Supporting Student Success with Intuitive, Approachable Data Visualization

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Abstract

New discoveries surrounding the mechanisms and function of human visual acuity have come with increasing rapidity, each clarifying the astounding pattern recognition, image retention, and processing speed of the human visual cognition system. However, the relationship between institutions of higher learning and data visualization can be classified as embryotic at best. This chapter will examine such a new paradigm in data visualization for higher education, examining obstacles and clearly defining benefits that have been illustrated through real-world case studies utilizing appropriate technologies. For data visualization to offer the most tangible value as student success assets in an educational setting, visualizations need to be made as functionally and cognitively accessible.
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formal training and takes full advantage of the intrinsic human ability to learn, communicate, and decode information visually. Such methods have often been called transparent due to their clarity and immediate accessibility (Perer & Schneiderman, 2008).

The relationship between institutions of higher learning and data visualization, whether at the organizational or at the classroom level, can be classified as embryotic at best. Traditionally, faculty members and administrators review performance data as rows of raw numbers or in charts and graphs, and usually only after a semester has concluded. The story is even more frustrating for the students, whose interaction with the data is limited to a spreadsheet showing earned grades on assignments, weighted gradebooks per course, or progression through standardized education programs via GPA. However, should more thorough, intuitive, transparent data visualization methods be applied, the results have the potential to be transformative, and early research projects conducted with students in academic environments would support this thesis. For example, by coupling the bimodal distribution of student scores with early warning signs of failure, a grant-based research project conducted at the Michigan Virtual University (Dickson, 2005) successfully performed visual data analyses to gauge student satisfaction with online courseware and lower the barrier to data-driven decision making for faculty in the early intervention of student failure. In areas of future research identified from the study, the researchers encouraged the development of adapted models for visual data representation to fit the specific needs of faculty and students as the previous study had illustrated the applicability of dynamics of student success through visual meta-analysis (Dickson, 2005). A similar undertaking by Canadian researchers successfully developed a Student Success System (S3) by using flexible predictive modeling, machine intelligence, and data visualization as an end-to-end solution for identifying at-risk students and designing interventions to mitigate that risk (Essa & Ayad, 2012).

Additionally, researchers from North Carolina General Assembly, in partnership with JMP Software, a data visualization–based interactive tool for desktop statistical discovery, conducted an experiment 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 various verticals of industry. With limited focus on materials generally covered in traditional mathematics curriculum, students were invited to explore...
data critically and visually to structure information for summary analysis. At the end of the program, students had developed a improved capacity to visually work with and understand data, understand the role of data in decision making, and achieve higher individual engagement with visual data (Brinkley, 2014).

Providing guided visualization examples has also been acknowledged as a catalyst for creative thought and problem solving and has been determined to offer innovative pedagogical formats to engage more intimately with higher education students (Honey-Roses, Le Menestrel, Arenas, Rauschmayer, & Rode, 2013).

Thus, a new paradigm exists in data visualization for higher education with clear benefits already being recognized by researchers and realized by early-adopting organizations. For data visualization to be of the most use in an educational setting, visualizations should be accessible to students and faculty, allowing both to share in data that is prudent to improve performance. Fortunately, recent research into the speed and power of human visual processing has given rise to new methods of data visualization that harness this ability, using universal visual language to instinctually highlight areas of improvement with no prior training required and to capitalize on data visualization as a mechanism to support student success.

**Review of the Literature**

The case for supporting student success with data visualization begins with understanding the power of pictures, and their impact on memorability, learning, and learning retention. Previous to the research of Thorpe et al. (1996), seminal research from the 1970s tells us that humans are extremely good at remembering thousands of pictures and a vast amount of visual detail. As a measure earmarked in the academic literature, the number of remembered images and context has been estimated to be roughly ten thousand images at an accurate recognition rate of approximately 83 percent (Standing, 1973).

In more recent years, attributes-based visual recognition has continued to receive much attention, particularly in the computer science literature, and numerous in-depth studies have provided clear data and learning opportunities. Thus, we now definitively know visualizations that blend information with influential features (such as color, density, and content themes, like recognizable icons or imagery) significantly and reliably increase learning, memorability, and recall (Borkin et al., 2013). Further, seeing and interacting with an image in combination with traditional written and verbal instruction has, too, been consistently associated with higher levels of retention and understanding of salient ideas. While research into the human cognitive capacity to remember visual stimuli remains ongoing, in the past few years researchers have worked to systematically study the intrinsic memorability of images and the interface between human cognition and computer vision. This body of study is ultimately intended to understand the predictive ability of visual memorability and how visuals can be designed to best leverage our innate visual recognition system.

**Visualization Stimulates Memory Retention**

A collaborative research project by computer scientists from Harvard and cognitive scientists from MIT explored cognitive memorability of visualizations to uncover empirical evidence to support the theory that while our memories are unique, we have the same embedded algorithm necessary to convert visual communication into memory and thereby learn and retain learning. To test this theory, researchers used a publicly available memorability data set and augmented the object and scene annotations with interpretable spatial, contextual, and aesthetic image proprieties (i.e., colors, shapes, etc.) (Isola et al., 2011).

The researchers found that, contrary to popular assumption, unusualness and aesthetic beauty are not associated with high memorability and are, instead, negatively correlated with memorability. Instead, a visualization is instantly and overwhelmingly more memorable if it includes a human-recognizable element (i.e., a photograph, person, cartoon, or logo). These items provide our memory with visual cues by which to build a story around, and offer a compelling case for the use of icons in visualizations like infographics that rely on symbols to communicate mass amounts of complex data in simple and meaningful ways.
Human-Like Symbols Provide Memory and Engagement Cues

Neuropsychology has long associated written word recognition with different functional areas of the brain, known as the visual word form area (VWFA). However, in recent studies, cognitive researchers have provided more modern empirical evidence that the VWFA overlaps with a subpart of the ventral visual cortex that exhibits special sensitivity to line junctions, including symbols and natural scenes (Dehaene & Cohen, 2011). As illustration of this finding, in a subsequent study on what makes a visual memorable, researchers built a broad, static visualization taxonomy to cover the large variety of data visualizations in use today. They then collected nearly six thousand visual representations of data from various publications and categorized them by a wide range of visual attributes.

The images were exposed to participants via Amazon Mechanical Turk to test the influence of features like color, density, and content themes on participants’ memorability. The results of the study validated previous findings that faces and human-centric scenes are more memorable than others—specifically, people and human-like objects contributed most positively to the memorability of images. These findings provide further support that certain design principles make visualizations inherently more memorable than others, irrespective of individual context and biases (Borkin et al., 2013).

Integration into the Student Experience

By synthesizing the implications of the aforementioned research, it can be reasonably assumed that integration of data visualization to support student learning and success can be achieved at the intersection of data and analytic accessibility and the application of known low-barrier visual cognitive engagement elements, particularly human-recognizable visual features. With a proximal goal in place, the question now becomes “How can educational institutions use transparent data visualizations to foster student success?”

Unfortunately, such implementations are somewhat challenging to find as more traditional forms of visualization, such as basic charts and graphs, still largely dominate the field. These basic visualization forms lack the key elements required for memorability and speedy visual consumption and understanding as demonstrated by Isola et al. (2011) and Borkin et al. (2013) and thus lack the required transparency necessary for an untrained student, parent, or faculty member to quickly understand relevant educational data. However, while homegrown academic solutions are still incubatory, commercially available data visualization software platforms exist that make the work of translating tabular, two-dimensional data into transparent visualizations more accessible. While these technologies are still in their nascent stages due to the prevailing reliance on older forms of data visualization, there are case studies provided by higher learning institutions that have implemented available technologies to positive effect, thereby proving the theory that data visualization can be useful in higher education to support student engagement if approached correctly.

Proven Practices, Examples, Results, and Lessons Learned

As an applied example, VisualCue Technologies LLC is one such software platform. Its technology translates key performance indicators into human-recognizable icons, each resembling in some recognizable way the metric they represent (see Figure 1). Thresholds are then introduced into the data, and these are the parameters by which the colors of the icons change based on educational best practices embraced by the institution. This data visualization technique takes full advantage of the key requirements for memorability put forth in the literature review. Icons provide recognizable, relatable elements with which to ground abstract data sets in visual language, thus making them accessible to the widest-possible range of users. And this approach serves to take full advantage of the speed and processing power in the human visual system as originally described by Thorpe et al. (1996) and reinforced through myriad continued scholarly research endeavors since. In essence, these new visualization techniques make even the largest data sets immediately and intuitively consumable.
Both reception and results have been positive. Students feel more included, and due to the transparent nature of the visualization, they are able to spot patterns faster and act on them with more certainty. Due to the frequency of the updates, students were able to successfully make micro-corrections to their learning and improve earlier in each term (G. Barretto, personal communication, January 23, 2016).

Seminole State College—Sanford, Florida

Located near Orlando, Florida, Seminole State College faced a different set of challenges from Colégio Notre Dame. In what might be a common concern among many institutions of higher education, the college simply did not have enough teachers and administrators to adequately analyze and tailor support for each student. While large class sizes are certainly nothing new to academia, for this smaller university having even fewer faculty and administrative staff exacerbated the problems caused from a lack of analytics. However, this organization decided that its ever-growing student population could benefit just as much from advanced analytics as those at a larger, more well-funded university. As such, its task was not only to analyze the academic performance of its students, but also compare those results with other key performance indicators, such as absenteeism, course history, and enrollment.

Rather than expect real-time feedback, Seminole State was more interested in looking at long-term trends alongside more granular information. Since implementing the transparent data visualization technology, the college has been effectively able to gain a sense of the student’s entire educational experience and support that impression with specific details to help improve student success on an individualized basis (K. Gilger, personal communication, January 20, 2016).

Conclusion

Whether through real-time corrections to student behavior or using more long-term analysis to augment a teacher’s skill set, the benefits remain the same. The institutions detailed above, and the scholarly support provided through the analysis of available literature on the positive benefits of student engagement with data visualization, illustrate enormous
benefit to student achievement and university data-driven decision making through the use of intuitive, approachable data visualization. Thus, the authors conclude that a combination of both real-time and long-term data analysis utilizing intuitive, pictorial data visualization techniques will produce tangible value for both students and faculty at any institution of higher education where it is implemented.

References


Author Biographies

Lindy Ryan is a researcher in the confluence of data discovery, visualization, and data science. She is a research associate with the Rutgers University Discovery Informatics Institute (RDI2) and an associate faculty member of City University of Seattle’s School of Applied Leadership. She is the author of *The Visual Imperative: Creating a Culture of Visual Discovery* (2016), a featured contributor to *Big Data Quarterly* and *Information Management*, and a frequent guest speaker at conferences such as the Data Summit, Teradata Partners, TDWI, and more.

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