Visualization Literacy for General Audiences - Can We Make A Difference?

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***Abstract*—In this panel, we will discuss strategies and challenges associated with increasing the visualization literacy of general audiences (and adjacent data-related fields). We will hear from experts who have tested various techniques to increase visualization literacy and developed interactive apps/games/websites to inform and educate varying audiences about the fundamentals of data visualization. We will hear from experts who have worked towards increasing the visualization literacy of participants through various strategies such as videos, websites, tutorials, and so on. The panel will discuss open challenges in the field of visualization literacy and the problems faced when introducing novel visualization techniques to potential users.**

***Index Terms*—visualization literacy, data science, domain experts**

I. Introduction

Data visualization literacy (DVL) [1] can be broadly defined as the ability to read, make, and explain data visualizations. DVL therefore is not just the ability to recognize and read a new visualization technique, but to also be able to apply novel techniques for exploration, communication, and explanation of data.

As Börner pointed out in her keynote on DVL at IEEE VIS 2019 [2], it is our responsibility as data visualization experts to increase the visualization literacy not only of experts but also of general audiences [3], [4] . Even though our field has contributed novel visualization and interaction techniques for interacting with data, have we done a good job to convey that to general audiences? Can a plumber or a bakery owner look at a visualization of their finances on their bank website and make sound decisions based on these visualizations? If we are to reach our goal of empowering anyone to read and construct data visualizations, are we doing our best to reach out to the 100s of domain and visualization experts that use data visualization effectively, learn from them, and then teach millions of others? Are DVL experts joining forces to create standards and frameworks that help many to properly name data visualizations, to correctly apply analysis and visualization workflows, and to effectively engage in data-driven storytelling? Why is it still difficult even for experts to use 10 different names for the very same data visualization type, to stop using rainbow colormaps and 3D bar charts, and to use areas [5] correctly?

II. Position Statement: Katy Börner

The Power of Data Visualization Frameworks: We experts must agree on (de-facto) standards for constructing, naming, and using data visualizations correctly. Plus, we must develop effective means to increase the DVL of millions. The data visualization literacy framework (DVL-FW) was developed via an extensive review of more than 600 publications documenting 50+ years of pioneering work by statisticians, cartographers, cognitive scientists, visualization experts, and others. These publications were selected using a combination of expert surveys and cited reference searches for key publications, such as Bertin [6], Cairo [7], Few [8], Harris [9], MacEachren [10], Munzner [11], Wilkinson [12] and Shneiderman [13]. An extended review of prior work and an earlier version of the DVL-FW were presented in Börner's *Atlas of Knowledge: Anyone Can Map* [14]. The DVL-FW has been applied and systematically revised over more than ten years to develop and validate exercises and assessments for residential and online courses at Indiana University. More than 8,500 students have applied the DVL-FW to solving 100+ real-world client projects. Student performance and feedback were used to expand the coverage, internal consistency, utility, and usability of the framework and the associated data visualization literacy indicators. Today, the DVL-FW now promotes both the reading and construction of data visualizations, a pairing analogous to that of both reading and writing in textual literacy and understanding and applying in mathematical literacy. Specifically, the new DVL-FW defines a typology with seven main types and a process model and associated metrics to measure the data visualization

literacy of students based on their ability to properly name and effectively use the framework, see [1]. It has been implemented in the Make-A-Vis (MAV) tool that introduces the DVL-FW to 1000s of students taking the Visual Analytics Certificate (https://visanalytics.cns.iu.edu).

A. Biography

Katy Börner is the Victor H. Yngve Distinguished Professor of Engineering and Information Science in the Department of Intelligent Systems Engineering, School of Informatics, Computing, and Engineering, Core Faculty of Cognitive Science, and Founding Director of the Cyberinfrastructure for Network Science Center at Indiana University in Bloomington, IN (https://cns.iu.edu). She is a Visiting Professor at the Royal Netherlands Academy of Arts and Sciences (KNAW) in The Netherlands and a curator of the international *Places and Spaces: Mapping Science* exhibit (https://scimaps.org). She was elected as an American Association for the Advancement of Science (AAAS) Fellow in 2012, an Alexander von Humboldt Fellow in 2017, and an Association for Computing Machinery (ACM) Fellow in 2018.

III. Position Statement: Robert S Laramee

On the Death of Visualization Literacy: The topics of visualization literacy, visualization relevance, and visualization in education are all inextricably tied together. In 2004, Bill Lorensen published his well-known paper "On the Death of Visualization" [15]. His position was essentially stating that visualization as a field would lose its relevance without more "customer"-facing research. I have also heard a number of colleagues in the field criticizing the visualization community as being too "inward-facing". In other words, visualization as a field, requires more outward-facing work (as opposed to inward facing). I believe this viewpoint applies to many academic disciplines (sometimes much more) and is not specific to visualization. The visualization community has responded to this with the beneficial introduction of application and design papers. The implications of this also extend to visualization education and visualization literacy. In order for visualization to gain relevance and thus educate users to become more visualization literate, the field has to somehow address the education space.

In my statement, I will offer some suggestions on how the visualization community can increase its relevance and thus encourage more visualization literacy research, with a special focus on education. The ultimate vision is that visualization literacy gains the same importance as language and mathematical literacy. However, there is still quite a long way to go before general education evolves in this direction [16], [17].

A. Biography

Robert S. Laramee received a bachelors degree in physics, cum laude, from the University of Massachusetts, Amherst (UMass). He received a master's degree in computer science from the University of New Hampshire, Durham. He was awarded a PhD from the Vienna University of Technology (Gruess Gott TUWien), Austria at the Institute of Computer Graphics and Algorithms in 2005. From 2001 to 2006 he was a researcher at the VRVis Research Center (www.vrvis.at) and a software engineer at AVL (www.avl.com) in the department of Advanced Simulation Technologies. He was Associate Professor at Swansea University (Prifysgol Cymru Abertawe), Wales in the Department of Computer Science (Adran Gwyddor Cyfrifiadur). He is currently Associate Professor of Data Visualization at the University of Nottingham.

IV. Position Statement: Lane Harrison

Towards Equitable Access to Visualization Literacy: The rise of visualization systems, toolkits, journalism, and social media have contributed to a saturation of visualization in peoples' daily lives. This saturation has led visualization literacy to be recognized as a present and growing challenge that deserves attention from the broader visualization community. People likely vary in their ability to read and use visualizations they encounter, leaving the visualization community with unanswered questions that have far-reaching implications. How and how much do people vary in visualization literacy? Are our guidelines, painstakingly developed through empirical studies, design, and evaluation, universally applicable? If people vary in visualization literacy, how is this literacy developed, and how can we better ensure equitable access to the power and promise of visualization-driven thinking?

My position on visualization literacy is a mix between optimism and urgency. We have reasons to be optimistic, because we have (perhaps unintentionally) laid a foundation for visualization literacy research in our community through decades of quantitative user studies [18]. These studies, alongside advances in visualization methods and models, might allow us to reinforce and bolster what we already know about visualization literacy as we continue to pursue new directions. We also have reason for urgency, because knowledge and interventions for visualization literacy are currently being developed by communities outside of VIS, such as learning sciences and education. Without coordinated engagement with these communities, we run the risk of significant missed opportunities to share the best visualization ideas and innovations beyond our borders.

A. Biography

Lane Harrison's research leverages quantitative and computational methods to understand and shape how people interpret, use, and create data visualizations and visual analytics tools. Data visualization is an indispensable tool for analysis and understanding. As we begin rely more on data visualizations when making high-impact, even life-critical decisions in areas like health and cyber security, we must ensure that people have the best tools and information for the decisions they face.

Lane is an Associate Professor of Computer Science at Worcester Polytechnic Institute. Previously, Lane was a Post-Doc in the Visual Analytics Lab at Tufts (VALT), with Remco Chang. Lane received his PhD from UNC-Charlotte, home of the Charlotte Visualization Center, with Aidong Lu.

V. Position Statement: Elif E. Firat

Barriers to Visualization Literacy: Understanding and interpreting the data displayed to formulate accurate observations exploiting visual designs is becoming increasingly important with the growing use of visualizations. As the development of users' visualization literacy gains importance in the educational and information visualization fields [19], it is clear that some challenges on how to assess and develop users' visualization literacy as well as the barriers to visualization literacy require further research.

It is a major challenge to identify barriers to comprehension and interpretation of visual designs before studying the evaluation and development of visualization literacy. Barriers that make it difficult to understand visualizations may be related to design components of visualizations (e.g. layout of space, data distribution), presentation of visual designs (lack of labels and legend), or users with diverse backgrounds (perceptual and cognitive biases). All factors that influence visualization literacy should be taken into consideration.

The assessment of users with different levels of visualization literacy skills is feasible by creating comprehensive tests. However, to determine the disparity between users and obtain reliable results, developing a series of visualization literacy assessment tests that include varying complexity, visual designs, and data sets is required but challenging at the same time. (Treemap Literacy Test [20])

To improve users' literacy skills, an interactive educational tool that assists the teaching and learning of a visual design by providing a more active learning experience is helpful. Developing a robust tool can facilitate the interpretation and exploration of data using interaction, as well as enable users to create and interpret the given imagery. The investigation provided by interaction also removes some barriers. However, developing a tool to advance visualization literacy is a great challenge and requires extensive consideration and development effort to diminish the impact of barriers to comprehension. (Educational Treemap Tool [20])

I plan to discuss some of the barriers associated with visualization literacy and related research we have done to identify those barriers for treemap and parallel coordinates plot literacy.

A. Biography

Elif E. Firat is a Ph.D. candidate in Information Visualization at the School of Computer Science, Nottingham University, with a focus on Visualization Literacy. Elif's research interests are focused on identifying barriers to visualization literacy and to improve non-expert users' visualization literacy skills by aiding both teaching and learning with a pedagogical tool. Elif received a Master's degree in Advanced Computer Science from Swansea University in 2017.

VI. Position Statement: Bum Chul Kwon

Validating Visualization Literacy: As we aim to increase the visualization literacy of general audiences, we need tools/tests [21], [22] that we can use to evaluate the current level of visualization literacy for an individual. Such community-approved tests can be used by researchers to identify baseline visualization literacy for their participants. Participants' literacy can then be tested before and after an intervention designed to improve visualization literacy to evaluate the changes/improvements in the participants' literacy. In previous work, we have experimented with different learning approaches to teach participants about parallel coordinates [23]. In studies such as those, we compare the different modalities being used to increase visualization literacy, but we rarely evaluate whether those modalities actually made an impact on the overall visualization literacy of an individual participant or a group of participants. We also need to increase our understanding of how cognitive characteristics are related to visualization literacy so that we can enhance visualization literacy of all [24].

In this panel, I will present some of our work on developing the Visualization Literacy Assessment Test (VLAT) [22], [24], [25] and will share our experiences with deploying the instrument with online users as well as with domain experts. Through the standardization of tests such as these, we can build and validate the impact of interventions on varying audiences.

A. Biography

Bum Chul Kwon is a researcher of data visualization and visual analytics at the Healthcare Analytics Research Group in IBM Research. His research area includes visual analytics, data visualization, human-computer interaction, healthcare, and machine learning. His research goal is to enhance users' abilities to derive knowledge from various forms of data through development of interactive visual analytics systems. He received his PhD and Master's degree in Industrial Engineering from Purdue University in West Lafayette, Indiana.

VII. Panel Moderator Biography - Alark Joshi

Alark Joshi is an Associate Professor and Department Chair of the Department of Computer Science at the University of San Francisco, where he works on data visualization projects with an emphasis on mobile data visualization. At the IEEE VIS conference, he has organized the Pedagogy of Data Visualization Workshop in 2016 and 2017 as well as award-winning panels at VIS 2009 and 2010.

He received his postdoctoral training at Yale University, where he was a core member of the BioImage Suite team. He received his PhD in Computer Science from the University of Maryland Baltimore County.

VIII. Panel Schedule

Due to the online nature of the conference, we plan to conduct the panel sequentially initially to allow panelists to state their position on Data Visualization Literacy. This will be followed by an interactive session moderated by Alark Joshi that will start with asking panelists questions specific to their position statements, along with taking questions from the audience to make the panel interactive and engaging.

- Introductions (5 minutes)
- Katy Börner - The Power of Data Visualization Frameworks (10 minutes)
- Robert Laramee - On the Death of Visualization Literacy (10 minutes)
- Lane Harrison - Towards Equitable Access to Visualization Literacy (10 minutes)
- Elif E. Firat - Barriers to Visualization Literacy (10 minutes)
- Bum Chul Kwon - Validating Visualization Literacy (10 minutes)
- Intra-Panel & Audience Discussion moderated by Alark Joshi (25 minutes)
- Discussion on Open Challenges in the Field of Data Visualization Literacy (DVL) (10 minutes)

REFERENCES

[1] K. Börner, A. Bueckle, and M. Ginda, "Data visualization literacy: Definitions, conceptual frameworks, exercises, and assessments," *Proceedings of the National Academy of Sciences*, vol. 116, no. 6, pp. 1857–1864, 2019.

[2] K. Börner, "Vis keynote address: Data visualization literacy," in *2019 IEEE Conference on Visual Analytics Science and Technology (VAST)*. IEEE, 2019, pp. 1–1.

[3] B. Alper, N. H. Riche, F. Chevalier, J. Boy, and M. Sezgin, "Visualization literacy at elementary school," in *Proceedings of the 2017 CHI conference on human factors in computing systems*, 2017, pp. 5485–5497.

[4] E. Huynh, A. Nyhout, P. Ganea, and F. Chevalier, "Designing narrative-focused role-playing games for visualization literacy in young children," *IEEE Transactions on Visualization and Computer Graphics*, vol. 27, no. 2, pp. 924–934, 2020.

[5] D. Skau and R. Kosara, "Arcs, angles, or areas: Individual data encodings in pie and donut charts," in *Computer Graphics Forum*, vol. 35, no. 3. Wiley Online Library, 2016, pp. 121–130.

[6] J. Bertin, "Semiology of graphics; diagrams networks maps," Tech. Rep., 1983.

[7] A. Cairo, *The Functional Art: An introduction to information graphics and visualization*. New Riders, 2012.

[8] S. Few, "Show me the numbers," *Analytics Pres*, 2004.

[9] J. Harris, D. Viljoen, A. Rencz, and R. Ryerson, "Integration and visualization of geoscience data," *Remote Sensing for the Earth Sciences. J. Wiley & Sons, Am. Soc. Photog. & RS*, vol. 3, pp. 307–354, 1999.

[10] A. M. MacEachren, *How maps work: representation, visualization, and design*. Guilford Press, 2004.

[11] T. Munzner, *Visualization analysis and design*. CRC press, 2014.

[12] L. Wilkinson, *The grammar of graphics*. Springer Science & Business Media, 2013.

[13] B. B. Bederson, B. B. Bederson, B. Shneiderman *et al.*, *The craft of information visualization: readings and reflections*. Morgan Kaufmann, 2003.

[14] K. Borner, *Atlas of knowledge: anyone can map*. MIT Press, 2015.

[15] B. Lorensen, "On the death of visualization," in *Position Papers NIH/NSF Proc. Fall 2004 Workshop Visualization Research Challenges*, vol. 1, no. 2, 2004, p. 5.

[16] L. Ryan, D. Silver, R. S. Laramee, and D. Ebert, "Teaching data visualization as a skill," *IEEE computer graphics and applications*, vol. 39, no. 2, pp. 95–103, 2019.

[17] A. Diehl, E. E. Firat, T. Torsney-Weir, A. Abdul-Rahman, B. Bach, R. S. Laramee, R. Pajarola, and M. Chen, "Visguided: A community-driven approach for education in visualization," in *Eurographics 2021 (EG 2021)*, 2021.

[18] H. Mansoor and L. Harrison, "Data visualization literacy and visualization biases: Cases for merging parallel threads," in *Cognitive Biases in Visualizations*. Springer, 2018, pp. 87–96.

[19] E. E. Firat and R. S. Laramee, "Towards a survey of interactive visualization for education," *Proc. Computer Graphics and Visual Computing*, pp. 91–101, 2018.

[20] E. E. Firat, A. Denisova, and R. S. Laramee, "Treemap literacy: A classroom-based investigation," in *Eurographics Proceedings*, 2020.

[21] J. Boy, R. A. Rensink, E. Bertini, and J.-D. Fekete, "A principled way of assessing visualization literacy," *IEEE transactions on visualization and computer graphics*, vol. 20, no. 12, pp. 1963–1972, 2014.

[22] S. Lee, S.-H. Kim, and B. C. Kwon, "VLAT: Development of a visualization literacy assessment test," *IEEE transactions on visualization and computer graphics*, vol. 23, no. 1, pp. 551–560, 2016.

[23] B. C. Kwon and B. Lee, "A comparative evaluation on online learning approaches using parallel coordinate visualization," in *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 2016, pp. 993–997.

[24] S. Lee, B. C. Kwon, J. Yang, B. C. Lee, and S.-H. Kim, "The correlation between users' cognitive characteristics and visualization literacy," *Applied Sciences*, vol. 9, no. 3, p. 488, 2019.

[25] S. Lee, "Investigation of visualization literacy: A visualization sense-making model, a visualization literacy assessment test, and the effects of cognitive characteristics," Ph.D. dissertation, Purdue University, 2017.