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## Full-Length Paper

### Providing Library Support for Interactive Scientific and Biomedical Visualizations with Tableau

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#### Abstract

Developing effective visualizations is crucial for understanding and communicating data in a variety of contexts. Tableau is an easy-to-use tool for creating customized, interactive visualizations. Although Tableau is often discussed in the context of business intelligence, it can also be used to create effective scientific and biomedical visualizations in the context of research, public health, and medical care.

This article provides a basic introduction to Tableau's uses and discusses the NIH Library's experience with providing support for Tableau. Four case studies demonstrate the range of services that the Library offers, as well as providing examples of the many different applications for Tableau.

The article also provides resources for learning Tableau and insights on developing a successful data visualization support service.

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Creating appropriate and effective visualizations is a key task in working with data, especially the large and complex datasets that often characterize modern scientific research. Data visualization makes it possible to demonstrate findings to various stakeholders in a coherent and straightforward manner and plays an important role in scientific communication. As many scientific journals have moved to web-based publishing platforms, the ability to incorporate interactive visualizations into articles has enhanced understandability and increased research transparency (Weissgerber et al. 2016). Exploratory visualization can also play a critical role in facilitating discovery by elucidating patterns or outliers in data (Wrobel et al. 2016), as well as uncovering errors and data quality problems (Xie et al. 2006).

While a variety of visualization tools exist, many of them require knowledge of programming languages like JavaScript, R, or Python, especially those tools that can be used to design interactive visualizations. Besides the complication of learning a programming language, building visualizations from scratch using such tools can be challenging to novice users who are unfamiliar with best practices for constructing and designing visualizations (Grammel, Tory and Storey 2010). On the other hand, easier-to-use tools like Excel lack interactivity and the flexibility necessary to create customized visualizations, and have difficulty with handling larger datasets.

Tableau software is a useful alternative to such tools, allowing users to easily create customized and interactive visualizations, including live-updating dashboards. Although Tableau is frequently described as business intelligence software, it can also be useful in a variety of scientific and research applications. Examples exist in the literature of Tableau being used in the contexts of epidemic surveillance and contact tracking (Sacks et al. 2015), healthcare utilization analysis (Weiss et al. 2011; Mukherjee, Wu and Jones 2016), clinical research data analysis (Lee, Thurston and Thurston 2017; Harris and Henderson 2016; Vincent, Hastings-Tolsma and Effken 2010), and basic science data analysis (Shih et al. 2011). This article will provide an introduction to Tableau and its uses in biomedical and scientific research contexts, discuss the NIH Library's experience with Tableau and other data visualization services, and offer guidance for developing library support for Tableau.

### **Tableau: A Brief Introduction**

Tableau software is designed specifically for creating interactive visualizations. Interactivity can be introduced into Tableau visualizations by utilizing filters (for example, using a filter to select only a specific year to show on the chart) and tooltips, which show a message when the cursor is placed over a data object (for example, showing information about a point on a scatterplot). Multiple visualizations can be combined on dashboards, which allow users to get a more complete view of their data by placing several charts in one place. Stories are another way of combining visualizations, presenting multiple visualizations one at a time in a sequence, similar to a slideshow. Tableau visualizations can be created using many different data types, including both static datasets (like an Excel file) and dynamic datasets (like a server or database). When Tableau is connected to a dynamically updating data source, the visualizations provide a live, automatically updating view of the data. Thus, Tableau is useful for creating dashboards that reflect the current status of a system or dataset.

Although Tableau's drag-and-drop interface is more user-friendly and easier to learn than many other visualization tools, effective use of the software does require some practice, as well as familiarity with best practices in data visualization. A thorough introduction to Tableau is

beyond the scope of this paper, but a wide range of free resources are available for users with varying levels of expertise. Because Tableau has a large user community, many publicly available examples of its dashboards and workbooks can provide inspiration and ideas. In addition, the Tableau Community website provides a forum to connect with other users to ask questions and share ideas (Tableau Software 2017b). Free video tutorials covering the different versions of Tableau are available on the official website (Tableau Software 2017d), and many third-party training websites like Coursera and Lynda.com also provide training.

Tableau software is available in several versions with similar visualization design functionality, which differ primarily in where and how visualizations can be viewed. Tableau Public is a free version available for Windows and Mac (Tableau Software 2017c). As its name implies, Tableau Public's visualizations can only be saved to and displayed on the Tableau Public website. While this free hosting solution may be desirable to users who want to deploy visualizations online but lack the resources to host on their own server, Tableau Public may not be appropriate for users who have privacy concerns about their data, like investigators whose research is still in progress or users working with personally identifiable information. The Tableau Public website can also be a useful resource for users who want to explore the functionality of Tableau; since thousands of users upload visualizations to the website, many examples are available that demonstrate some of the ways that Tableau Public can be used and provide design inspiration.

Tableau Desktop, available in Personal and Professional versions, allows users to save files to their own computer or network, rather than the Tableau Public website. While it is not free, it may be a more appropriate choice for users who do not wish to make their visualizations publicly available. Tableau Desktop is required to create and edit content, but for users who only need to view previously created Tableau Desktop files, Tableau Reader is available for free. Similar to the Adobe Acrobat PDF Reader, the free Tableau Reader cannot be used to edit visualizations, but can be useful for users who only need to view visualizations. For example, one member of a team might make an interactive, live-updating dashboard in Tableau Desktop and the rest of the team could view it using Tableau Reader without having to purchase additional Tableau Desktop licenses.

For groups that need enterprise-level solutions that allow for simultaneous users, Tableau Server and Tableau Online may be useful. Tableau Server requires hosting on the user's own server, while Tableau Online is hosted in the cloud by Tableau. Most research groups would likely not need such a large-scale visualization service as Tableau Server or Tableau Online, but it may be relevant to users seeking an institution-wide solution that can deploy information to many users.

As with any software, Tableau does have limitations that mean it is not necessarily the best tool for every job. Tableau is best suited to interactive visualizations that will be viewed within Tableau software. Visualizations can be saved as PDFs, but using this format saves only a static view of the chart, not any of its interactive features. Because much of the meaning of Tableau visualizations are embedded in their interactivity, static renderings of the charts may lack crucial information for interpreting the charts. Thus, other tools that are intended for static charts may be more appropriate for users who want to create charts for scientific posters or publications. Additionally, while Tableau does provide a wider variety of chart types than simpler tools, like Excel, it still only offers a set "menu" of visualizations that can be applied to

data. Users who want to explore more novel chart forms or customize their visualizations to a greater degree than is possible in Tableau may need to explore using a programming-based tool, like the JavaScript library D3 (Bostock 2017) or R's ggplot2 package (Wickham 2013).

### **Developing Capacity for Tableau Support at the NIH Library**

The National Institutes of Health (NIH) Library provides support for researchers and staff at the NIH. NIH's Intramural Research Program is the world's largest biomedical research institution, with over 1,200 principal investigators and 4,000 postdoctoral fellows. In addition, the Library supports customers at related institutions within the United States Department of Health and Human Services, many of whom conduct work in public health and health policy.

In 2014, the NIH Library conducted a survey of its customers regarding data literacy training needs (Federer, Lu and Joubert 2016). Respondents (n = 190) rated data visualization as the most important of the nine data-related tasks in the survey, with 85% indicating that the relevance of data visualization to their work was High or Very high. Only 38% of respondents considered their expertise in data visualization High or Very high. In a follow-up survey on data visualization conducted by the Library in 2015 (160 respondents), more respondents were interested in Tableau than any of the other nineteen visualization tools included in the survey, with 35% of respondents indicating that they were interested in learning Tableau. These findings suggested that data visualization services, and Tableau support in particular, would be of interest to the Library's users. As a result, the Library's Data Services team and other Library staff developed a number of initiatives to support this need.

In order to highlight visualization as a service, the Library purchased a large data visualization touchscreen<sup>1</sup> that was placed in the Technology Hub, a space for featuring new technologies in the Library's main reading room. Tableau Reader was installed on the data visualization touchscreen to allow customers to view previously created Tableau visualizations. Tableau Desktop was installed on the adjacent Data Services workstation, which can be reserved or used on a walk-in basis as available. Making the software available on the Data Services workstation allows customers to try out Tableau software before making the decision to purchase it for themselves, practice using it, and make visualizations that can be opened with Tableau Reader.

Staff from the Data Services team who were interested in supporting Tableau undertook training to gain expertise in Tableau specifically, as well as data visualization more broadly. The Library's Research Data Informationist completed an online certification in Data Visualization from New York University<sup>2</sup>, which focused on design and best practices for visualization in general, and also learned Tableau through freely available online materials. Other members of the Data Services team and Library staff completed Tableau-specific training, including offerings from Lynda.com, Coursera, and the Knight Center for Journalism in the Americas (Francis 2016; Sullins 2017; Egger and Schaich Borg 2017; Cairo and Krause 2016). Table 1 contains a list of classes and other suggested resources that NIH Library staff have found useful in learning Tableau and data visualization skills in general.

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1 The touchscreen consists of a Samsung DM65D - 65" Class (64.5" viewable) LED display with a Samsung Touch Overlay CY-TE65ECC.

2 NYU no longer offers this certificate, but the individual courses are still available for online and in-person registration at <https://www.sps.nyu.edu/professional-pathways/search.html?keyword=data%20visualization>

**Table 1:** Tableau and data visualization resources.

<b>Tableau-specific Resources</b>
Tableau Health User Group   <a href="https://community.tableau.com/groups/healthcare">https://community.tableau.com/groups/healthcare</a>
Integrating Tableau and R for Data Science <a href="https://www.lynda.com/Tableau-tutorials/Integrating-Tableau-R-Data-Science/553698-2.html">https://www.lynda.com/Tableau-tutorials/Integrating-Tableau-R-Data-Science/553698-2.html</a>
Tableau 10 for Data Scientists <a href="https://www.lynda.com/Tableau-tutorials/Tableau-10-Data-Scientists/476621-2.html">https://www.lynda.com/Tableau-tutorials/Tableau-10-Data-Scientists/476621-2.html</a>
Data Visualization and Communication with Tableau   <a href="https://www.coursera.org/learn/analytics-tableau">https://www.coursera.org/learn/analytics-tableau</a>
<b>General Data Visualization Resources</b>
The Quartz Guide to Bad Data   <a href="https://github.com/Quartz/bad-data-guide">https://github.com/Quartz/bad-data-guide</a>
Ethics of Data Visualization   <a href="http://cslu.ohsu.edu/~bedricks/courses/cs631/lectures/week10_lec2.pdf">http://cslu.ohsu.edu/~bedricks/courses/cs631/lectures/week10_lec2.pdf</a>
HealthDataViz Blog   <a href="http://www.healthdataviz.com/blog/">http://www.healthdataviz.com/blog/</a>
FlowingData Blog   <a href="http://flowingdata.com/">http://flowingdata.com/</a>

In order to foster community and encourage sharing of ideas and skills around Tableau as well as data visualization in general at the NIH, the Library created a Data Visualization Community of Practice (COP). The COP email list serves as a means for interested individuals to communicate, ask questions, and share expertise. Quarterly meetings, with in-person and webinar attendance, featured talks on tools and applications as well as discussions of exemplary visualizations. Participants were encouraged to present their own data visualization projects. For example, a COP member from the Administration for Children and Families, a division of HHS, presented a data-driven child welfare workforce dashboard their group had developed using Tableau (Administration for Children and Families 2014). The COP provided Library staff supporting data visualization an opportunity to learn directly from customers about the tools and types of visualizations that most interested them, including Tableau, and helped inform the development of the Library's data visualization services.

### **Biomedical and Health Sciences Applications of Tableau: Four Case Studies**

Since the Library began supporting Tableau in 2014, Library staff have provided support for a range of discipline-specific applications. This support has taken various forms, including one-on-one and group consultations, in-person training, webinars, and special events, allowing customers to take advantage of the type of training or support that is most convenient for them. Meeting the distinct needs of the Library's various customer groups also requires tailoring content to focus on specific data types and subject areas. Here, four case studies are presented as a cross-section of the types of support the Library provides and use cases for Tableau in biomedical and health sciences work.

### *Introduction to Biological Data Visualization with Tableau*

In January 2016, the Library offered a course titled “Introduction to Biological Data Visualization with Tableau,” focused on training scientists on how to utilize Tableau Desktop for the purpose of visualizing research data. The instructor for the course was a researcher who used Tableau in her own work and volunteered to share her expertise after attending meetings of the Data Visualization COP that the Library hosted. In order to be able to offer attendees a hands-on experience, the Library’s Data Services team leader worked with NIH’s Tableau vendor to obtain temporary trial licenses for the Library’s training laptops. The two-hour course covered an introduction to terminology and basic functionality, how to create several different types of charts and graphs, and how to combine visualizations into dashboards and stories. After the popularity of the January course, which had 19 attendees, a second session was held in April 2016, with 13 attendees.

Because Tableau has more typically been used in business intelligence rather than research settings, many online training modules use examples and datasets relevant to business or marketing. Though the fundamental skills used in these sorts of examples still hold in research data contexts, attendees at data-related classes offered at NIH Library have often commented that they prefer to see examples using data similar to the type of data they might use in their work. Thus, for this class, the instructor used a scientific research dataset, the classic Fisher’s iris dataset (Fisher 1936). Having a scientist teach the class and using scientific data for the hands-on exercises seemed to help attendees connect the skills they learned to their own work and to understand more clearly how they might use Tableau with their own research data.

In addition to providing a handout with suggested resources and materials for follow-up after the course, the instructor also prepared workbooks that contained the final visualizations and dashboards that were used for the hands-on portion of the class. These materials were emailed to attendees as well as posted on the class website (NIH Library 2017). Although the final visualizations were made available after the class as workbooks, some attendees commented in the post-class evaluations that they would have liked a handout with complete instructions and screenshots of each step, as some of them had difficulty keeping up with the hands-on exercises in class.

### *Tableau for Health and Policy Data*

While the Introduction to Biological Data Visualization with Tableau class appealed to the NIH audience, consisting primarily of biomedical researchers, the Library’s customer community at the Department of Health and Human Services (HHS) focuses more on public health and policy issues. In addition, most of these offices are located in downtown Washington, D.C. rather than on the NIH main campus in Bethesda, MD, making in-person attendance at the Library challenging for these customers. To meet the unique needs of these users, Library staff developed a series of Tableau classes focusing on public health and policy-related data and offered these sessions by webinar. Altogether, the Library has offered five webinar sessions for specific HHS groups, with over 275 total attendees.

Like the session on biological data visualization, the webinars assumed attendees did not have experience with Tableau and therefore covered basic functionality and other introductory topics. Based on feedback from users and the experience with the Introduction to Biological

Data Visualization with Tableau class, Library staff who developed these classes felt that it was crucial to use datasets relevant to public health and policy analysts. Datasets used for these classes included USDA Supplemental Nutrition Assistance Program (SNAP) data (United States Department of Agriculture Economic Research Service 2016), CDC Behavioral Risk Factor Surveillance System (BRFSS) spatial data (Centers for Disease Control and Prevention 2015), and data from the U.S. Census Bureau Survey of Income and Program Participation (SIPP) survey (United States Census Bureau 2017). In addition, the webinars for these groups focused more on geographic visualizations, which had not been an area of focus in the in-person sessions for researchers. Materials from these webinars, including handouts and Tableau workbooks, are available on the Library's website (NIH Library 2017).

### *Tableau for Mapping and GIS Day*

Geographic information systems (GIS) tools are used to create geographic visualizations, which have uses in public health, biomedical research, and other scientific applications. GIS Day is a worldwide celebration of GIS tools and their impact on society and technology, celebrated annually in November (Esri 2017). Though Tableau is not designed as a GIS tool, it is capable of creating geographic visualizations that can be standalone visualizations or included as part of a dashboard (Tableau Software 2017a). This mapping capability was featured in a presentation at the NIH Library's special event in honor of GIS Day in 2016.

Held on November 16, 2016, the GIS Day event was offered in-person at the Library as well as by webinar, with 40 participants overall. A trainer from Tableau taught the session, which focused on exploratory data visualization with maps, creating advanced map-based visualizations, and incorporating maps into dashboards. Having representatives from Tableau on hand presented an opportunity for attendees to ask in-depth questions about mapping and other Tableau issues. In addition, Library staff from the Technology Hub team were present to answer questions about the Library's support for Tableau, GIS, and mapping. Like the Data Visualization COP, this event provided a useful opportunity for Library staff to connect with the users of visualization products and services.

### *Consulting on Tableau Visualizations for Hospital Data*

While classroom- and webinar-based Tableau training sessions have been an efficient way to provide support to groups and meet the general needs of many customers, some groups and individuals need further consultation to learn more advanced techniques or to apply skills to complex, specialized problems. The Library has worked with several clinical care groups within the NIH's Clinical Center, which provides inpatient care for participants in clinical trials at the NIH, providing assistance on using Tableau to develop dashboards to monitor various aspects of their clinical work. Although some of these departments already had some data visualizations and dashboards, these dashboards were in systems that were difficult to customize, with data presented only in a few predefined ways that were not as helpful as their users would like. Tableau is well-suited to the sorts of live dashboards that these groups wanted, and had the advantage of being more interactive and customizable than the systems that were currently in place.

The Nursing Department was interested in utilizing Tableau to create specialized control charts, like c-charts that track the total number of falls per day and u-charts that monitor the

number of new infections per day. The Surgical Services Department wanted to track data about surgeries, including length of time and assigned staff. Library staff assisted by providing Tableau training for staff in these departments, as well as consulting on how to create the desired visualizations and dashboards. Based on the success of these departments and others with developing dashboards in Tableau, the Clinical Center has considered licensing Tableau site-wide for broader use within the hospital.

### *Recommendations for Developing Tableau and Visualization Support*

For libraries interested in developing support services for data visualization, Tableau may be a useful tool with which to begin. Since Tableau does not require learning a programming language, and given the wide availability of free training resources, it can be very approachable and easy to learn. Learning Tableau can also have the added benefit for librarians of being useful for analysis and visualization of library data (Murphy 2013, 2015). In addition, Tableau tends to be widely heard-of and may have more name recognition than other visualization tools, so library users may be more likely to utilize Tableau classes and support.

Libraries may also be able to utilize existing Tableau knowledge and skills within their community. The NIH Library's class on biological visualization in Tableau was successful in part because it was taught by a scientist who understood the needs of other scientists. Especially for early-career professionals like postdoctoral fellows, volunteering to teach a class can be a useful opportunity to gain teaching experience, while also benefiting the library by bringing in outside expertise and lessening the burden of supporting visualization for library staff. The Data Visualization COP also allowed the Library to capitalize on existing Tableau knowledge and skills.

Whether library staff or outside volunteers are teaching classes, attendees may benefit most from instruction specifically tailored to their area of interest, with examples featuring data similar to what they typically use and visualizations of the type they are likely to create. Adult learning theory emphasizes that adults learn best when the real-world applications of instruction are clear and relevant to them (Knowles 1970). Thus, instructors in science and biomedical libraries may find that the business intelligence examples often used in Tableau instruction are less useful than examples that feature research data, public health data, or other types of information that are more directly relevant to the attendees' work.

Finally, outreach to the community can be an essential step in creating a successful visualization service, whether focusing on Tableau or other tools. The two surveys that the NIH Library conducted were essential in determining the types of services and tools that would be most useful to the community. In addition, the Data Visualization COP represented a valuable resource for remaining engaged with the community on an ongoing basis. The quarterly meetings provided insight into the types of visualizations and tools that were relevant to the community and gave library staff a chance to network with individuals who were interested in using the Library's services, as well as others who were able to offer help with supporting the service. Especially given that technology and user needs can change quickly, ongoing evaluation and community engagement can help ensure long-term success of a data visualization service.

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