Using Participatory Design Research to Support the Teaching and Learning of Data Literacy in Social Studies

Tamara L. Shreiner

Grand Valley State University

Mark Guzdial

University of Michigan

Bahare Naimipour

University of Michigan

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Abstract

Using participatory design methods, we present results from efforts to build an OER with an embedded task-specific programming tool for teaching data literacy in social studies. Findings indicate teachers want resources to help them teach data literacy but they have specific requirements to make the tools both useful and usable.

Introduction

Data and data visualizations are everywhere. They are used to inform and persuade, to show us changes over time, snapshots of our present, and projections for the future. In a data-laden society such as ours, an informed citizen must also be a data-literate citizen (Bowen & Bartley, 2014; Franklin et al., 2015; Gould, 2017). They must be able to make sense of data visualizations like maps and graphs just as readily as they can make sense of written arguments and explanations. And because the data visualizations that people will be required to make sense of as citizens are often tied to social, political, and economic issues, it makes sense that they should be an essential part of social studies instruction.

To be sure, NCSS's (2013) *C3 Framework* already recommends students learn how to use and construct data visualizations throughout school. And these recommendations are reflected in curriculum standards across the fifty U.S. states and the District of Columbia, which

invariably require that students interpret, create, and use data visualizations from elementary through high school (Shreiner, 2020). Social studies textbooks, trade books, and periodicals are filled with a variety of data visualizations, and as many as 90% provide information not found in surrounding text (Fingeret, 2012; Shreiner, 2018). Yet, school texts rarely provide support to help students make sense of data visualizations, or integrate them with surrounding verbal text (Shreiner, 2018). It is no surprise, then, that students tend to ignore data visualizations in texts, which may negatively impact both reading comprehension and quality of disciplinary reasoning (Roberts et al., 2015; Shreiner, 2019). Even if students pay attention to data visualizations, they might have difficulty interpreting and evaluating them (Brugar & Roberts, 2017; Duke et al., 2013; Maltese et al., 2015; Shah & Hoeffner, 2002; Shah et al., 1999). This is particularly true if students lack understanding of context or content related to the data (Friel et al., 2001; Maltese et al., 2015; Shah & Hoeffner, 2002), or if a data visualization contains information not directly related to a question or topic a student is trying to address (Strobel et al., 2018).

Given all of these challenges, teaching data literacy within the context of social studies, rather than as a set of general skills, is critical. Indeed, teachers may be the most important factor in mitigation of students' challenges with data visualizations (Rockoff, 2004; Stronge et al., 2011). However, recent research suggests that most teachers do not teach data literacy as part of social studies instruction, feel unprepared to do so, and lack resources that would help (Shreiner & Dykes, 2020). In light of this gap in teachers' knowledge and teaching resources, we have built a pedagogical support system to assist teachers in efforts to incorporate data literacy into social studies instruction. This system includes an open educational resource (OER) with guidance for teachers on analyzing and using data visualizations primary and secondary source data visualizations, exemplary lessons that integrate data literacy, and a variety of manuals to

guide teachers in using online data visualization creation tools (Figure 1). Additionally, embedded in the OER is a task-specific computing tool our team has designed to support data inquiry in social studies. We have built this pedagogical support system using participatory design research methods with both undergraduate pre-service and practicing social studies teachers. Our research asks:

RQ1: How do we give social studies teachers effective, accessible professional learning opportunities that will help teachers feel prepared and supported in teaching data literacy in social studies?

RQ2: What features of purpose-built educational technologies and resources do teachers find useful and usable for teaching data literacy in social studies?

Theoretical Framework

Our research design sits at the intersection of research on teacher knowledge, research on teacher efficacy, and the Technology Acceptance Model. First, several scholars (Ball & Forzani, 2009; Ball et al., 2008; Putnam & Borko, 2000) have argued that the specialized knowledge of teachers has a significant impact on teacher decision-making and their ability to impact student learning. Such knowledge is complex, consisting of subject matter content knowledge, curricular knowledge, and pedagogical content knowledge (Shulman, 1986). Thus, teacher education and professional development should provide teachers with situated learning environments that build their knowledge for teaching, and teacher educators should consider ways to provide pedagogical tools for teachers that will distribute cognitive processes of teaching and alleviate the cognitive load for teachers (Putnam & Borko, 2000).

At the same time, another line of research (e.g., Bandura, 1997; Tschannen-Moran et al., 1998; Wolters & Daugherty, 2007) has focused on teacher efficacy, arguing that a teacher's

belief that they can successfully carry out a teaching task influences the teacher's performance of a teaching task. Mastery experiences (direct teaching experiences); vicarious experiences (watching peers teach); physiological and emotional states (feelings of success and confidence); and social and verbal persuasion (receiving positive feedback) are key sources of efficacy information for teachers (Bandura, 1997; Tschannen-Moran & Hoy, 2001; Tschannen-Moran et al., 1998). As Tschannen-Moran et al. (1998) have argued, teachers process efficacy information to assess their teaching competence and analyze the teaching task. Perceived teaching competence involves judgments about one's current functioning related to the teaching task, while analysis of a teaching task entails a teacher making judgments about the difficulty of the task and the likelihood of success. Therefore, while professional learning opportunities can help strengthen teachers' knowledge and provide efficacy information through teaching experiences and positive feedback (Charalambous et al., 2008; Newton et al., 2012), consideration should also be given to teachers' judgements about their own competencies, as well as their judgments about the kinds of resources and conditions that will help them achieve success with students.

Our work assumes that computational technology can provide teachers with the resources they need to teach data literacy in social studies. However, the Technology Acceptance Model predicts that teachers will only adopt technology if teachers perceive that the technology is *useful* (e.g., facilitates learning towards standards and objectives) and is *usable* (which includes computer interface usability but also context, like fitting into course schedules). In order to adopt technology for data literacy, the teacher must believe that the technology can help to achieve their learning goals (e.g., address a student learning challenge) while fitting into their existing structures and constraints (e.g., available class time), and that the teacher can successfully

implement the activity (e.g., self-efficacy stemming from knowledge and experience) (Holden & Rada, 2011).

Methods

Our work uses participatory design research (PDR) methods (Spinuzzi, 2005) to develop a pedagogical support system consisting of an OER and a task-specific tool called DV4L. Our goals for the support system were to (1) build teachers' knowledge about data literacy in social studies; (2) increase teachers' confidence in their competencies related to teaching data literacy; (3) alleviate perceived challenges in implementing data literacy; and (4) provide teachers with data literacy-related tools they believe are useful and usable enough for adoption. PDR focuses on tacit use of resources and tools by participants in the early phases of design. Like other studies on the use of technology in education (Abel & Evans, 2013; Wilkerson, 2017), the main participants or stakeholders in our work are teachers. We view PDR as means to empower current and future social studies teachers by designing or redesigning resources and tools to be better tuned with what teachers actually do in their classroom and the kinds tools they use, based on their unique context, students, and needs (Bang & Vossoughi, 2016).

Our research process focused on two separate but interrelated parts of the pedagogical support system we are designing: the OER (see *Figure 1*) and the task-specific tool embedded within the OER (see *Figure 2*). The OER was designed to help teachers learn about data literacy, while providing them with multiple resources to help with standards-based implementation. It has six "modules" organized around driving questions and with one or more subsections of content or resources (see *Table 1* for descriptions). The content is based on several studies (Author, 2018, 2019, 2020) related to data literacy in social studies, including the role that data visualizations play in social studies curricular materials across the United States.

Figure 1

Snapshot of pages from open educational resource on data literacy for social studies

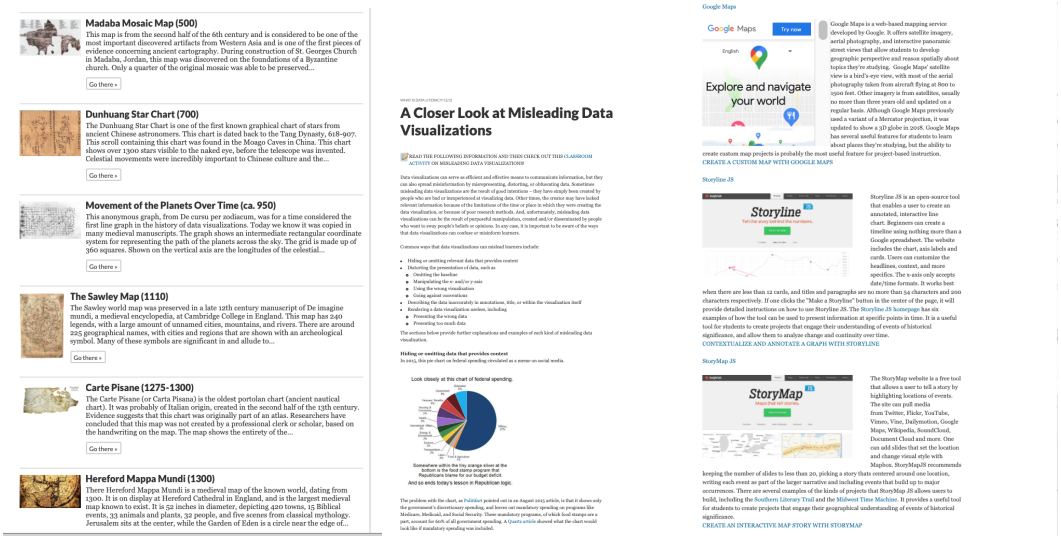


Figure 2

Data inquiry and visualization tool embedded in OER

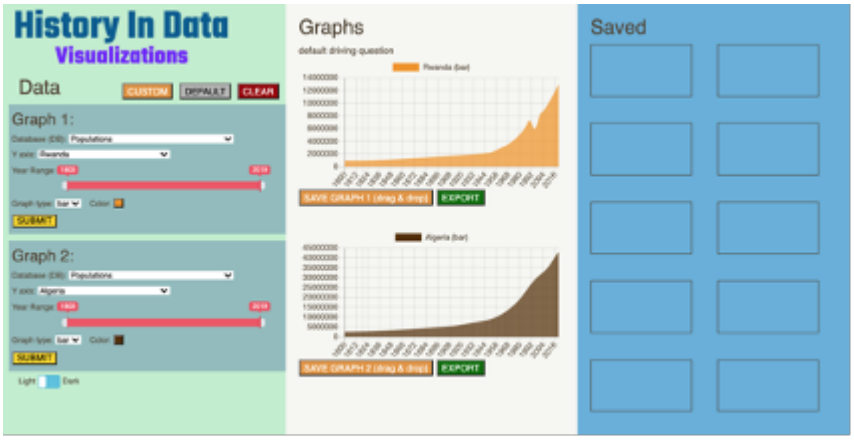


Table 1

OER Module Descriptions

Driving Question	Summary of Content
What is data literacy?	Provides an introduction to data literacy and its importance for informed and competent citizenship. Also contains an article, "A Closer Look at Misleading Data Visualizations" that provides information about the multiple ways designers can manipulate data visualizations.
Why teach data literacy in social studies?	Addresses the role that data visualizations play in social studies standards, assessments, and texts. It also provides links to resources that can be used to support data literacy as a component of disciplinary literacy. Special features include "Primary source data visualizations," and "Finding data and data visualizations online." The section on finding data and data visualizations online has several lesson plans that use the featured websites to teach data literacy.
What kinds of data visualizations will students encounter in social studies?	Presents a taxonomy of the commonly used types of data visualizations in social studies and how they might be used to show pattern, distributions, change over time, spatial relationships, and more.
How do students learn with data visualizations?	Explains benefits and challenges of learning with timelines, maps, and graphs, including how they can support disciplinary literacy.
How should students analyze data visualizations in social studies?	Uses research-based principles to guide teachers' implementation of data literacy instruction. One subsection provides guidance on teaching sociocritical data literacy.
How can students create and integrate data visualizations in social studies?	Highlights free online resources teachers can use to help students create their own data visualizations or data visualization-based projects. Each resource is accompanied by a manual that provides specific guidance on creating social studies projects. Among the tools highlighted is the one our team has created, DV4L.

The task-specific tool (see Figure 2) we have been working on uses the power of computing to enhance learning of data literacy in social studies while also helping students learn concepts and skills in computing. In our tool, students specify visualizations with pull-down menus. We always show two visualizations because historical inquiry often begins with two pieces of data or accounts that do not agree (Bain, 2000). The visualizations thus become the focus of the inquiry process and are intended to support the historical inquiry process. We build in computing knowledge and skills by showing the program as a concise description of how the graph is presented. The student does not *write* the program. We present the program as a useful description to *read* which can optionally be *edited* for ease in rapidly exploring a set of variables (e.g., different databases or date ranges) during inquiry.

Participants

We worked with both practicing and pre-service teachers from one midwestern state for our research. Our first group of stakeholders were 11 practicing social studies teachers who participated in two separate professional learning opportunities (PLO). There were six middle school teachers and five high school teachers. Ten teachers taught U.S. and/or world history, and one teacher taught civics and economics. Two teachers were first-year teachers, two had taught between two and five years, and seven had over five years of teaching experience. Two teachers were from the same school, but the remaining were dispersed throughout the state.

Our second set of stakeholders were social studies pre-service teachers enrolled over three semesters in Author 1's class, which focuses on data literacy for social studies teaching. In total, we conducted participatory design sessions with 52 pre-service teachers, all juniors and seniors who were far along in their preparation program but had not yet begun student teaching. The pre-service teachers provided feedback on task-specific computing tools, including DV4L.

Data Collection and Analysis

Practicing Teacher Data

The 11 practicing teachers were participants in the most comprehensive version of the pedagogical support system and thus provided feedback on all aspects of the system. They participated in a professional learning opportunity that consisted of three synchronous one-hour sessions, and asynchronous work on the OER and with the resources and tools embedded in the OER between sessions. During their asynchronous work, we asked teachers to look specifically at DV4L, along with other tools of their choosing. All teachers completed pre- and post-questionnaires, which consisted of Likert-scale questions to measure their current experiences with teaching data literacy, their confidence with teaching and working with data visualizations and technology, and their views on the importance of data literacy. The questionnaires also included open-ended questions about their use of technology tools. We used a semi-structured focus group protocol for all sessions, which were recorded and transcribed. The first session was focused on meeting the teachers and learning about their teaching context and experience. We used the two additional meetings to ask for feedback on the OER and DV4L. We analyzed the questionnaires by comparing teachers' responses from pre-questionnaire to post-questionnaire, and looking for changes in responses. We analyzed transcripts from the focus group sessions using a combination of *a priori* and emergent codes (Miles et al., 2020). Our *a priori* codes were focused on statements about the structure of the professional learning opportunity, knowledge gained through the experience, and comments about the usefulness and usability of the lessons and tools embedded in the OER, including DV4L (see *Table 2*).

Table 2

Codes and Descriptions

A priori category	Code	Code Description
PLO Structure	PLO-time	Teacher commented that there was not enough time for exploration in PLO
Knowledge Gained	KN-imp-cdl	Teacher commented that they gained knowledge about how important critical data literacy is.
	KN-imp-st	Teacher commented that they gained knowledge about how prevalent data literacy is in the state standards.
	KN-ps-dv	Teacher commented that they learned about how many primary source data visualizations exist.
	KN-imp-backknow	Teacher commented that they gained knowledge about how important students' background knowledge is for interpreting data visualizations.
OER Usefulness	OER-USF-ps-st	Teacher thinks primary sources are useful when they connect to state standards.
	OER-USF-ps-excurr	Teacher thinks primary sources are useful when they fit with their existing curriculum.
	OER-USF-les-st	Teacher thinks lessons are useful when they connect to state standards.
	OER-USF-les-dif	Teacher thinks lessons are useful when they provide ideas for differentiating instruction.
	OER-USF-les-projidea	Teacher thinks lessons are useful when they provide new ideas for student projects or activities.
	OER-USF-les-starter	Teacher thinks lessons are useful when they include ideas for activating prior knowledge and prompting inquiry.
	OER-USF-onlindv-excurr	Teacher commented on the usefulness of having links to websites with data visualizations that connect with existing curriculum.
	OER-USF-tools-excurr	Teacher commented on usefulness of a tool embedded in the OER because it connects to existing curriculum.
	OER-USF-tools-projidea	Teacher commented on usefulness of a tool embedded in the OER because it provides new ideas for student projects or activities.
	OER-USF-tools-studchal	Teacher commented on the usefulness of a tool for helping them address student challenges.
	OER-USF-tools-necskill	Teacher commented on the usefulness of a tool for teaching students skills they think will be useful outside of school.
	OER-USF-missing-visualproc	Teacher said they wanted more resources that would help them visualize complex processes or concepts.
	OER-USF-missing-simpletool	Teacher said they wanted simple tools that would help them visualize timelines and maps as aid to understanding social studies.

OER Usability	OER-USAB-nav	Teacher said OER would be more usable if it could be navigated more easily.
	OER-USAB-less text	Teacher said OER would be more usable if it had less text so they could find necessary information more efficiently.
	OER-USAB-lessonind	Teacher likes to be able to find lessons or activities easily, such as through a lesson index.
	OER-USAB-self-contained	Teacher likes when everything is contained on websites; there are not a lot of new windows opening.
	OER-USAB-tool-simple	Teacher commented on a tool embedded on OER as being usable because it has a simple design.
	OER-USAB-tool-specdir	Teacher commented on a tool embedded on OER as being usable because it was accompanied by specific directions.
	OER-USAB-tool-complicated	Teacher commented on a tool embedded on OER as being unusable because it is too complicated or has too many steps to follow to make it work.
	OER-USAB-tool-studbeh	Teacher commented on a tool embedded on OER as being unusable because they imagined student behaviors and students becoming confused.
DV4L Usefulness	DV4L-USF-excurr	Teacher commented on DV4L being useful because it relates to topics in their existing curriculum.
	DV4L-USF-missing-projidea	Teacher commented that they wanted ideas for how to use DV4L in the classroom.
	DV4L-USF-missing-graphmanip	Teacher commented on the need to be able to manipulate the graphs or zoom in on different aspects.
	DV4L-USF-missing-CDLsupport	Teacher commented on the need for DV4L to be more supportive of critical data literacy (e.g. showing source information).
DV4L Usability	DV4L-USAB-simple	Teacher commented on usability of DV4L because it has a simple design.
	DV4L-USAB-unmetexpec	Teacher commented that DV4L was frustrating to use because they thought it had functionality that did not exist (e.g., type in a question and data is populated).

Pre-Service Teacher Data

Sessions with the pre-service teachers were conducted in Author 1's class. The results of our first two sessions have been published (Naimipour et al., 2020) and used to inform our first prototype of DV4L which was used by the pre-service teachers in the third session. Although all the pre-service teachers contributed to the development of DV4L, in this paper, we focus on

feedback from the third session where we asked the pre-service teachers to explore three technology tools as design probes (Wallace et al., 2013) that could be used for creating visualizations, one of which was DV4L. The other two tools were the programming-based tool Vega-lite, and the 6-12th grade non-programming tool CODAP. The third session was the first session where DV4L was included, but none of our participants knew it was our prototype until the end of the session in order to facilitate a less biased discussion and greater feedback.

After introductions in the in-class session, we divided the pre-service teachers into three groups, and each group explored one of the three tools for ten minutes. We scaffolded social studies data manipulation and visualization with activity sheets (Wilkerson, 2017) to guide pre-service teacher use of the technology tools. Then they came together as a whole group and discussed their experiences for ten minutes. At that point, based on their initial experience and the class discussion, the pre-service teachers chose what tool they wanted to explore for the following ten minutes. This approach gave the pre-service teachers the agency to choose and made them more inclined to provide their thoughts and opinions while being more engaged in the tool they chose to explore. After ten minutes, everyone came together to discuss their experiences as a group for the remaining thirty minutes of class. This was a longer more fruitful discussion since most had tried a second tool and were able to compare and discuss what they liked or did not like about the tools they tried. The following week, each participant anonymously reflected on their experience and current tool preference in writing. Our data sources include pre- and post-session questionnaires, observations of pre-service teachers' tacit use of the tools, and notes on the whole group discussions where the goal was to elicit their design ideas and needs.

Findings

Effectiveness of the Pedagogical Support System

All of the practicing teachers with whom we worked believed that data literacy was important at the outset of our research. For example, all 11 practicing teachers indicated on their pre-questionnaire that they agreed or strongly agreed that it is important for students to learn how to analyze timelines, maps, and timelines. Almost all of them indicated that it is also important for students to create timelines, maps, and graphs, the one exception being a high school teacher who said they disagreed that it is important for students to create maps. All eleven teachers also indicated that timelines, maps, and graphs help students learn social studies content. Yet only three of the eleven teachers reported having had any classes or professional development related to teaching data literacy. Two of the teachers said they had a single professional development session that touched on data literacy, and one teacher said data literacy was a part of a general literacy education class in college.

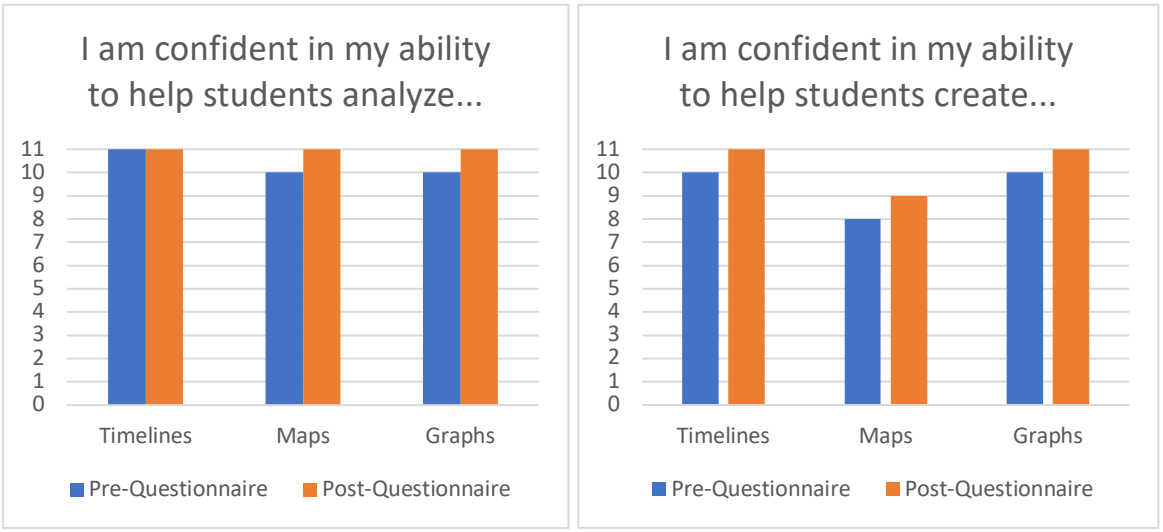
Despite lack of training, teachers were already relatively confident in their abilities to help students analyze and create data visualizations. At the beginning of the PLO, all teachers felt confident in their abilities to help students both analyze and create timelines. Only one teacher disagreed that they were confident in their ability to help students analyze maps and graphs, and only one teacher disagreed that they were confident in their ability to help students create graphs. However, three teachers reported lacking confidence in their ability to help students create maps (see *Figure 3*).

Interestingly, teachers were less confident in their own abilities to analyze and create data visualizations. For example, although ten teachers reported being confident in their ability to analyze timelines and graphs, this did not extend to confidence in their abilities to recognize flaws and inaccuracies in timelines and graphs. For these items, nine teachers said they could

recognize inaccuracies in timelines and only seven said they could recognize inaccuracies in graphs. Eight teachers reported being confident in their ability to analyze maps, and the number fell to six for confidence in abilities to recognize flaws and inaccuracies (see *Figure 4*). As for creating data visualizations, although almost all teachers reported feeling confident in creating data visualizations with paper and pencil, they were far less confident in their abilities to create them with computers (see *Figure 5*).

Figure 3

Practicing teachers' confidence in their abilities to help students analyze and create data visualizations

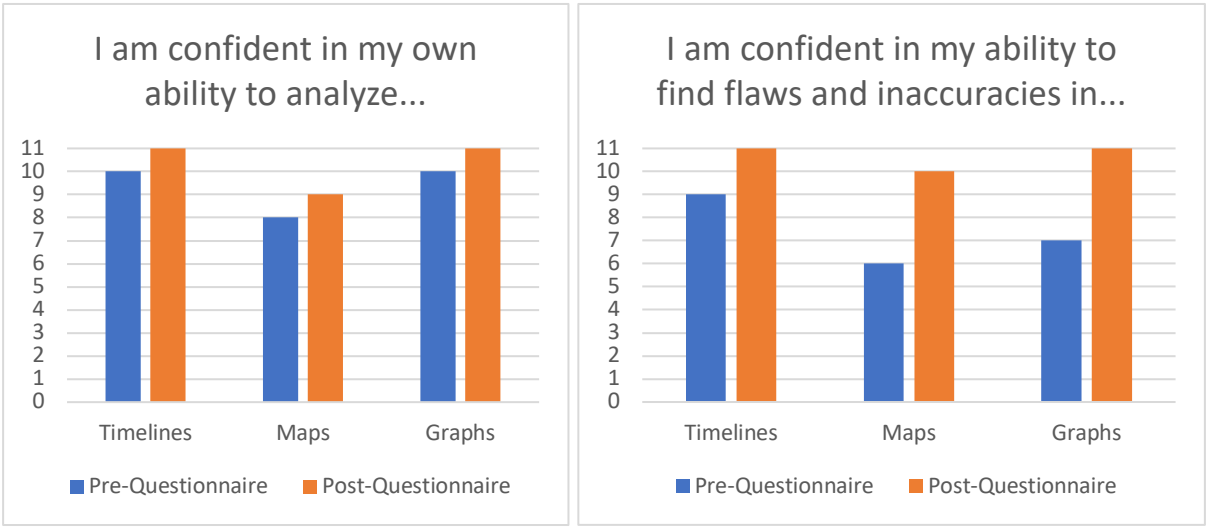


At the end of the PLO, the questionnaires indicated promising growth in teachers' confidence in several areas. Even though most teachers were already confident in their abilities to help students analyze data visualizations, all teachers were confident in their abilities by the end of the session. There was similar growth with respect to helping students create data visualizations, save for the creation of maps; here, one teacher grew in confidence but there were

still two teachers who did not feel confident in their ability to help students create maps (see *Figure 3)*.

Figure 4

Practicing teachers' confidence in their own abilities to analyze and evaluate the accuracy of data visualizations

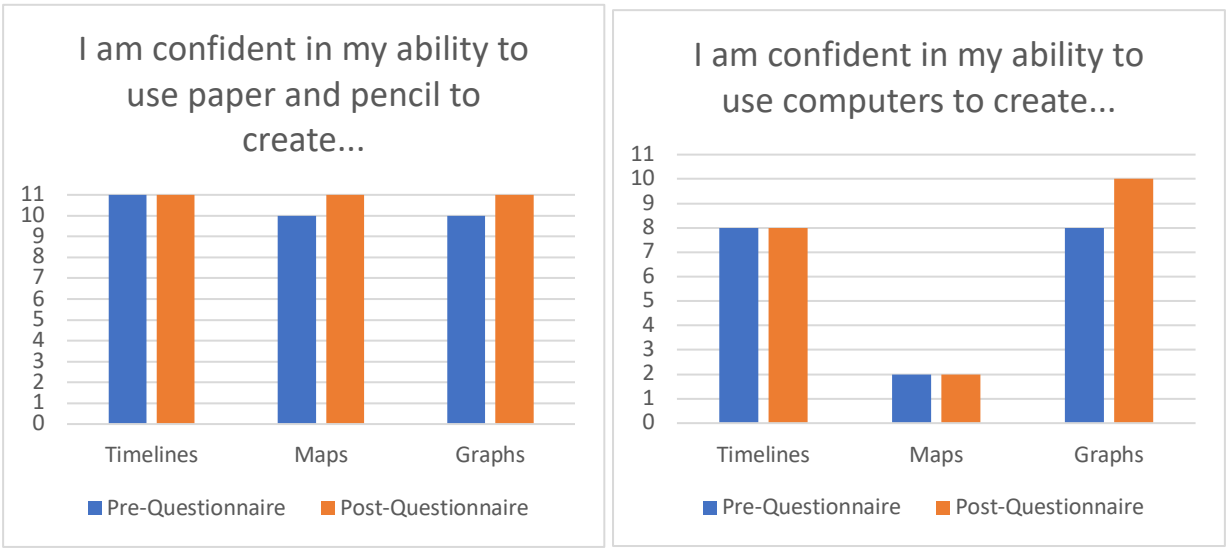


We saw more dramatic growth in teachers' confidence in their own abilities, particularly in their abilities to recognize flaws and inaccuracies in data visualizations. For example, at the beginning of the PLO, only six and seven teachers felt confident in their abilities to find inaccuracies in maps and graphs, respectively (see *Figure 4*). By the end, however, these numbers had grown to ten and eleven. Teachers' growth in confidence with respect to using computers to create data visualizations was less promising. We saw no growth in teachers'

confidence in using computers to build timelines and maps, and only two teachers reported feeling more confident using computers to create graphs at the end of the PLO (see *Figure 5*).

Figure 5

Practicing teachers' confidence in their own abilities to create analog or digital data visualizations



During the focus groups, teachers also reported knowledge growth in several key areas. The most frequent comments were about knowledge of the different ways data visualizations can be manipulated to mislead, and the importance of critical data literacy. This likely explains the growth in teachers' confidence to find flaws and inaccuracies in data visualizations. There were also several comments about the primary source data visualizations featured on the website, and

not previously realizing that many primary sources used in history are examples of data visualizations. In addition, a few teachers commented on gaining knowledge about how prevalent references to data visualizations are in state standards, and the importance of background knowledge for students trying to interpret data visualizations.

Feedback on the Usefulness and Usability of the OER

Whether talking about lessons and activities or online tools, three themes surfaced through teachers' comments about usefulness of the OER and its resources: connections to standards, connections to their existing curriculum, and inspiration for new project ideas. Teachers appreciated when resources had explicit references to state standards, and by extension, standardized tests and other measures that held them accountable. Comments about standards typically surfaced when discussing primary source data visualizations or the lessons and activities that were connected to websites with data visualizations. At the same time, teachers mentioned that certain resources or tools "spoke" to them when they could see its connections to topics they already taught. They would comment about a unit of instruction or activity they would teach every year, and how a primary source, or online resource, or activity could supplement what they already do.

Where teachers seemed most enthusiastic in their comments, however, were instances when they were inspired by an online tool and the ideas provided for students completing a project with the tool. The most frequent mentions were of Google Earth, Timeline JS, and StoryMapsJS, but there were also mentions of Google Sheets/Charts and ArcGIS StoryMaps. Teachers were particularly drawn to high-quality appearance in the final products, and the tools' ability to help them teach temporal and spatial thinking in history.

At the same time, teachers were discouraged from using tools—even ones they found intriguing like Timeline JS—if they felt they were too difficult to use. One teacher mentioned that the manual for Timeline JS had too many steps and that she became frustrated when something went wrong. Teachers expressed a desire for tools that had a simple user interface and left little room for error, primarily so that students would not be distracted or frustrated, and so they could concentrate on helping students gain content knowledge, rather than skills in using the computing tool itself. The only time a teacher talked about the value of a tool based on the skills a student could gain through trial and error with it, was in regard to Google Sheets. The teacher felt it would be valuable for students to use the tool because "work with spreadsheets" is so common in the workforce. Teachers also mentioned different abilities of students within a grade and across grades. In both tools and activities, teachers wanted ideas for differentiating instruction and meeting the needs of diverse learners.

When we asked teachers to give us ideas about the kinds of resources and tools they would find useful and that were not featured on the OER, they focused on two areas: simple tools for creating timelines and maps, particularly those that would help students visualize time and space simultaneously, and visuals that would help them explain complex processes and concepts, such as shifting trade connections throughout time, latitude and longitude, and map projections.

Feedback on the Usefulness and Usability of DV4L

Similar themes about usefulness and usability ran through our first two sessions with pre-service teachers, where they were introduced to DV4L and other computing tools. Most pre-service teachers in our first session wanted a tool that they perceived as useful for their students' learning, while those in our second session preferred tools that they "perceived as easy to use" for themselves (Naimipour et al., 2020). In our third session, where we chose tools that we were

confident the teachers would think were usable, pedagogical usefulness was the primary theme. Yet, interestingly, the pre-service teachers seemed less focused on meeting standards than the practicing teachers were. Instead, they focused mainly on how creating data visualizations might help students learn, or help them focus students' attention on ideas they were trying to teach. For example, more than half of the pre-service teachers stated that they want data visualizations tools to create exemplars or models for students or that might be used by students in their own inquiry. One pre-service teacher said "(with discipline-specific K-12 technology) I like that if you are able to create your own visualization you can format how your students think about the visual." More than a third of the pre-service teachers discussed how making their own visualizations changed the ways they and their students might think and learn about data literacy. We heard one pre-service teacher say: "I think making your own data visualization allows for a deeper connection and understanding of the data" and another said "It (technology) helps one better understand how data works and what it is telling to someone."

Around three fourths of the pre-service teachers in our third session preferred DV4L over the two other data visualization tools CODAP and Vega-lite, and comments revealed the importance of both its usability and its usefulness. One pre-service teacher explained that they preferred our prototype over other tools because "(with the prototype DV4L) I found myself asking questions connected to the data itself, rather than asking questions in order to figure out how to work the visual." Another pre-service teacher felt that DV4L "focus(ed) on the information being relayed rather than the coding that goes into creating it." These pre-service teachers wanted to adopt a tool for themselves that "focus(es) more on the data than on trying to figure out how to use the tool." Tools like DV4L offer them all these possibilities, while also

respecting a teachers' time limitations, making it worth the effort for them to adopt DV4L into their data literacy curricula.

Yet, when we asked practicing teachers from the PLOs to share which tools they would use with students, only three shared that they planned to use DV4L in their teaching. The practicing teachers who talked about experimenting with DV4L during the PLO said they liked it for some of the same reasons they liked other relatively useful and usable tools: they could see how the data sources connected to topics they already taught and it had a simple design that would not be overwhelming for students. However, teachers also commented about the need for more datasets connected to topics they teach, and for the tool to be more supportive of critical data literacy by providing source information and links to the raw data. The most salient comments for us though were ones that related to teachers desire to be inspired by new projects – we just had not provided enough information about how they could use this with students or how to build interesting projects and activities around it. In what follows, we will discuss these findings and the implications for future work.

Discussion

Data literacy is important for students to learn, and teaching students data literacy through social studies can provide them with tools they need to view data through a critical lens (Shreiner, 2020; Philip, et al., 2016). Unfortunately, research indicates that teachers do not often teach data literacy in social studies, and standards do a poor job of giving teachers guidance they need to teach it well (Shreiner, 2020; Shreiner & Dykes, 2020). But if we want teachers to teach data literacy, they must have access to tools and resources that will give them a sense of efficacy, and that they judge as useful and usable. With this in mind, we have been building a pedagogical support system consisting of an OER and social studies-specific computing tools to (1) build

teachers' knowledge about data literacy in social studies; (2) increase teachers' confidence in their competencies related to teaching data literacy; (3) alleviate perceived challenges in implementing data literacy; and (4) provide teachers with data literacy-related tools they believe are useful and usable enough for adoption. Our research indicates both successes and areas for improvement.

Teachers did gain new knowledge through the OER, especially about the different ways that data can mislead and indications that a graph maker may be trying to manipulate people's interpretations. This seemed to give teachers more confidence that they could recognize flaws and manipulations in data visualizations. In addition, several teachers learned about the prevalence of references to data visualization in state standards and the vast number of primary sources that are also data visualizations. By providing resources that would help them connect data literacy instruction to their state standards, as well as providing several resources that they could see connected to the standards-based instruction they already provide to their students, we seemed successful in helping to alleviate some of the perceived challenges to implementing data literacy. We also provided scaffolding in the form of manuals and activity ideas around several online tools, such as Google Earth and Timeline JS, that made the tools seem more usable and useful for teachers.

However, we were not as successful as we had hoped in convincing teachers to adopt our task-specific programming tool, DV4L. Indeed, only three out of 11 practicing teachers indicated that they planned to use it in their social studies classrooms. Nor were we as successful as we hoped in helping teachers feel comfortable using computers to create data visualization and data-based projects. We think three factors explain these shortcomings. First, teachers indicated in their post-questionnaires that they did not have enough time to explore the OER and its tools

with our support, nor to discuss possible uses for the tools with their peers. Several teachers suggested that we structure the PLO as a full day or multi-day workshops to provide such support. Second, we need to provide teachers with more ideas for using DV4L with students, especially activities that are clearly tied to standards, connect to themes and topics teachers are already likely teaching, and that have been vetted in classrooms. And finally, we need to create more computer-based tools and accompanying curricular resources to meet social studies teachers' specific needs.

Some of this work is already underway. For example, we have a working prototype timeline visualization tool (TimelineBuilder) which we have designed to address the usability challenges teachers reported with TimelineJS. We are also working on a set of tools that will help teachers differentiate instruction for students with differing levels of experience and skills in analyzing data visualizations. This includes a tool that will help students slowly construct data visualizations by drawing their attention to specific visual elements, as well as tool that helps students slowly analyze data visualizations by masking all but one visual element at a time and allowing them to make connections between all the elements in order to extract information. These tools may help students to understand how the different visual elements collectively convey meaning. And with these tools, students can work at their own pace, and independently, allowing the teacher to attend to the needs of students who are struggling.

Our work is explicitly driven by the needs of the teachers who are contributing to our research through their participation in design sessions. We hope that by continuing to build usable and useful tools, and providing teachers with the supports they need to feel knowledgeable and confident about teaching data literacy, we will in turn help students gain the data literacy skills they need for informed, competent citizenship.

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