

Visualization Techniques to Cultivate Data Literacy

Lindy Ryan

Abstract

Visual literacy, supported by the use of visualization in teaching and instruction, ultimately achieves a greater degree of learning (Stokes, 2002). This chapter will discuss and analyze how visualization approaches, coupled with a focus on increasing information understanding and analysis, will extend visual literacy to cultivate visual data literacy; construct critical and higher-level thinking; encourage data-driven decision-making; and transform learning from a participatory, passive experience to a rich and interactive one via visual dialogue. This chapter will provide examples for how to integrate information and visualization to develop data literacy, drawing from academic literature and case studies from practiced, interdisciplinary data visualization educators.

Using Visualization Techniques to Cultivate Data Literacy

Established learning theories outline how learners acquire different types of information and through which processes (including classic conditioning, behavior theory, functionalism, sign learning, mathematical learning, information processes models, and/or neuron-linguistic programming and cognitive sciences) (Penrose, 2006). As a core construct, many of these support the role of visualization as a key component of learning and retention. Visual literacy is the ability to read, interpret, and understand information presented in non-word form (Wileman, 1993). Visual literacy, supported by the use of visualization in teaching and instruction, ultimately achieves a greater degree of learning.

Using visualization approaches, coupled with a focus on increasing information understanding and analysis, extends visual literacy to cultivate visual data literacy; construct critical and higher-level thinking; encourage data-driven decision-making; and provide learners with a deeper degree of data fluency for analysis and communication. This chapter will provide examples for how to integrate information and visualization to develop data literacy, drawing from academic literature and case studies from practiced, interdisciplinary data visualization practitioners and educators.

Visual Learning Key to Data Literacy

Visual learning is a part of intrinsic human cognitive hardwiring as a learning, storytelling, and communication mechanism. The ability to visually learn from and consume information is a core construct of the deeply engrained visualizer-verbalizer hypothesis (wherein learning is a combination of verbal and visual elements) (Stokes, 2002). This is particularly relevant as an evolving understanding of the cognitive style construct continues to emerge with today's advances in multi-media and visual technologies (Stokes, 2002; Mayer & Massa, 2003).

Today, visual learning may be tipping the scales of this hypothesis in terms of both cognitive ability (human capabilities) and cognitive style (how people process and represent information by preference). One possible explanation could be attributed to the globalization of classroom education increasingly directed to both English-speaking and

non-English-speaking audiences that reduces dependency on verbal instruction and increases visual methods of interactive learning to span language and cultural barriers. Another reason for the use of visualization is to compensate for a documented drop in vocabulary. Per Bleed's study (as cited in Penrose, 2006), it is estimated that the vocabulary of 14-year-old youth dropped from 25,000 words in 1950 to only 10,000 words in 1999 – a reduction in verbal lexis of 60%. Seeing and interacting with an image in combination with traditional written and verbal instruction, instead, has been associated with higher levels of retention and understanding of salient ideas. Moreover, visualization that blends information with influential features (like color, density, and content themes) significantly and consistently increases learning, memorability, and recall (Borkin et al., 2013).

With increasing technological competencies, the ability to place emphasis on visually-oriented approaches in learning has evolved from an information presentation mindset to the integration of interdisciplinary approaches designed to cultivate data literacy and critical thinking to support the needs of an increasingly data-dependent and analytical culture. Incorporating more visual elements into learning helps to foster interdependency between the two modes of thought, balancing verbal and visual learning (Stokes, 2002). This approach to learning complements previous research that has proposed multiple literacies are necessary to meet the challenges of society, including print, visual, aural, media, computer, and ecoliteracy (Kellner, 1998; Stokes, 2002).

Incorporating Data into Visual Learning

As the need to gather and examine data becomes increasingly critical across all verticals of industry, it brings alongside it a growing need to introduce and establish data literacy skills to build capabilities for understanding data (Brinkley, 2014). Building on the paradigm of visual literacy, various learning objectives for data literacy can be achieved by using data visualization tools, which typically include elements of design, statistics visualization, and communication. These all have benefits, including enabling students to think creatively and map conceptual and physical space; helping students examine changes and hypothesize reasons for change; and providing the ability to create persuasive visual representations to support arguments or recommendations (Hitchcock, Miller, Pontes, & Wieniek, 2014).

To achieve data literacy through visualization, visual learning should be extended to project data in a way that reduces complexity while capturing important information in a meaningful and memorable way (Fayaad, Grinstein, & Wierse, 2001). Many case studies in the literature, such as those by Godehardt (2009), provided the design, prototypic implementation, and evaluation of a framework for contextualized visualization as a learning support mechanism for ongoing, informal, and visually-supported learning. However, there are many practical examples of bringing data visualization into the classroom to foster data literacy, irrespective of subject, to appeal to a broader educational context. Two major approaches to visual data literacy have been proposed as extensions of visual literacy models (Stokes, 2002).

The first is to leverage visualization to read and decode to assist learners with various analytical techniques. The following example explores the use of visualization in teaching mathematics and statistics. While students have traditionally been taught to draw graphics to visualize mathematical information, the growth of user-friendly computing technologies has spurred a trend to teach statistical concepts using interactive data visualization tools (Forbes, Chapman, Harraway, Stirling, & Wild, 2014). Further, Moore (as cited in Forbes et al., 2014) made the case that pictorial vision is a prerequisite for the understanding of concepts of statistical inference. Putting this theory into practice, an enrichment program for high school students interested in a career in the science of mathematics was designed by researchers from the North Carolina General Assembly in partnership with JMP Software, an interactive software for desktop statistical discovery. As an experiment, this program was intended to expose students to data in a unique and exciting way by allowing them to engage with information and describe, visualize, and critique data sets from health care, education, and business. With a very limited focus on material covered in traditional mathematics curriculum, students were invited to explore data critically and visually to structure information for summary analysis (Brinkley, 2014). At the end of the program, students had developed a proven capacity to visually work with and understand data, as well as to understand the role of data in decision-making (Brinkley, 2014).

The second proposed method to visual data literacy is to encode visuals with data as communication tools. One type of visualization applicable under this concept is the infographic, which visually communicates complex quantitative and/or qualitative information through the combination

of data displays, lists, graphics, and other data elements (including words) (Toth, 2013). Infographics have been shown to help highlight literacy concerns to teach students what information is valuable and how to use it effectively, especially in business courses. In one study, students were directed to design a meaningful infographic as part of the learning process. Results showed an increase in student engagement and a deeper understanding for the visual data design process, while the production approach of the infographic supported traditional pedagogical elements, such as writing proposals, performing research, and meeting citation and documentation requirements (Toth, 2013).

Special Considerations

The use of visualization to promote data literacy should be carefully planned. Applying the use of visualizations depends largely on the content and thus must be used in the appropriate context. While many forms of graphics exist, visualizations that incorporate illustrations and text (again, the verbalizer-visualizer hypothesis) depict patterns of concepts and ideas that serve as frameworks to promote learning, whereas those that steer learners toward exciting presentation can interfere (Stokes, 2002). This includes using visualization in photographs for realism, drawings, diagrams, or maps, as well as deciding when to use visualizations for effective visual support of data and information (Penrose, 2006). Additionally, Dwyer (as cited in Stokes, 2002) stated that visualization must be used within the educational context, as visualization alone does not maximize achievement.

When using data visualizations to support visual data literacy, instructors must highlight connections between visualization, design, and elements of science, and engage students in group critiques to explore and develop a position of personal insight and experience with data visualizations (Dykes, Keefe, Kindlmann, Munzer, & Joshi, 2010). As an intellectual endeavor, providing guided visualization examples has also been acknowledged as a catalyst for creative thought and problem-solving, as well as offers innovative pedagogical formats for teaching ethics and decision-making alongside complementary frameworks like Six Sigma, which involves the continuous and systematic use of data (Honey-Roses, Le Menestrel, Arenas, Rauschmayer, & Rode, 2013).

Conclusion

Using visualization as part of a suite of multiple intelligences can be used in the classroom to develop engaging assignments; increase critical thinking and intrapersonal competencies; and assess course outcomes—further strengthening visual literacy. Paired with approaches that combine data and information, advanced data visualization will extend visual literacy to cultivate visual data literacy, providing learners with a deeper degree of data fluency for analysis and communication. To be successful, educators should possess skills that include the language of imagery and techniques for teaching visually to integrate visual data literacy as an exemplary educational practice (Stokes, 2002).

As academics align with the needs and demands of industry and corporations for emerging workers, visual literacy should be extended to include visual data literacy. As such, there is increased expectation to deliver graduates with enhanced knowledge and technical skills that leverage advanced visualization techniques for critical business competencies and data-driven decision-making (Hitchcock et al., 2014). This is driven by a progressively data-reliant and analytical business culture wherein workers are expected to use data visualization techniques to graphically see business data to clearly interpret meanings, patterns, and trends, as well as make decisions that affect the business, internal and external stakeholders, and society at large.

References

- Borkin, M., Vo, A., Bylinski, Z., Isola, P., Sunkavalli, S., Oliva, A., & Pfister, H. (2013). Proceedings from IEEE INFOVIS 2013: *What makes a visualization memorable?* Atlanta, GA: IEEE.
- Brinkley, J. (2014). Proceedings from JMP discovery summit 2014: *Using JMP as a catalyst for teaching data-driven decision making to high school students*. Greenville, NC: JMP SAS.
- Dykes, J., Keefe, D., Kindlmann, G., Munzer, F., & Joshi, A. (2010). Proceedings from IEEE VizWeek: *Perspectives on teaching data visualization (Best Panel Award)*. Minneapolis, MN: University of Minnesota.
- Fayyad, U., Grinstein, G., & Wierse, A. (2001). *Information visualization in data mining and knowledge discovery*. San Francisco, CA: Morgan Kaufman.
- Forbes, S., Chapman, J., Harraway, J., Stirling, D., & Wild, C. (2014). Use of data visualization in the teaching of statistics: A New Zealand perspective. *Statistics Education Journal*, 13(2), 187-201.
- Godehardt, E. (2009). A framework for contextualized visualization supporting informal learning. *International Journal of Advanced Corporate Learning*, 2(3), 21-26.
- Hitchcock, W., Miller, F., Pontes, M., & Wieniek, D. (2014). Proceedings from the Marketing Management Association Fall 2014: *Teaching data visualization*.
- Honey-Roses, J., Le Menestrel, M., Arenas, D., Rauschmayer, F., & Rode, J. (2013). Enriching intergenerational decision-making with guided visualization exercises. *Journal of Business Ethics*, 122(4), 675-680.
- Kellner, D. (1998). Multiple literacies and critical pedagogy in a multi-cultural society. *Educational Theory*, 48(1), 103-122.
- Mayer, R. E., & Massa, L. J. (2003). Three facets of visual and verbal learners: Cognitive ability, cognitive style, and learning preference. *Journal of Educational Psychology*, 95(4), 833-846.
- Penrose, J. (2006). Teaching the essential role of visualization in preparing instructions. *Business Communication Quarterly*, 69(4), 411-417.

Stokes, S. (2002). Visual literacy in teaching and learning: A literature perspective. *Electronic Journal for the Integration of Technology in Education*, 1(1), 10-19.

Toth, C. (2013). Revisiting a genre: Teaching infographics in business and professional communication courses. *Business Communication Quarterly*, 76(4), 446-457.

Wileman, R. E. (1993). *Visual communicating*. Englewood Cliffs, NJ: Educational Technology Publications.