Data Visualization Technology to Support Inquiry and Chronological Understanding in Social Studies

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Data literacy, an important goal for social studies education, involves teaching students how to comprehend, analyze, interpret, evaluate, create, and argue with data and data visualizations such as timelines, maps, and graphs [1]. Digital tools allow us to more easily construct and view data visualizations, especially when working with larger datasets. There are freely available large datasets that have been gathered with clear and authoritative provenance and would be interesting in social studies classes. For example, the United Nations' UNdata [2] provides datasets including nations' populations, GDPs, and CO2 emissions. These datasets contain hundreds or thousands of data points, which makes them impractical to graph on a whiteboard or with pencil and paper.

Digital data visualizations can support rapid inquiry and exploration that would be difficult on paper – such as revising a data visualization, adding data to an existing data visualization, or creating multiple data visualizations of the same variable at multiple times or places for easy comparison. Though there are many digital data visualization creation tools available, few have been designed *specifically* for use in a social studies classroom. Existing tools have been designed for application in areas like journalism, science, or statistics, so they often lack features important to social studies data inquiry.

We are a group of researchers in computer science education and social studies education who are interested in understanding how K-12 teacher pedagogy in the area of social studies data inquiry can be supported with technological tools. In designing new digital tools for data visualization, we aim to be responsive to social studies teachers. We base our designs and features around the specific needs of teachers and social studies education. By creating new tools, we can make it easier to use digital data visualizations within K-12 social studies classrooms.

Challenges and Opportunities Within Digital Data Visualization

We began our work by talking to prospective and current social studies teachers [3, 4]. We asked them what features they liked in existing data visualization tools, what parts would be challenging to teach, and how they might want to use digital data visualization in their classrooms. We learned that teachers liked the data visualizations they could create with some existing tools, but that many of the tools were difficult to use in the context of social studies [3]. Existing tools such as CODAP and Vega-lite were created for other domains, which their features reflected. Most importantly, they lacked mechanisms needed by social studies teachers such as support for both BCE and CE dates or the ability to have a driving question built into the interface.

Our purpose-built data visualization tools contain features useful and usable in social studies instruction. We learned from the teachers we talked to that they care most about the questions

that drive curiosity and inquiry, and stories that can be created with data and events. Here, we describe our two tools centered on data inquiry and chronological understanding.

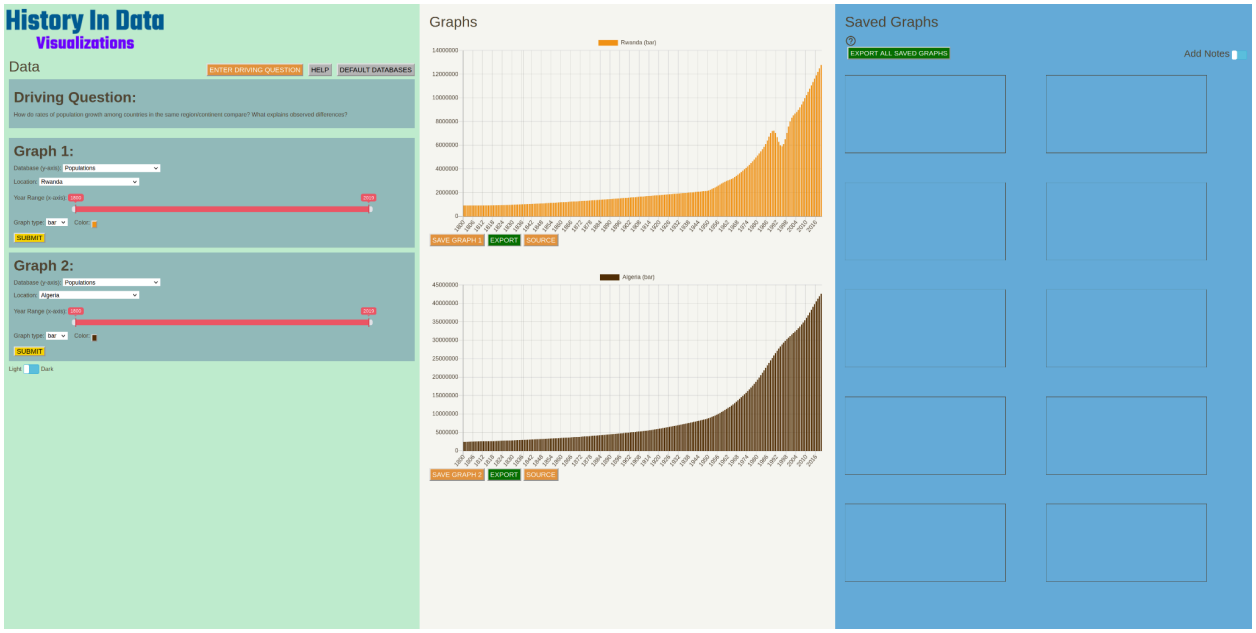

Figure 1. An example of creating graphs with Data Visualization for Literacy. Two graphs are displayed, one of the population of Rwanda from 1800 to 2019, and a second of the population of Algeria from 1800 to 2019.

Data Visualization for Literacy

An important part of social studies education is the process of inquiry through data: asking questions and finding answers through data exploration. In Data Visualization for Literacy (DV4L) [5], students can create graphs using large historical datasets, edit graphs, and compare multiple graphs. Alongside the graphs, DV4L contains features useful to social studies inquiry, such as the ability to specify a driving question within the tool and view the source of each dataset.

Using DV4L begins with the creation of graphs. Menus for specifying the graphs are on the left-hand side of the screen, and the created graphs are on the right-hand side (as shown in Figure 1). DV4L starts with graphs already created, so that all use is focused on specification and modification. DV4L always shows two graphs at one time, because comparing the graphs can prompt inquiry into similarities and differences between them. Students can specify a dataset and a type of graph. There are many datasets already available in the tool, about topics like countries' populations and military spending, so teachers do not need to spend time finding, verifying, and formatting sources of data. In relation to a chosen dataset, a range of years can be specified to only graph portions of that dataset. Any graph can be saved by dragging it to the right, to provide a trace of inquiry and later revision.

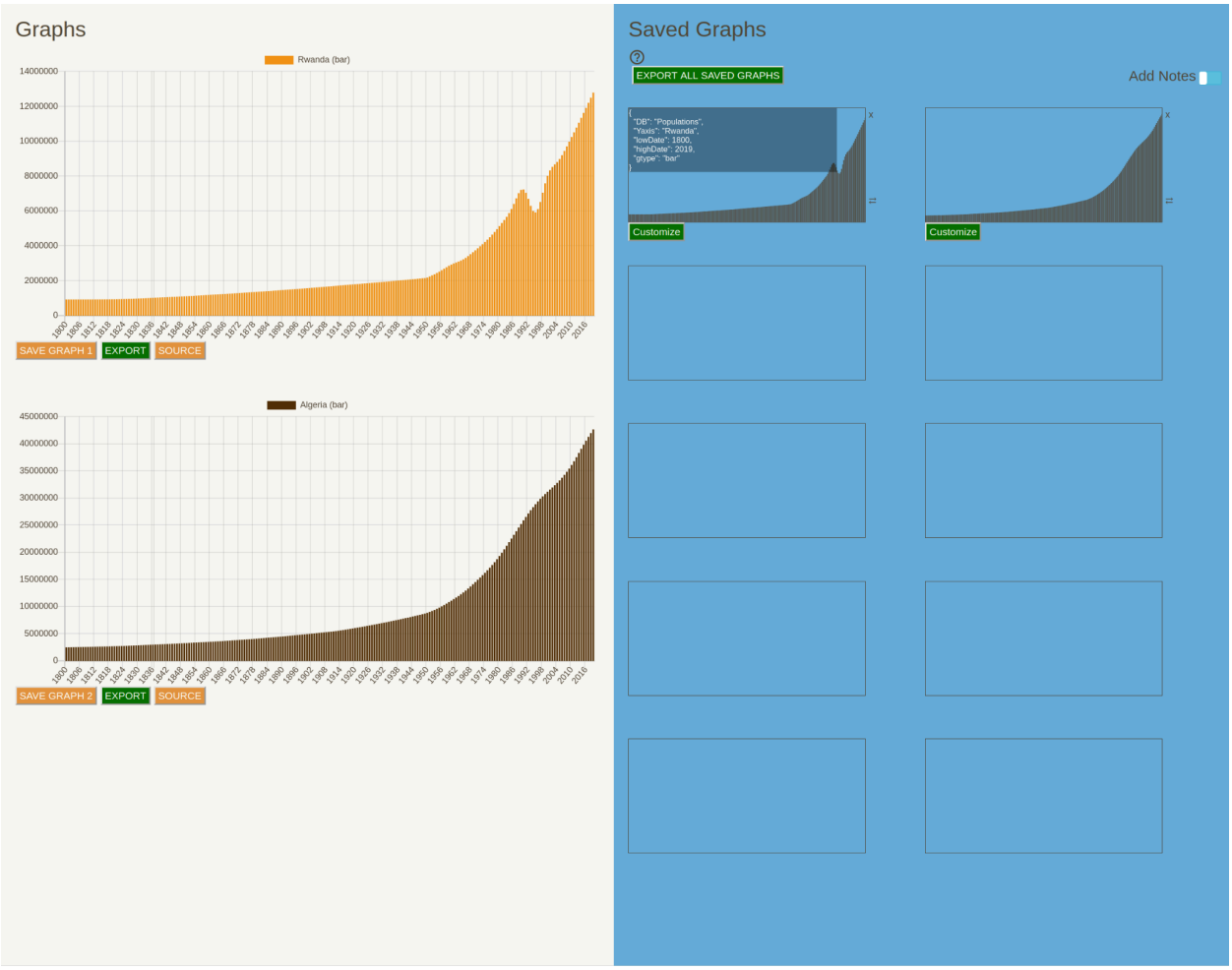

Figure 2. A demonstration of saved graphs in DV4L. Two graphs are shown in the "Saved Graphs" portion of the screen. Hovering over the first reveals that it is a bar graph of Rwanda's population from 1800 to 2019.

TimelineBuilder

We created TimelineBuilder [6] to ease creation of timeline visualizations. Timelines can help students understand historical narratives by supporting their understanding of chronology. Teachers had told us that they had used other tools, such as TimelineJS, but found them to be error-prone and complicated.

In TimelineBuilder, events are added through the menu on the left-hand side of the page. Every event must have a name, start date, and end date. A unique date feature in TimelineBuilder is that the start or end date can be specified as a duration. So if a start date and a duration of 'one year' is specified, then an end date need not be specified. Events can also have optional fields, such as a geographic location or a description. An event is created once you click **add event**, and then the menus can be used to create additional events. Events appear on the timeline, shown on the right-hand side, as soon as they are created.

Events in TimelineBuilder can be added in any order, not just chronologically, which can be helpful for students when they are trying to sequence events from a complex narrative. Any number of events can be created and are then displayed in chronological order on a timeline. We have designed it to automatically show all overlapping events to support students' understanding of concurrence, as well as series of events across both large and short time frames. Both BCE and CE dates can currently be accommodated by TimelineBuilder through entering BCE dates as a negative number, which demonstrates how those dates may be viewed on a number line and situated in time.

In addition to the timeline of events, TimelineBuilder has an editable title and driving question field for each timeline. Like DV4L, the driving question field is meant to make explicit the question which the data visualization is being created to answer. Timelines in TimelineBuilder can currently be saved through screenshots or printing the page, and should continually be accessible through the same browser on the same computer, even if the page is closed.

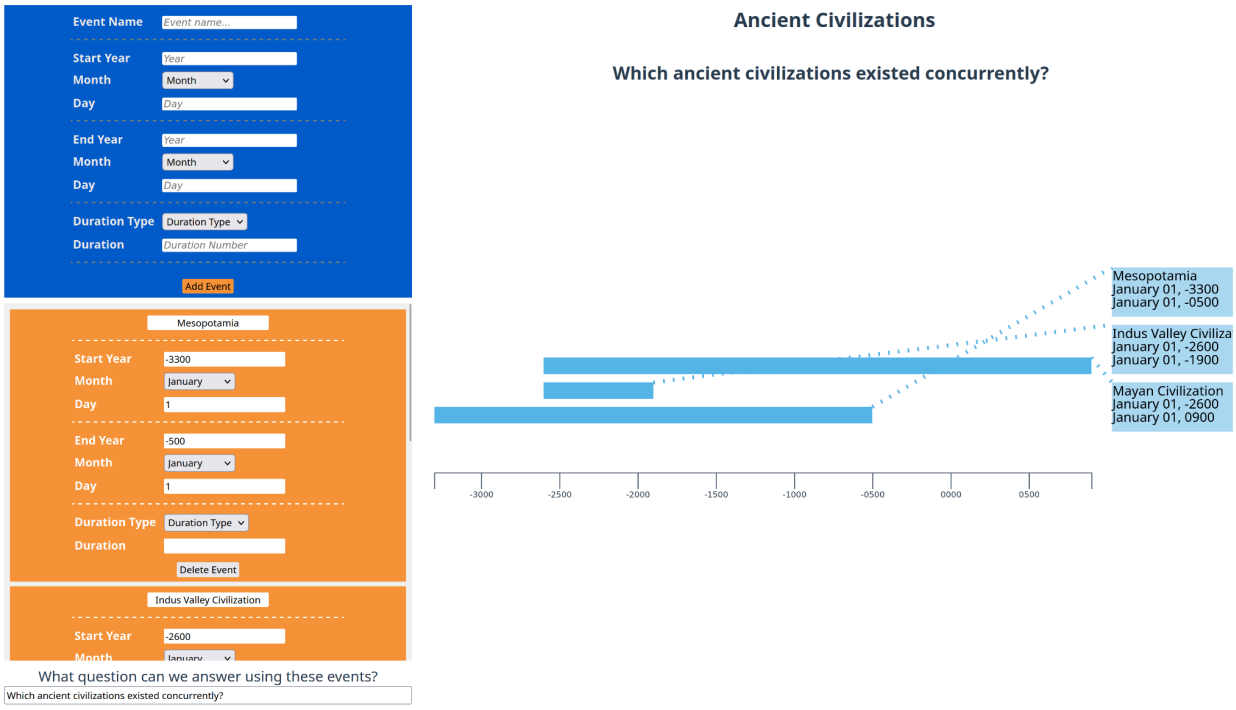

Figure 3. An example of creating a timeline with TimelineBuilder. A timeline of Ancient Civilizations is shown, containing events which describe the years in which Mesopotamia, the Indus Valley Civilization, and the Mayan Civilization existed.

Computer Programming and Data Visualizations

TimelineBuilder and DV4L do not require the use of computer programming in order to create or manipulate data visualizations. As shown, data visualizations can be fully specified using the familiar controls of menus and selections. Some high school teachers have told us that they are interested in using programming languages with their students to manipulate data visualizations within DV4L, so we have made it an option. In the "Scripting" version of DV4L [7] (as seen in

Figure 3), on the right-hand side of the menus are text boxes. Definitions of the graphs are then shown in two ways: through the menus, and also through a programming script definition. These are linked so that updating one also updates the other. The scripts are an alternate specification for the graph in a programming language inspired by the tool Vega-lite which was explored by pre-service teachers [3,4]. The specification can be edited, causing the graph and menus to update automatically in the same way editing the menus does.

This specification contains a definition of the same menus and menu inputs used to create the graph. However, instead of choosing from a list, the inputs here can be typed directly. For example, if you wanted to change the beginning of the date range from “1800” to “1900,” all you would have to do is change the number next to “lowDate.” High school social studies teachers have especially found this helpful, as editing the text specification can be more efficient than changing the menus when working with complex sets of graphs and/or making detailed changes. In contrast, middle school social studies teachers have told us that the scripts are confusing, and that they can distract students and increase the likelihood of mistakes. We are continuing to explore where and how elements of programming may be useful to teaching and learning about data visualizations in K-12 social studies classrooms.

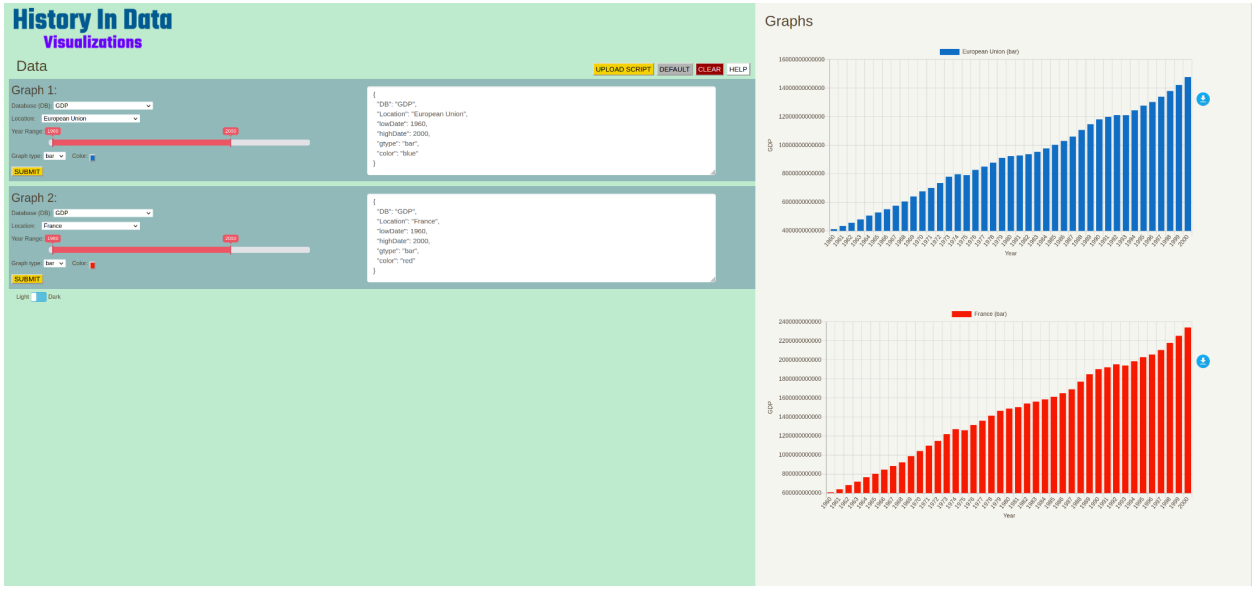

Figure 4. The scripting view of Data Visualizations for Learning, in which graphs can be edited by menus and by editing textual inputs.

Conclusion

We have created two digital data visualization tools, DV4L and TimelineBuilder, designed specifically for use in social studies classrooms and based on feedback from prospective and current social studies teachers. While we recognize that there are many online data visualization tools that can be used in classrooms in a multitude of ways, we differentiate our tools in that they have been created with K-12 social studies in mind. We have taken care to include features that teachers tell us would be useful in social studies data inquiry lessons and activities. Our tools are still in a prototype phase, but are free to use and online. We hope that

by creating tools specific to social studies, we can aid the teaching of data literacy and of inquiry through data.

Notes

1. Tamara L. Shreiner, “Teaching Data Literacy for Civic Competence: The Social Studies Teacher's Crucial Role,” Social Education 87, no. 4 (2023): 262-269.
2. “UNdata,” http://data.un.org/.
3. Bahare Naimipour, Mark Guzdial, and Tamara L. Shreiner, “Engaging Pre-Service Teachers in Front-End Design: Developing Technology for a Social Studies Classroom,” In *2020 IEEE Frontiers in Education Conference* (2020): 1-9.
4. Bahare Naimipour, Mark Guzdial, Tamara L. Shreiner, and Ilana Spencer, “From Guided Exploration to Possible Adoption: Patterns of Pre-Service Social Studies Teacher Engagement with Programming and Non-Programming Based Learning Technology Tools,” In *Society for Information Technology & Teacher Education International Conference* (2021): 1508-1513.
5. “Data Visualization for Literacy,” http://historyindata.org/dv4l/.
6. “TimelineBuilder,” https://timelinebuilder.eecs.umich.edu/.
7. “Data Visualization for Literacy: Scripting” http://historyindata.org/dv4l/scripting/.

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