

Engaging Pre-Service Teachers in Front-End Design: Developing Technology for a Social Studies Classroom

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Abstract—This research full paper presents front-end design activity with social studies pre-service teachers to inform the design of data visualization technology tools. Data visualizations are powerful tools that social studies teachers use to explore the narratives they want their students to learn. They can serve as evidence for historical arguments and prompts that start students on a path of inquiry. The ability to analyze, interpret, evaluate, and use data and data visualizations – known as data literacy – has become an increasingly important component of K-12 social studies education in recent years.

While there are many technological innovations that have been developed to support engineering education in K-12 classrooms, adoption of these tools has been low. Our hypothesis is that adoption may improve if teachers are involved in the front-end design process of technology intended for use in their classrooms. This work describes the results of two Participatory Design (PD) sessions about data visualization with pre-service social studies teachers.

In our design sessions, thirty-two pre-service teachers evaluated programming and non-programming data visualization experiences, and then told us what they would like in future data visualization tools. The Minimal Manual was used as a guide in the design of the activity sheets to scaffold use of the tools. After each PD session, we used conjecture mapping to process and analyze the data.

Although there were minor design differences in the two PD sessions, the pre-service teachers' evaluations were surprisingly different from one another. These results suggest that PD sessions might be highly idiosyncratic, and we cannot reliably generalize from just a single PD session. We found that secondary focused pre-service teachers tended to be more interested in the data visualization tools than elementary focused pre-service teachers. Further sessions and analysis are necessary to make more reliable conclusions about the characteristics pre-service social studies teachers would like to see in a pedagogical tool they would consider adopting in their classroom. Our work informs other researchers who are considering PD for developing K-12 education interventions.

Keywords—*participatory design, conjecture map, data literacy, programming technology tools, teacher adoption, K-12*

I. INTRODUCTION

Engineering skills play a role in disciplinary practice across K-12. For example, data manipulation, visualization, simulation, and modeling play a role in national standards in science and mathematics [1], [2]. Primary and secondary teachers are challenged to teach science, technology, engineering, and mathematics (STEM) skills, since they often do not have academic backgrounds in those subjects [3]. Our approach to ease adoption of engineering skills is to work with pre-service teachers to develop technologies that match their needs and abilities. This paper presents what we have learned in helping social studies pre-service teachers to create and teach data visualizations.

The ability to comprehend, analyze, and interpret data and visual representations of data is what is generally known as data literacy. Recently, content standards for K-12 schools [4], [5] have included data literacy as a critical component of students' social studies education [6]. This includes being able to analyze and create data visualizations. Data visualizations are used to support the factual stories teachers want their students to learn and social studies textbooks are full of them. But reading and interpreting these visualizations can be a daunting task, and research shows that the task doesn't become easier with time. Zandan and May [7] found that 88% of people in the US believe claims are more persuasive if they are supported by data, but only one in three feel that they actually understand how to read and interpret data. Shreiner and Dykes [8] explain that social studies teachers are not really being taught about how to read and interpret data visualizations, let alone how to teach it.

With the inclusion of K-12 data literacy requirements in social studies standards in Michigan, increasing data literacy is now a social studies teacher's pedagogical goal [4]. One of the main ways believed to increase data literacy is to help students see connections between data visualizations and the data or history it was drawn from [9]. Our aim is to increase K-12

students' exposure to computer science, while at the same time improving data literacy, by designing a technology tool specifically to support social studies teachers and their students in creating their own data visualizations.

In this work, we share our front-end design process that is informing our design of a computing-based technology tool for data visualization in social studies curricula in Michigan. Data visualization often involves some level of programming or programming-like activities. Few US high school students ever learn how to use computing at the level of programming or computer science. In the US, even though 30-50% of high schools offer computer science classes, fewer than 1% of students actually take any of those classes [10]. Our goal is to integrate opportunities to learn and use computing in the context of social studies classes.

Technology tools are not just magically adapted by students for pedagogical purposes. Tools that students are exposed to must first be introduced and adopted by teachers. While there are many technological innovations that have been developed to support engineering education in K-12 classrooms [11], adoption of these tools by teachers seems to be low unless they are experienced or seen experienced by teachers in context [12]. Our hypothesis is that adoption may improve if pre-service teachers are involved in the front-end design process of technology intended for use in their classrooms.

In an effort to tackle some of the challenges of using technology in a social studies classroom, this work describes the results of two Participatory Design (PD) sessions about data visualization with social studies K-12 pre-service teachers using guided activity sheets. Each activity sheet scaffolds the pre-service teachers through the design of a data visualization using a specific existing technology tool. Through these two sessions, the following two research questions were explored:

How can we engage non-STEM pre-service teachers in a STEM activity?

How do pre-service teachers respond to the STEM activity and what accounts for differences in responses?

The following sections will provide background on the PD method and why we chose pre-service teachers as our design informants. We then discuss our session design approach and implementation for each PD session. The last two sections address the research questions we explored.

II. BACKGROUND

The origins of PD go back to Scandinavia in the 1970's [13] that focused on workers in their workplaces. PD is meant to empower the typical user of a tool by designing or redesigning a tool to be better tuned with how the worker actually engages with it in their work environment. It has been used in various contexts, but our focus here is its use in education, and even more specifically engineering education. Since the 1980's, PD work has found its way into new directions and areas of focus. In the field of education, PD has been used in a variety of studies, including work that aims to create more teacher-friendly learning analytic dashboards [14], student participation in redesigning class instruction, teacher and student PD in educational technology [15], and even work using PD to inform

the renovation of education buildings [16]. These studies still lie within the foundational intentions of PD, which empowers the user by valuing their interactions with tools.

Our goal for integration of data literacy programming technology tools into non-engineering classes is to address two interrelated objectives. Computer science in the context of physics has been shown to lead to better learning of physics while also making computer science more relevant and useful [17], [18]. Programming has also been used as a scaffold to stimulate the development of conceptual understanding [19]–[21]. In our work, we want programming-like activities to support social studies learning, and for social studies learning to provide a context for exploring what programming feels like [22].

Ultimately, the teacher decides which tools to integrate in the classroom. The 'teacher effect' explains more variance in student learning than any other factor [12]. It is the teacher's will and talent, and their comfort with the 'tool' that determines the success of any technology integration effort [23]. Too often, the teacher is the stakeholder who typically has no voice in design choices made for technology meant to be integrated into their classrooms. Our strategy is to change this trend by involving pre-service teachers in the design of a social studies-specific tool for data visualization, so that it meets their criteria for usefulness and usability.

How can teachers without prior training and support in teaching data literacy, not to mention programming, be expected to teach it? There are plenty of STEM resources that could aid curriculum design in data literacy, but it seems that adoption of these tools is low perhaps because in-service teachers have little or no university training related to data literacy [8]. In order for us to gain insight on how to think and go about designing a tool that would have a higher chance of adoption than tools that already exist, we need to see how pre-service teachers engage with current tools. Through their participatory engagement with the tools, we can observe the tacit behavior associated with their engagement and make design decisions that better support pre-service teachers accordingly. Our goal is to bridge the gap between current theories of learning and available technologies for social studies education by designing an easy-to-use and useful visualization tool for social studies. We believe this approach will motivate data literacy teaching and learning and promote student agency, while also exposing students in social studies classes to computer science.

In our PD sessions, we ask pre-service teachers to use existing data visualization tools. Existing tools are thus *design prototypes*, and the use and critique of these prototypes is intended to ultimately result in tools to improve and support social studies teachers' pedagogical goals. By showing pre-service teachers, who typically have little experience with data visualization tools existing tools, we inform them about the state of the art and provide them a grounding for describing what they would really like for their classes. The practice of engaging users in use and critique of existing tools to inform future tools is sometimes called *prototrialing* [24] or *experience prototyping* [25]. Use of PD is not common in engineering education contexts, but we believe that its use in designing educational technology will lead not only to greater social studies teacher

adoption, but also greater student interest, efficacy, and agency in STEM technology and programming.

III. APPROACH

Design Ethnography Plans

The third author (Shreiner) is a social studies education researcher who has studied the role of data visualizations in history classes. She has found that data visualizations are common in history textbooks [26] but are not consistently used effectively by students [8]. She is a co-designer along with the first two authors on a data visualization tool, which would be designed to support data inquiry and increase data literacy, specifically for social studies teachers and their students. We use a participatory design approach to determine what social studies pre-service teachers (and students) would want in such a tool. We designed, supported, and studied a single college class session in two different semesters in a data literacy class for pre-service social studies teachers. This work describes our front-end design process in these two PD sessions (PD1 and PD2). The design of the front-end process was focused around the topic and use of existing technology tools that could be used to generate data visualizations. The feedback from these sessions is guiding us towards designing a more adoptable and effective data visualization technology tool for social studies teachers.

A. The Participatory Design Method

We wanted to actively observe the tacit behavior of the pre-service teachers with the technology tools, and then engage them in discussing their thoughts and opinions afterwards. We also wanted to make sure the pre-service teachers were not influenced by our presence or felt uncomfortable with giving their real opinions. In addition, we wanted to give the pre-service teachers the power and voice of design informants with the researchers acting only as observers and facilitators of this opportunity to work with the technology. For these reasons, we chose our guiding people-focused design philosophy to be the PD method.

The PD sessions were conducted in the pre-service teachers' normal class environment and in the presence of their regular class professor (third author). All of the content and data used in the activity sheets, along with the driving questions, were chosen in consultation with the third author and co-designer, to make sure it all aligned with appropriate K-12 social studies content. In addition, the pre-service teachers were asked to complete the activity sheets on their own personal technology devices. All of these measures, of observing a participants' experience using the tools of interest in as close a context and format as the tool's expected use as possible, were designed to help further implement the PD philosophy.

a) Creating the Activity Sheets: In traditional PD studies, researcher observations are made while the participants are actively using or working with the object or tool of interest as part of their normal work routine. In our work however, pre-service teachers had very little experience teaching, and most of the pre-service teachers had very little if any prior experience creating a data visualization. We knew that the pre-service teachers needed guides for the technology tools to generate a data visualization and potentially make some modifications in less than twenty minutes. But dealing with traditional help

guides and manuals for the first time, would not only take lots of time, it might also create frustration and cognitive load issues that we wanted to avoid. Based on these constraints, we decided to take a slightly different approach.

In the 1980's there was a desire for people that were not academically trained in any technological field to learn how to work with technology devices. Instruction manuals were long, and many people didn't have the time or the need to get through much of what it entailed. The Minimal Manual was a design approach to address these difficulties [27]. A Minimal Manual is significantly briefer than a traditional manual. It guides users specifically in their tasks of interest, pays special attention to error recognition and recovery guidance, while also helping users simultaneously learn the technology tool while being productive. For these reasons, the Minimal Manual was used as a guide in the design of the activity sheets to scaffold use of the tools. For each technology tool we wanted the pre-service teachers to explore, a Minimal Manual or 'activity sheet' as we called it, was designed.

These activity sheets served two main purposes. First, as a way to acquaint the pre-service teachers with the technology tools, and as an example they could envision their students using in their future classrooms. Second, the activity sheets served as a way to have conversations around the tools after they had some time to complete the activity sheets. In order to minimize differences between activity sheets, the same dataset, similar data visualizations, and time for completion was applied across the activity sheets. In PD1 and PD2, visualizations showed measured and predicted life expectancies given the decade of birth and the country of birth. The activity sheets led students through comparisons of how the life expectancies differed by continents. Only the last section of each activity sheet was different, and explored tool-specific features. The goal was to give pre-service teachers the opportunity to explore other relevant capabilities of the tool.

b) Pair Programming: Think alouds can be intimidating and may feel uncomfortable and odd, especially in a classroom setting as opposed to a one-on-one setting. But we needed to know how pre-service teachers felt about the tools as they are using them. Since using programming tools is a first for many pre-service social studies teachers, we decided to use pair programming to address both of these issues. Pair programming is a practice in which two programmers work side-by-side at one computer, continuously collaborating on the same design, algorithm, code, or test [28]. Before the pre-service teachers started working on the activity sheets, they were asked to pair-up with someone. They were introduced to and asked to use the pair programming technique. In the final survey for both PD sessions, pre-service teachers showed explicit appreciation for the technique.

B. Pre- and Post- Class Surveys

Online pre- and post-PD session surveys were designed and links were emailed, through the class instructor, for both PD sessions. Consent forms in accordance with university guidelines were obtained from all pre-service teachers before the collection of any data. The pre-class survey was created to familiarize us with class demographics like expected graduation date, prior teaching experience, and level of

experience working with data visualizations in addition to their exposure and feelings towards programming.

The post-session survey was much longer than the pre-session survey. Since the PD session activities were done in pairs and the discussion was a whole class activity, the post-session survey focused on the individual opinions of the pre-service teachers regarding the events that unfolded in the session. The post-session survey makes sure everyone has the opportunity to be heard and also allows us to triangulate the data. Topics and opinions in the post-survey included: the specific features the pre-service teachers liked or disliked in the technology tools, their feelings about programming, whether they would choose any of the tools for themselves or their students, and their feelings about the overall session experience.

C. PD Session Discussions

A reflection activity, in the form of a whole class discussion, was designed to gain insight into how the pre-service teachers felt about the technology tools. In order to motivate more participation, we kept the slides to a minimum, focusing mostly on comparing the different aspects of the tools visually. The goal was to elicit opinions and discussions that cannot or would not be expressed through surveys or observation alone.

In short, we observed and captured detailed data about learning, usability, and social interactions as pre-service teachers interacted with existing software [15]. We also consulted with the pre-service teachers for feedback on how to improve those designs. In this way, participants are best described as design informants [29].

Implementation

In order to better explore how the pre-service teachers interact with technology tools that can be used to generate data visualizations, both PD sessions incorporated three design criteria. The first was the inclusion of multiple existing technology environments (design probes) that would give the pre-service teachers a range of options to explore and compare. The second was the design of scaffolded activity sheets that would guarantee the success of the pre-service teachers in creating a data visualization in a set amount of time. The third was the planning of a discussion around what the pre-service teachers are looking for in a data visualization tool for themselves and for their students that would be primed using existing technology tools.

In alignment with the spirit of PD, additional features were implemented in the sessions including: conducting the PD session during normal class time, in the same classroom their class is held normally, and in the presence of their instructor. Although the general design approach was the same for both PD sessions, they differed in some ways based on the feedback we received after the first session. The remainder of this section will describe the details of each PD session.

Participatory Design Session 1 (PD1)

In Spring 2019, during the eighth week of a sixteen-week semester, we conducted our pilot PD session with ten male and eight female social studies pre-service teachers at a large midwestern university. All of the pre-service teachers indicated that they expected to graduate within two or three semesters

following the class. The majority of the pre-service teachers were working towards obtaining a graduate certificate in secondary education. This was a unique seventy-five-minute class session where we asked pre-service teachers, taking a course on data literacy, to inform the design of a data visualization technology tool specifically for social studies education.

Consent forms and pre-class surveys were emailed through the class instructor (third author) around two weeks prior to the PD session. All authors were present during the session and took observation notes throughout the session. After introductions, the pre-service teachers were asked to pair up and introduced to the pair programming technique. Around half of the pairs were asked to work on the Vega-lite activity sheet, while the other half of the pairs were asked to work on the JavaScript activity sheet (Fig. 1).

Vega-lite [30] was developed by the University of Washington’s Interactive Data Lab, and is a declarative program specifically for interactive graphics and data visualizations. It uses JSON syntax to generate visualizations. The programming environment is on the left, while the visualization appears on the right side of the Vega-lite environment (Fig. 2).

The JavaScript activity sheet was developed using JSFiddle, an integrated development environment (IDE) software service that provides the basic tools required to write and test software in snippets (Fig. 3). We used JavaScript syntax to create the data visualizations for the JavaScript activity sheet.

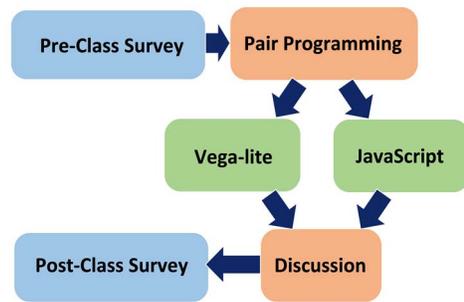


Fig. 1. PD1 Session Design

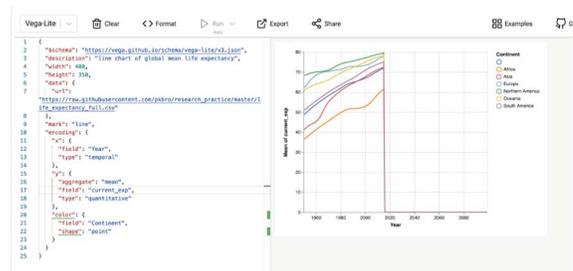


Fig. 2. Vega-lite Code and Editor as used in PD1 and PD2



Fig. 3. JavaScript Code and Editor as used in PD1 and PD2

The pre-service teachers were asked to work on the activity sheets for twenty minutes. Links to both activity sheets were available to the pre-service teachers during this time, so pairs that finished their activity sheet early, were given the option to work on the other activity sheet if they wished. During the twenty minutes, the first and second author walked around the classroom to answer questions, in addition to taking notes on any activity or conversations they observed. Once the twenty minutes was over, we engaged in a whole class discussion. Our questions involved a lot of comparisons between the two activity sheets on the surface, but the main goal was to motivate them to share their thoughts about how these tools were similar to things they had seen before or made them think about their use in the classroom.

At the end of the discussion, a link to the post-class survey was shared and also later emailed to the pre-service teachers. A debrief session amongst the three authors (one of whom was the class instructor) took place after the session. The debrief session was particularly useful in discussing comments or points of view that were brought up during the session about the technology tools, activity sheets, and social studies education.

Participatory Design Session 2 (PD2)

Our second PD session took place during the sixth week of the Fall 2019 semester, with all the location and class details the same as the first PD session. The majority in this session were also secondary education focused. All, except one, of the pre-service teachers in this session were undergraduate students. The fourteen pre-service teachers, eight male and six female, were asked to take the pre and post class survey, work on three activity sheets, and participate in the feedback discussions that followed. As shown in Fig. 4, we added a third activity sheet based on the Common Online Data Analysis Platform (CODAP) [31]. CODAP is a click, drag, and drop based data analysis tool designed for grades 6 through 14 (Fig. 5). It comes with preloaded data sets and is designed for use in various school subjects. You can use one of their preloaded datasets, or you can import your own.

We decided to structure the PD session so that everyone would have a chance to work on all three activity sheets, and in the same order as everyone else. This would give the pre-service teachers equal exploration time and the ability to compare all the tools together. In PD1, some pre-service teachers were hesitant to speak-up if they only had a chance to

try one of the tools. But in order to try all three tools, we could not allocate more than ten minutes per activity.

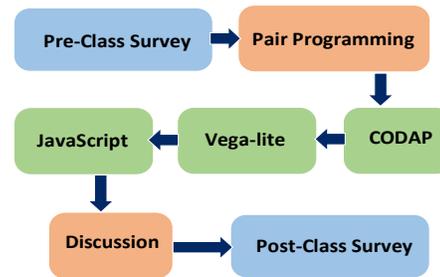


Fig. 4. PD2 Session Design

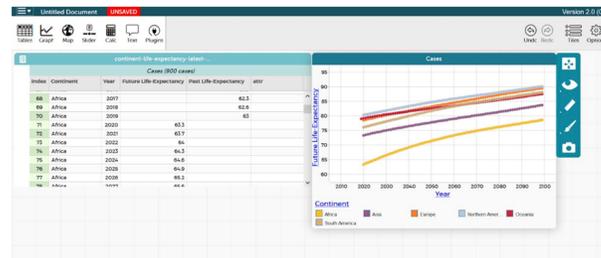


Fig. 5. CODAP as used in PD2

Our discussion prompts involved a lot of comparisons between the three activity sheets to provide surface level design feedback, and similar to PD1, our other goal was to motivate them to share their thoughts about how these tools were similar to ones they had seen or used before or made them think about their use in the classroom. At the end of the discussion, a link to the post-survey was shared and also later emailed to the pre-service teachers. This session also included a debrief session.

Analytic Framework

To try and understand how the different pre-service teacher participant groups influenced the design of the future task-specific technology tool, we used Sandoval's [32] conjecture mapping technique. Conjecture mapping is intended to help researchers systematically describe the material and theoretical aspects of learning environment design—what Sandoval calls the embodiment of a design conjecture, and the mediating processes through which that design is expected to contribute to learning. Material aspects included the software tools, activity sheets, and any other task and participant structures used to facilitate the PD session. Theoretical conjectures described how experiences structured through our design are expected to lead to desired learning outcomes. The assumed links that connect elements of the embodiment to certain mediating processes that are expected to foster learning, are called design conjectures.

Similar to Wilkerson's SiMSAM project [15], we chose conjecture mapping as an analytic approach for three main reasons. First, it allowed us to analyze the influence of participant input on both the material and theoretical products of design. Second, conjecture mapping created a degree of structural organization that allowed us to isolate and trace changes in both specific design elements, and the corresponding theories that we expected each design element to trigger. Third, conjecture mapping created a visual that made analysis across the two sessions simpler and available for study in ways that would otherwise be challenging.

IV. THE PRE-SERVICE TEACHERS WERE SUCCESSFUL

In the first PD session, ten of the eighteen teachers that participated in the PD session and pre-class survey, completed the post-class survey. From these post-survey participants, four started the PD session working on the JavaScript activity sheet, while the other six said they started on the Vega-lite activity sheet. Around half of the pairs began with the JavaScript activity sheet, and half the Vega-lite. Most of the pairs were able to finish the first activity sheet they were working on, and had a chance to start working on the other activity sheet, in the twenty minutes time that they were given. Those that had started with the Vega-lite activity, were more likely to have had a chance to work on the JavaScript activity as well.

In the second PD session, seven of the fourteen pre-service teachers that participated in the PD session and pre-class survey completed the post-class survey. In this session, all the pre-service teachers tried all three activity sheets and in the same order, with ten minutes to complete each activity. During the discussion, all the pre-service teachers indicated that they were able to create and modify a data visualization using the provided scaffolding in the activity sheets for all three tools. But two of the pre-service teachers suggested having more time to work on the activity sheets in the survey.

In PD1, pre-service teachers indicated in the survey and discussion that provided similar scaffolding, they all wanted to use similar activity sheets in their future classrooms. Interestingly, exactly half of the pre-service teachers that completed the post survey preferred to use Vega-lite in their classrooms, while the other half preferred JavaScript. All except two of the pre-service teachers in the post-class survey preferred the same activity sheet for their students as they did for themselves.

All the pre-service teachers in PD2 said they wanted to use the same tool for themselves and their students. More specifically, six out of the seven post-survey responses indicated that they would prefer to use CODAP for their classrooms. Only one pre-service teacher with JavaScript experience, preferred Vega-lite for himself and his students.

Overall, the pre-service teachers engaged very well with the tools and activities provided. Less than half of the pre-service teachers had ever created a data visualization, and those that had, had only used Excel to do so. In response to our first research question (*how can we engage non-STEM pre-service teachers in a STEM activity*), we engaged non-STEM pre-service teachers in a STEM activity using the PD method successfully by using heavily scaffolded activity sheets, pair

programming, and an interactive discussion. Through our guided PD process, we observed the pre-service teachers interactions with the tools with the provided scaffolding through the activity sheets, provided multiple technology tools that enabled them to compare, and recorded their reflections during the discussion and individual textual responses through the survey.

V. EXPLAINING PRE-SERVICE TEACHER SUCCESS

As described in the previous section, our pre-service teacher groups engaged in the STEM activities successfully. Interestingly though, the level of engagement and response was very different between the two groups of pre-service teachers. Thinking about how the user of a technology tool might decide to integrate it in their classroom is an important aspect of our project.

Studies have explored teacher values, beliefs, and attitudes about the consequences of technology adoption [33]–[35]. The results from these studies indicate that various K-12 teachers used technology that aligned with their value beliefs. Value beliefs in one study is summarized as professional and student needs. Student needs is described as teachers believing in the value of technology and being more likely to adopt it if students were seen to be more engaged, have improved comprehension, and learn from the tool in ways useful for other applications as well [33]. The Technology Adoption Model (TAM) [36] has been used in related studies. The main TAM components of 'perceived ease of use' and 'perceived usefulness' may shed light onto why our two PD sessions were so different. Teachers that perceive a tool as easy to use, are more likely to adopt it in their classrooms. Teachers that found the technology tools aligning with their pedagogical goals for their students, might perceive the tool as more useful. To help us gain greater insight as to why we were seeing the differences we were seeing using the TAM lens, we coded our data based on Saldaña's Values coding technique [37]. We wanted to uncover the values, attitudes, and beliefs the pre-service teachers have towards the data visualization prototypes they were provided. This allowed us to not only be informed of the specific features the pre-service social studies teachers preferred having in a technology tool they might consider adopting in their classrooms, but also informed us of the values, attitudes, and beliefs that led to those preferences. Not all pre-service teachers will have the same preferences, and trying to understand why those differences exist, will help us design tools that better support a broader spectrum of teacher interests.

In PD1, one pre-service teacher preferred to have Vega-lite for herself and JavaScript for her students, stating:

I don't mind keeping life simple for me, but I wanted to challenge my students and give them useful, new skills.

This PD1 pre-service teacher wanted her students to use a tool she perceived more challenging, because of the greater learning value it might offer them.

Another pre-service teacher in PD1 preferred to have JavaScript for himself and Vega-lite for his students, stating a somewhat different reason:

I would like Java because it would let me do more to the visualization. Vega-lite would be better for students because it seems far more simple.

These statements gave us an idea of what some pre-service teachers in PD1 valued. They believed in the learning opportunities that the programming tools offer their students and were willing to learn how to work with the tools themselves as a result. They did not seem to value anything more than student learning in their tool preferences.

In PD2, pre-service teachers chose CODAP as their tool of choice for both themselves and their students, except for one pre-service teacher that chose Vega-lite because he “like[s] programming”. None of the pre-service teachers talked about how their choices were related to student learning. The pre-service teachers in PD1 seemed to consider their students much more often, while pre-service teachers in PD2 focused more on their personal preferences.

All the pre-service teachers appeared to value the exposure to programming they were given through the sessions. But they differed in how they saw programming being useful for their teaching purposes. In PD1, pre-service teachers expressed interest and relevance in the learning opportunities the tools had to offer, with one pre-service teacher stating:

It (programming) really makes you see how visualizations can mold data to show a specific story, for better or worse.

And another pre-service teacher thought programming:

makes you focus more on questions rather than answers.

These two pre-service teachers saw a connection between the activities they did using the programming tools, and their pedagogical goals as future social studies teachers.

However, in PD2, responses from two pre-service teachers were echoed by many others in both the surveys and in-class discussion. One pre-service teacher preferred the non-programming CODAP over the programming tools because:

CODAP is easy to use and you can explore it without breaking it.

While another simply said because “CODAP is easy”.

The pre-service teachers in PD2 showed less interest in the programming activity sheets, often got side-tracked and looked at other functions of the tools during the session. They saw less application in their future classrooms. These opinions were very different from what we saw in PD1. In PD2, pre-service teachers did not discuss their pedagogical goals, student learning, or state standards in their reasons for choosing CODAP over Vega-lite and JavaScript.

There are a few other reasons why these differences between the two sessions may have emerged besides the pre-service teachers’ future pedagogical goals. One of those reasons may be because the sessions were designed slightly differently. PD2 took place a few weeks earlier in the semester compared to PD1. The sessions took place in a data literacy class. Pre-service teachers in PD1 were further along in the course compared to PD2, which may have made them more comfortable with data visualization tools. This may have

helped the pre-service teachers in PD1 focus on the pedagogical uses of the tools rather than being focused on the ease of use of the tools. Besides differences in how PD1 and PD2 were designed, participant characteristics may also have played a role. We know that pre-service teachers in PD1 were older on average and part of a graduate teaching certificate program. We also know that a significant number of the pre-service teachers in PD2 were unsure about their identities as teachers, had learning challenges, and ultimately ended up leaving the teacher education program.

Other session design differences were guided through our analysis using the conjecture map after the completion of the first PD session. Using the PD method enabled us to look at the tacit behavior of the pairs as they were working on the activity sheets. This allowed us to realize that in the first PD session, the pre-service teachers did pay attention to the data itself, or question where the data came from or how it looked. But in order for social studies students to connect data with history, one of the goals of data literacy, students need to explore and investigate the data. This connection was made clearer through the conjecture map, so in the next iteration of the activity sheets, we added ‘pauses’ at the end of each section that asked the pairs to reflect on their data visualization before moving onto the next activity. This resulted in PD2 pre-service teachers paying much more attention to the dataset compared to what was seen in PD1.

The pre-service teachers in PD1 also had more time to internalize the technology tools. They had twenty minutes to spend on roughly the same activity that PD2 pre-service teachers spent only ten minutes on. We also included an additional activity using CODAP in PD2 that was not included in PD1. Asking the pre-service teachers in PD2 to try out three tools they had never seen before in thirty minutes. Regardless of the improved scaffolding that may have been provided in the activity sheets, having had less time and more tools to try may have caused cognitive load issues for pre-service teachers in PD2. While in PD1, the pre-service teachers spent more time on their activity, and were not asked to look at the second activity sheet unless they wanted to. This may have given the pre-service teachers in PD1 more time to process and reflect on the learning possibilities with the tools rather than feeling constrained with time.

A third possible reason for the differences seen in the two PD sessions, was their focus on the applications of the tools based on their elementary or secondary concentration. Preference of CODAP over Vega-lite and JavaScript, may have been because PD2 had many more pre-service teachers with an elementary education concentration participating in the class discussion and survey. Pre-service teachers in PD1 were primarily graduate students and had a greater number of secondary education teachers that actively participated in the session. The pre-service teachers with elementary focus were less interested and saw less application for their purposes. This made evaluating the tools somewhat difficult because none of these technology tools are meant to be used by students below the sixth grade. One pre-service teacher in PD2 said:

I am going to be an elementary school teacher and I think that CODAP is the most appropriate for the age group. The

other two software's include more complex visualizations that would be too confusing for elementary students.

This challenge may have influenced many elementary focused pre-service teacher opinions when considering programming for their students. While the CODAP tool was only tried by the pre-service teachers in PD2, many of them cited preference of the tool simply because they thought their future elementary students would not be able to program, and said things like:

programming ones too complex for elementary school

And

elementary kids make timelines.

This pre-service teacher did not seem to see the value in a programming tool that focused on two-dimensional visualizations, when all she needed for her purposes was one-dimensional graphs. The instructor of the class later in the debrief explicitly disagreed with this statement and believed that these pre-service teachers probably know very little about what the social studies curricula standards entail. But none of the other PD2 pre-service teachers mentioned this important element of curriculum standards. In fact, except for one teacher showing interest in a map feature in the CODAP tool, no one else mentioned anything about how these tools may help them achieve their curriculum standards, or more generally, their pedagogical goals. In their surveys, PD2 pre-service teachers felt there was learning value in the session, but they did not see how that value was useful for them. One pre-service teacher said:

I appreciated the exposure to programming, even if I do not find it particularly useful for lesson planning.

In PD1 on the other hand, none of the pre-service teachers mentioned the programming tools not being useful, and multiple pre-service teachers asked for things like:

More understanding about how the data goes into the program and how the program works.

And

I would like to actually learn how to write the code to make a visualization.

Ultimately, the trend that was seen in the second PD session indicated correlations with the TAM components of 'perceived ease of use' and 'perceived usefulness'. Pre-service teachers that perceived a technology tool as being 'easy' or 'unbreakable', were more likely to show interest in adopting that tool in their classroom. Similarly, pre-service teachers that perceived a tool as being useful for elementary students, were more likely to adopt that tool over others. We don't know whether any of these pre-service teachers will adopt any of these tools. However, TAM did show us that adoption might happen if pre-service teachers perceive 'ease of use' and 'usefulness' in the technologies they are exploring.

VI. LIMITATIONS

Our PD sessions and results are limited to one university and over the course of one semester. Results seem to indicate that various class demographics and student characteristics

influence class discussions. Following pre-service teachers through the remainder of their training may provide much greater insight and is part of our future work. Good design requires multiple iterations and reflection and we have only had two PD sessions so far. Future iterations and evolution of the PD sessions will likely lead to improved pre-service teacher engagement and more informative design feedback, resulting in greater interest in integrating a data visualization technology tool in their future social studies classroom.

VII. CONCLUSION

Our study describes our front-end design process where the goal is to learn about how elementary and secondary school pre-service social studies teachers use existing tools that can generate data visualizations. Teaching engineering skills (data manipulation and visualization) in non-STEM classes provides the opportunity to reach a more diverse population of students than might typically take STEM-oriented classes. The challenge is how to engage the non-STEM pre-service teacher, and our answer is the use of a PD process where pre-service teachers tell us what works, what doesn't, and what they need through surveys, discussion, and prototyping.

We were surprised to see such different responses to our design prototypes in our first two PD sessions. In particular, our results suggested that pre-service teacher experience within their disciplinary class influenced what they valued in technology. Our more experienced pre-service teachers valued more the student perspective on technology, while the less experienced valued more the ease of presenting and use of the technology. The lesson learned is that we need multiple PD sessions to inform our design work because the variance in pre-service teacher skills, preferences, and perspectives is so large.

We are unlikely to find or design a single data visualization tool that meets all teachers' needs, both because of variance in teachers and because of variance in schools and contexts. We have now completed the third PD session and have our own designed prototype that would be adoptable by teachers – but not all teachers.

In this work we presented the value of a PD approach for gaining feedback from pre-service teachers for an engineering learning activity. Our contributions in this paper include the demonstration of PD as a front-end design process for K-12 pre-service teachers, and a description of the experiences of non-STEM pre-service teachers in learning and using data visualization prototypes.

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