would already have ideas about Phosphorous and Chlorophyll from the first game (Speed data-ing). The game rule was to look at the first card (1970-1979) and guess the level of Phosphorous in the next card (1980-1989) based on the action taken by the authority. They could do that by looking at the information in the card and also using knowledge from the previous game, or even by looking at external information sources. All visualizations had been collected from websites or created from the raw water data. Information was provided by an expert in water quality who helped to understand the history of the lake and the actions that had affected the water quality.

3 DESIGN PATTERN FOR THE COMIC

The data comic strip used in this research was designed based on the design pattern of Benjamin Bach. In his paper, he facilitated comic creation from data by introducing some design patterns. The narrative power of comics comes from the combination of pictures and words. In data comic, pictures are the visual evidence of the data. Data comic combines both word and picture for better understanding. This combination can be a) paragraph with the picture, b) putting text into the picture or c) picture into text [3] (see Figure 2). We used the second combination, putting text into the picture for our data comics. According to [4] we selected the temporal pattern for the Hauki bytes comic panels, with each panel representing a decade's worth of data. This pattern is designed to highlight a temporal change in the data. We combined this with a narrative pattern where we explained the history, made a connection between the reader and the data, and lastly ended up with a question & answer for the subsequent card which involves the reader with the story (see Figure 3). Speed data-ing was intended to give background information that is needed to interpret the data sets in hauki bytes. The comic panels in these cards reflect the expose pattern under narrative pattern which introduces data context, problems, questions, demonstrating importance (see Figure 3).

To create a meaningful story, the sequence and connection between comic panels are very important. In the original data comic technique, the panels are generally ordered on a 2D canvas which can be a paper, screen, slide, etc. [4]. However, we made a key change in order to use these within co-design. We prepared each panel as a separate card. We introduced a simple game mechanic and flow of activities to encourage viewing the cards in an intended, coherent, linear order (in temporal order by decade) but this also meant that participants could pick up cards and look at them in any order or compare different decade against each other more easily (for example the first and last). There were two reasons: first, having separate cards made it easier for several people to engage with the comic at the same time. Second, we wanted to encourage critical thinking
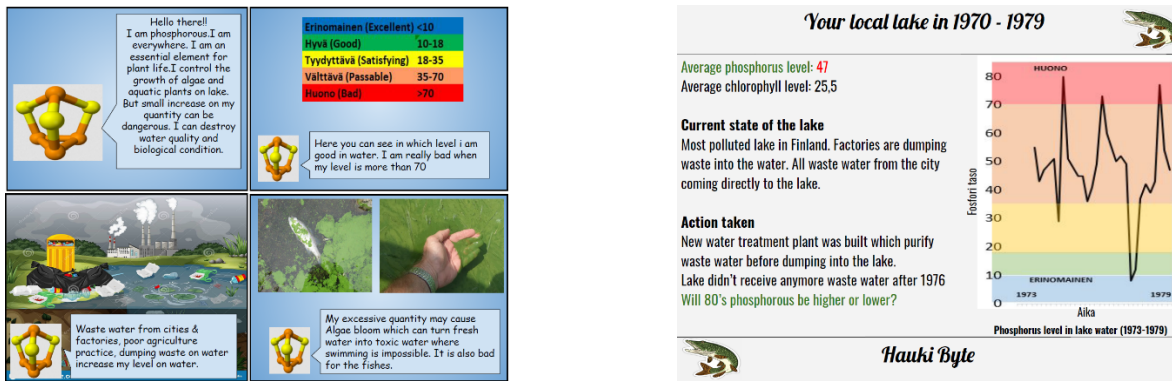
Figure 1: Speed data-ing(left), Hauki byte(right)
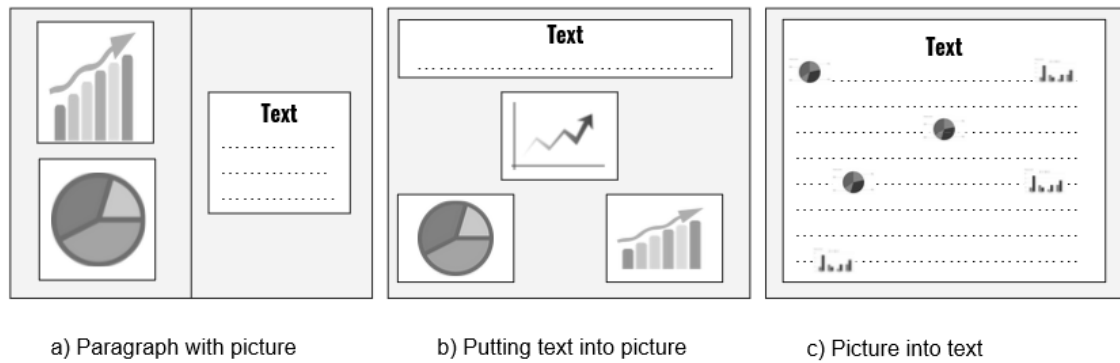
Figure 2: Combination of words and pictures (reproduced from [3])

Figure 3: Data comic patterns. Narrative pattern (left), Temporal pattern (right). (reproduced from [4])

and to give the impression that the data and interpretations were somehow not fixed and did not necessarily tell the whole story.

4 WORKSHOP

We ran a workshop to investigate 1) the usefulness of the card game; 2) whether the design of the card game helps to understand the topic; 3) whether data comic makes the learning process easier

Figure 4: Co-design workshop. Top left card game Hauki Byte, top right card game Speed data-ing, below left participants playing the card games, below right the mythological character Näkkitär (by Pihla Karhu, costume design by Mira Silvennoinen, props maker by Aino Kallioinen, hair and makeup by Janina Kuparinen, photo by drama educator and director of Theatrum Olga Lasse Kantola)

The workshop was based on a concept of data drama and included some arts-based methods that supported the process of interpreting data. Arts-based methods are based on specific form of arts. We can classify them into different categories such as visual art, moving images, performing art, live art, literary art, multiple method approach. In our research we used data drama which lies under performing art category [7]. This paper focuses primarily on the card games rather than the entire data drama experience, so we only introduce the aspects of the arts-based approaches that are needed to explain what happened. In the data drama participants were tasked with helping a mythological character called Näkkitär, who came from the future with a puzzle (see Figure 4). Some of the water in the future lake was good quality and some were not. Näkkitär thought that the answer to why this happened could be found from history, but all she had were some fragments of data and historical facts in the form of the data games and she could not read the data herself. She, therefore, asked for help from the participants, to analyze the historical water data through card games. Participants were given two physical sets of card games "Hauki byte" and "Speed data-ing" (see Figure 4). Then they were asked to play the games in two groups and ideate solutions for the mythological character. The groups were led not by researchers but instead by 12 older students who were part of a training program learning to use using arts-based approaches for youthwork through both theory and practical application. Conducting the workshop was part of their demonstration activities for the course and as such an important part of the process was in preparing these youth workers to lead the school students in the activities, which meant i) learning to make sense of how to read and interpret data comics ii) to co-create space for their use iii) find a way to use them as tools for facilitating discussions
around water issues iv) rehearsing using data comics: ideating, testing and rehearsing what drama convention to use, how and why.

4.1 Participants

The workshop was tailored for students from different backgrounds, although most of the students who chose to participate in the workshop were from a school specializing in art and drawing. Recruitment occurred as part of a larger event that was being organized in the city and to which a number of schools had signed up to participate. This workshop was one of six possible workshops that students from participating schools could choose to attend. There weren't any specific skill requirements and due to the COVID-19 situation the number of students was limited. Participants worked in groups and also individually.

4.2 Procedure

The goal of the workshop was to teach teenagers about lake water pollution and familiarize them with the history of a local lake, Vesijärvi, near Lahti in southern Finland which got polluted in the 1960s, and a restoration program that started in the 1970s. The goal was to tell the story in an interactive way with games based on data comics and raise awareness about water pollution's causes and effects. The main workshop was carried out over 6 hours during a weekday. The program started with an introduction to the workshop and a warm welcome from the organizers. Some introductory games were played to break the ice and get to know each other. After the introduction session participants were divided into two groups. Groups were formed based on a match-making game which was played in the introduction session. Each group had one or two student facilitators who facilitated the games and other activities. Groups were given two sets of card games (the first game was Speed data-ing and the second game was Hauki Byte). Participants played both of the games and had short discussions with the group facilitators regarding the contents of the games. As the workshop was formed as a part of the drama, in the end, they needed to help the mythological character who came from the future by predicting which of the two futures (good water

versus bad water) they imagine would happen based on the trends identified from the hauki byte cards (which had shown a steady improvement in phosphorous and chlorophyll) and then what could have happened to cause water pollution between now and the future, in the case where the water had got worse. Participants made different kinds of sketches based on the history of the lake which they learned from the card games.

5 RESULTS AND IMPLICATIONS

In total 10 students participated in the workshop and 12 youth education students from Theatrum Olga agreed to facilitate the whole workshop process. We succeeded to perform a face-to-face workshop but due to the covid restrictions, it was not possible to increase the number of participants. Yet it was enough to yield rich qualitative data to inform our research question.

5.1 Assessing the impact of comic visualization and card game through online surveys

To understand how the data comic and card games affected participants' output we performed surveys both with the participants and facilitators. The open-ended survey responses were analyzed with inductive thematic analysis [5]. Following their six-phase process, we coded the answers and generated themes informed by our research question. with the analysis, the process resulted in four different themes. They are summarized as follows. We highlight the main themes in bold and include some selected quotes for illustration. We also demonstrate some close-ended survey answers to support the themes.

Sensemaking. The main objective of including data comics as a visualization technique in the workshop was to make sense of the data that we curated. It happens to be a successful initiative because almost all participants understood the concept that we were trying to explain. 10 out of 10 facilitators agreed that the card games were simple and helped students understand the topic. Our goal of engaging citizens with the physical environment through relevant data was accomplished.

> "My opinion of the game surprised me positively, as it allowed me to learn and bring out the interest of the group and it was not very difficult for anything other than the initial awkwardness."

> "I learned a lot about the water lake and what things affect our water and how they relate to each other."

> "I learned different ways to express information, which is for example but diagrams, how to make it clearer and can express it in different ways and practical terms. I also learned something about the health of the lake and the dangers to its health."

Interesting and easy way of visualization. The process of visualizing the data should be simple and fun. Instead of reading some plain texts or looking at complex datasheets, comic visualization of data is interesting and easy to use. According to the responses it was fun, simple and something different which they have never experienced before. 10 out of 10 facilitators agreed that the game and visualization were simple ways of learning about water elements

and 8 out of 10 facilitators agreed that it was easier to understand the history of the lake through this process.

> "The game was certainly a fun and different way for participants to learn and internalize things. I also learned a lot about this format and how it is utilized in teaching. Also, as a facilitator, I learned a lot about the topic and things stayed in my mind, I think the participants did too."

> "I liked the simplicity of card games the most. For simplicity, the cards are easy to use in different ways"

> "I liked the pictures of the cards the most."

> "I liked the illustration most informative"

Interactive. The role of the card games was to improve interaction and ensure active participation in the co-design process. Participants were given different tasks along with the card games which involved them in discussion and ideating solutions as a team. Participants mentioned that the games were effective to start a conversation and motivating teamwork.

> "About teamwork and how everyone got involved and participated well"

> "[the card games] work well to prompt a conversation"

Design issues. We also found some drawbacks in our design. Some of the participants quoted that it was difficult for them to understand the concept and gathering informative data to come up with a solution. Based on the result analysis the overall concept of understanding the data we curated and guessing the future based on data was complex for teenagers.

> "Evaluating what will happen in the future was difficult"

> "We could have reviewed more in-depth information about what phosphorous and chlorophyll are, where else you can find them etc. Now they remained only as chemical names. Lake history cards were all similar to each other, which makes sense, but made them boring in the long run. "

5.2 Assessing game activities through analyzing workshop video

The results of the survey mainly focused on demonstrating the effectiveness of comic visualization in card games. To understand how participants were engaging with the game activities within the broader context of the arts-based approach and data drama, we analyzed the video captured during the workshop activities. For analysis, we used a three-stage qualitative analysis process with an aim of generating an evidence-based description of the workshop process and guidelines for coding video material [17]. For initial codes, we used codes for the process [20], data comic literature, and teamwork codes as interpreted from Dickinson & McIntyre [21] by [22]. Based on the analysis, the game process had three distinct stages (see Figure 5). The first stage was understanding the concepts of water elements by playing speed data-ing. In this stage, the framing allowed participants to turn from students into communicators where they needed to explain the quantitative data to
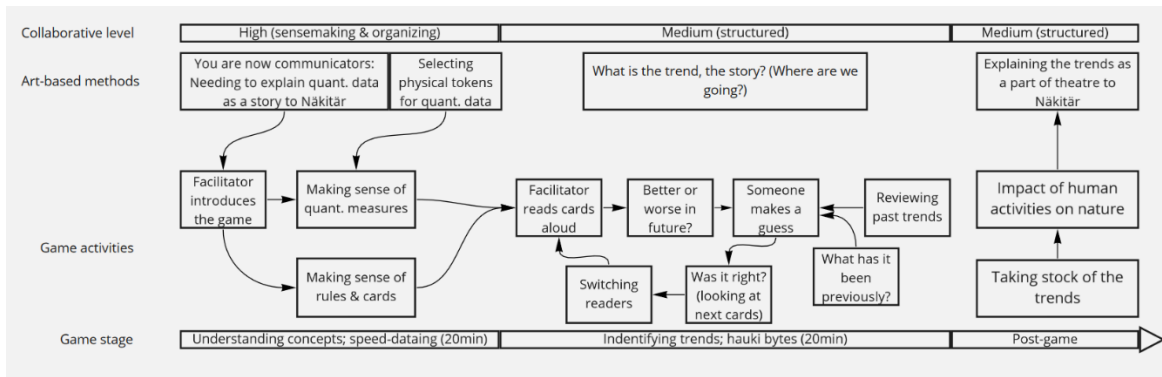
Md Tanvir Hasan et al.

Figure 5: Video analysis of the workshop

the mythological character (Näkkitär) by selecting physical tokens (cards of speed data-ing).

Facilitators played their part by guiding students through the games. After making sense of the first data comic card game, participants went to the second stage. According to the analysis of the video, the collaboration level was high in this stage. In the second stage, participants played Hauki bytes. The facilitators helped participants to read the cards and based on this they needed to guess the future (in other words, the next decade). The process went on until they finished playing all the cards. We label this stage as 'identifying trends' as that was the game purpose and collaboration level was medium. Finally, in the post-game stage participants used their knowledge gathered through the games and explained to the mythological character (Näkkitär) what they had discovered, as a part of the ongoing drama. In the last stage of analysis, analytical coding, we distill the key characteristics and advantages of the data comics workshop through the lens of our research question. They are listed as follows.

Art-based methods added real stakes to game activities. Because of the story and art-based approach, participants engaged themselves more with the game.

Art-based method framing turned participants from students to communicators. Participants were tasked to explain the data we curated to a mythological character. It was a part of the learning process where participants turned themselves into communicators, as opposed to being passive recipients of data.

In the end, students identified trends and placed them in the context of human activities. At the end of the game, students understood the history of the lake and related their learning to a real-life context.

Student-driven setup, facilitation, and preparation were important parts of the process. The first stage with speed data-ing was more collaborative and student-driven. Once the groups felt that they were ready and had understood the concepts, the sensemaking and game activities in the middle were quicker and more mechanical. However, the game and the story context added stakes to the process: Had there not been the cards and the narrative, the students might not have taken similar efforts to prepare.

6 LESSONS LEARNED AND INSIGHTS FOR PRACTITIONERS

Our initial research question was 'what role do data curation and data visualization play to support sense-making within a time-limited situation, such as co-design?'. Based on our experience in conducting this workshop and analyzing the process, we identify the following points:

- The combination of arts-based framing alongside card games was of the most importance. Neither approach would work well on its own. The card games supported participants to quickly understand the data, but the arts-based approach was crucial to support collaborative aspects of sensemaking, relating the data to own experience and coming up with ideas.
- A tool such as a data comic can be used to increase engagement and to quickly convey information, but the work has to be done somewhere and by someone - in this case originally by the water expert, then by the researchers in creating the games, and subsequently by the facilitators in learning how to use the cards with the final users, the school students. In each stage, the level of expertise and time required to engage with and understand the information was reduced. This implies that in a co-design scenario where many are already data and/or domain experts some of this effort may be unnecessary but if participants are neither data experts nor domain experts it is highly effective to convey information efficiently to inspire collaborative ideation.

7 CONCLUSION

Data can be a useful resource within a co-design process for understanding problems and ideating solutions. However, the complexity lies in making sense of this data. Especially for people with limited data literacy skills. Typically, co-design workshops are time-limited, and it is not possible to teach data literacy skills during the workshop. Data comic is one approach that can bring data closer to people in a short time. Existing comics have been framed as static artifacts which limits them to use within a participatory process. In our approach, we created interactive data comics in the form of a card game. Cards are quite typical tools used in co-design scenarios. Cards have the benefit that they can be picked up and passed

around. By curating data on cards, we make the data more tangible and by making the game interactive we can provide a storyline with different ways that people can interact with the story such as by encountering cards in different orders. In the case study, we explored the extent to which these interactive data comics help participants to understand the data quickly and without learning new skills. During the workshop, the participants worked in two separate groups to make sense of the information contained in the interactive data comics. Our findings were that overall the facilitators felt the games worked well and participants picked up the information quickly. The principles that Bach identified lent themselves well to being turned into interactive form, by making each panel into a separate card instead of curated into a fixed sequence. We did not test all the principles but could do so in the future. The game principles were easy to apply. The biggest resource was in having an expert to make sense of the data in the first place and to help to put it into the context, thereby providing a good starting point for others to start making their own sense. The raw data in the form of an excel sheet would have been too difficult for the participants to use without guidance. In the future, we would be interested to see how the cards support the exploration of different parts of the data such as framing new questions from it. E.g., not just predicting the future, but also finding out about different aspects of the lake which were in the dataset but not on the cards.

ACKNOWLEDGMENTS

REFERENCES

[1] Aristeidou, M., Scanlon, E. and Sharples, M. (2017) 'Profiles of engagement in online communities of citizen science participation', Computers in Human Behavior, 74, pp. 246–256. doi: 10.1016/j.chb.2017.04.044.

[2] B, E. E., Vogel, S. and Fran, N. C. (2021) 'Tales from the Materialverse: Comic-Based Narratives and Character Cut-Outs for Co-Design Fiction', 1, pp. 302–311. doi: 10.1007/978-3-030-85616-8.

[3] Bach, B. *et al.* (2017) 'The Emerging Genre of Data Comics', IEEE computer graphics and applications, 37(3), pp. 6–13. doi: 10.1109/MCG.2017.33.

[4] Bach, B. *et al.* (2018) 'Design patterns for data comics', Conference on Human Factors in Computing Systems - Proceedings, 2018-April, pp. 1–12. doi: 10.1145/3173574.3173612.

[5] Braun, V., & Clarke, V. (2012). Thematic analysis. In H. Cooper, P. M. Camic, D. L. Long, A. T. Panter, D. Rindskopf, & K. J. Sher (Eds.), APA handbook of research methods in psychology, Vol. 2. Research designs: Quantitative, qualitative, neuropsychological, and biological (pp. 57–71). American Psychological Association. https://doi.org/10.1037/13620-004

[6] Consolvo, S. *et al.* (2006) 'Design requirements for technologies that encourage physical activity', Conference on Human Factors in Computing Systems - Proceedings, 1, pp. 457–466. doi: 10.1145/1124772.1124840.

[7] Coemans, S., & Hannes, K. (2017). Researchers under the spell of the arts: Two decades of using arts-based methods in community-based inquiry with vulnerable populations. Educational Research Review, 22, 34-49.

[8] Dykes, T. *et al.* (2016) 'RTD comics: A medium for representing research through design', DIS 2016 - Proceedings of the 2016 ACM Conference on Designing Interactive Systems: Fuse, (23), pp. 971–981. doi: 10.1145/2901790.2901821.

[9] Elsden, C. *et al.* (2016) 'Metadating: Exploring the romance and future of personal data', Conference on Human Factors in Computing Systems - Proceedings, pp. 685–698. doi: 10.1145/2858036.2858173.

[10] Elsden, C., Kirk, D. S. and Durrant, A. C. (2016) 'A Quantified Past: Toward Design for Remembering With Personal Informatics', Human-Computer Interaction, 31(6), pp. 518–557. doi: 10.1080/07370024.2015.1093422.

[11] Froehlich, J. *et al.* (2009) 'HydroSense: Infrastructure-mediated single-point sensing of whole-home water activity', ACM International Conference Proceeding Series, pp. 235–244. doi: 10.1145/1620545.1620581.

[12] Hiniker, A., Sobel, K. and Lee, B. (2017) 'Co-designing with preschoolers using fictional inquiry and comicboarding', Conference on Human Factors in Computing Systems - Proceedings, 2017-May, pp. 5767–5772. doi: 10.1145/3025453.3025588.

[13] Mamykina, L., Mynatt, E. D. and Kaufmann, D. (2006) 'Investigating health management practices of individuals with diabetes', Conference on Human Factors in Computing Systems - Proceedings, 2, pp. 927–936. doi: 10.1145/1124772.1124910.

[14] Moraveji, N. *et al.* (2007) 'Comicboarding: Using comics as proxies for participatory design with children', Conference on Human Factors in Computing Systems - Proceedings, pp. 1371–1374. doi: 10.1145/1240624.1240832.

[15] Sturdee, M. *et al.* (2018) 'Sketch & The lizard king: Supporting image inclusion in HCI publishing', Conference on Human Factors in Computing Systems - Proceedings, 2018-April, pp. 1–12. doi: 10.1145/3170427.3188408.

[16] Sturdee, M. and Lindley, J. (2019) 'Sketching & drawing as future inquiry in HCI', ACM International Conference Proceeding Series. doi: 10.1145/3363384.3363402.

[17] Wicks, D. (2017) The Coding Manual for Qualitative Researchers (3rd edition), Qualitative Research in Organizations and Management: An International Journal. doi: 10.1108/qrom-08-2016-1408.

[18] Wang, Z., Bach, B. and Dingwall, H. (2019) 'Teaching data visualization and storytelling with data comic workshops', Conference on Human Factors in Computing Systems - Proceedings, pp. 1–9. doi: 10.1145/3290607.3299043.

[19] Adams, J. and Owens, A. (2016) Creativity and Democracy in Education: practices and politics of learning through the arts. Oxon. & New York: Routledge.

[20] Urquhart, C. (2012). Grounded theory for qualitative research: A practical guide. Sage.

[21] Dickinson, T. L., & McIntyre, R. M. (1997). A conceptual framework for teamwork measurement. In Team performance assessment and measurement (pp. 31-56). Psychology Press.

[22] Vivian, R., Falkner, K., & Falkner, N. (2013, November). Analyzing computer science students' teamwork role adoption in an online self-organized teamwork activity. In Proceedings of the 13th Koli Calling International Conference on Computing Education Research (pp. 105-114).