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Challenges and Opportunities in Teaching and Learning Data Literacy through Art

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Abstract: Achieving data literacy is challenging when schools narrowly focus on statistical reasoning rather than on meaning- and inference-making. Without attention to the social contexts of data, learners can fail to develop a critical stance toward data, to understand the nature and production of data, the questions that it can answer, and the ways that data can be used to inform and misinform. We explore art as an accessible and personally relevant approach to developing middle school students' data literacy. We designed and implemented a 2-week long arts-integrated unit in a grade 7 classroom. Interviews with two teachers and two students following the unit, and analysis of students' artworks and pre/post survey responses, reveal opportunities and challenges at the intersection of data science and art. We discuss pedagogical considerations for other interdisciplinary approaches to data literacy.

Art as an approach to data science

It is essential that young people become data literate. With public and private institutions increasingly amassing personal data, learners must be able to think critically about the sources, representations, and claims being made about data. This reasoning includes an ability to understand the nature of data and how to extract meaning from data patterns, as well as to make critical inferences about data based on context, and the extent to which evidence from the data supports a claim (Makar & Rubin, 2018). Cultivating data literacy is challenging because school mathematics tends to narrowly focus on statistical reasoning, and to present data as objective and devoid of context (Franklin et al., 2015).

We explore an approach to broadening participation in data science by integrating art and mathematics in a middle school classroom-based unit. This project builds on existing efforts to tie school-based data literacy instruction more closely to personal and social contexts (e.g. Kahn, 2020) by incorporating an interdisciplinary focus on art (c.f. Lupi & Posavec, 2016). Interdisciplinary approaches to mathematics and data literacy can be valuable for engaging students who are disengaged in mathematics and can support deeper data literacy learning (Stornaiuolo, 2020). It allows learning through the making process through which learners can engage in meaningful reflection (Turkle & Papert, 1990). Moreover, *data art* is a distinct art form that engages audiences with both emotional and intellectual properties of data (D'Ignazio & Klein, 2020; Hall, 2008). In negotiating these priorities, the artist represents the situated nature of data, a fundamental principle of critical perspectives.

We explore a form of data-driven art-making, in which learners identify a message to convey, reflect on the different perspectives and complexities involved in a data set, and determine how to use materials to communicate that message to evoke a desired reaction from an audience. As students engage in asking questions, gathering and interpreting data, and communicating an evidence-based claim or argument to inform or persuade, our conjecture is that an arts-based approach will encourage a critical perspective on data that is often absent from mathematics alone. Such a perspective would involve connecting data to context, identifying patterns in data at an aggregate, and weighing the warrant of the data for supporting arguments or claims (Makar & Rubin, 2018).

To examine the opportunities and challenges in students engaging in art-making for data literacy, we designed and implemented a unit, and asked: (1) *What value do teachers perceive in an arts-integrated approach to data science?* and (2) *How does this approach engage students with data?* By understanding teachers' goals and students' experiences, we can better design similar interdisciplinary activities that are feasible for the classroom.

Methods: Context, participants, and data

To explore the value of an arts-integrated approach to supporting data literacy, we co-designed and implemented a unit with two teachers, one art teacher (Kelly, female) and one math teacher (Bruce, male)) and their 25 seventh grade students. Kelly and Bruce teach at the same private school in the United States, in which their administration

encourages interdisciplinary connections between subjects. Kelly and Bruce identified the theme of social interaction, which they felt would interest their students. The two-week unit was presented as a way for the students to explore the theme using both data and art through two activities: (1) a data drawing, which involved students collecting, organizing, and visualizing data using hand-made drawings to reveal patterns about their everyday social experiences (e.g., the number of times they heard the word "pandemic;" number of conversations they had and with whom); and (2) a data sculpture, which involved students using materials found in their homes to communicate a pattern found in their exploration of data on teens' use of social media. For this activity, we provided students with a tool (bit.ly/sm-pew) to explore an existing data set on teens' use of social media (Pew Research Center, 2015). This tool allowed students to explore the responses to survey questions (e.g., "Does social media make you feel better connected to your friends' feelings?") and group the data based on characteristics (e.g., gender, age, race/ethnicity, etc.). Because of the COVID-19 related school shutdown, students completed the activities asynchronously from their homes, sharing photographs of their artwork with peers, and responding to reflective prompts using the Web-based Inquiry Science Environment (WISE, wise.berkeley.edu). To support students' navigation through the unit, teachers corresponded with students via email and Google Classroom, and facilitated optional virtual synchronous check-in sessions once per week.

Our data consist of (1) a post-unit group interview with two students (whom we name Ariel (female) and Yamil (male)), which asked them to reflect on their experiences during the unit and to elaborate on the decisions they made in creating their artwork; (2) individual post-implementation interviews with each teacher, in which we ask them to reflect on how the unit met or failed to meet their learning goals, and on notable observations of student learning; (3) student artifacts (artwork, artist statements, and written reflections on their processes); (4) responses to a pre and post survey that probed students' engagement and self-perceived competencies in math and art, and their abilities to critique existing data-based art; and (5) researchers' reflections on our experiences co-designing the unit over the several months prior to its implementation, and in supporting teachers throughout its implementation. Three researchers conducted a thematic analysis of the data using an open coding approach to develop descriptive categories, and refining these through discussion and re-reading of transcripts (Saldaña, 2015). To answer RQ1, we describe the key themes that emerged from our analysis focusing mostly on the interviews with the teachers. To answer RQ2, we use our multiple data sources to construct narratives of students' experiences. For the purposes of this paper, we focus on students' data sculptures.

Findings

RQ1 What value do teachers find in an arts-integrated approach to data science?

The teachers indicated three main benefits from implementing an arts-integrated approach to data science with their students. First, it enabled students to contextualize ideas in the real world, increasing their awareness of the applications of art and math. Kelly noted that she "liked showing students why people create art (…) that it's more than just being an artist." She stated that a valuable part of the activity was showing students that "art can also help us understand concepts in other fields," and that data-based artists "exist and (...) this is an option for them instead of doing the graphs and the bar charts, you could make it more expressive (...) you can kind of go further with your statistics." Similarly, Bruce wanted students to use mathematical tools to accomplish a meaningful and practical goal, "not only are they working with the numbers, but they're taking that information and then doing something else with it, with the hope that it'll you know stick in their brain a little bit." Additionally, an arts-based approach was seen as important for students to recognize the real-world implications of data. Kelly observed that the activities allowed students to see "the overall story of the numbers, they were looking at. It wasn't just 90% of this or 40% of this. They saw: 'OK, so real people. So I'm going to tell the story of the person.' So that (...) puts a narrative into their math class."

Second, the teachers chose this curriculum to provide students with opportunities to use art and math to pursue their own interests. For example, Bruce appreciated that students "had to come up with their own question, and (...) find a topic they like to learn." He also noted that although the activity was less math-focused than he would typically assign, it was especially appropriate for asynchronous learning. Students "were able to do something that they might enjoy for school work" while incorporating diverse materials, connecting to "a lot of different topics and com[ing] up with their own ideas." Kelly also noted the ways that students seemed to build personal relevance, "I think [the topic choices] were very relevant to them because you know you can see in some of their storytelling, you know it sounds like they were kind of talking about their own experience".

Third, the curriculum provided new ways for students to work with data, demonstrate their understanding, and facilitate assessment of students' learning. Bruce noted that these types of interdisciplinary approaches provide him with an opportunity to promote inclusivity by helping him "make things, both the information and the assessment of what they've learned, kind of accessible to as many students as I can." By

providing many options he hopes learners can "find their comfort zone." The unit also provided new ways to assess learning, particularly how and whether students were able to transfer knowledge across contexts. He could see that the students were "not just regurgitating information exactly the way it was taught to them. They were shown some examples of how to read this data, what they could do with it, and they proved that they were able to do independent thinking with that by doing different types of projects that we didn't show them. (...) they have to be able to make inferences about the data (...) and the project was a good way to assess that."

RQ2 How did students engage with data through art?

Ariel. Ariel's pre and post-survey responses showed she developed a new awareness of the relationship between data and art. By the end of the unit, she expressed a belief that the quality of data-driven art resides in "how much [it] can show the meaning of a graph..." Ariel began the data sculpture project by exploring the Pew data set. She was intrigued by how frequently teens' used the internet, a finding based on a graph titled "overall, how often do you use the internet?" From this discovery, she attempts to answer "how the internet can be impactful on the minds of teenagers." She then misrepresented the data by making a claim grounded in her own perceptions of teens' internet use: "social media appear to affect different people in different ways by finding what they are interested in, attracting them into that subject, and making you lost into the world of social media." Using this statement, she mapped variables onto different visual attributes (Figure 1, left) to contrast teens who do and do not use the internet.

Ariel used the colors and arrangement of crayons, scissors, and hair elastics to symbolize the attitude differences she perceived between the two groups. The open scissors and scattered arrangement of objects in one pile represents the "open-mindedness," imagination, and inclination toward "drama" that she perceived in teens who use the internet. Meanwhile the circular shape of the hair elastics and the square arrangement of crayons in the second pile represent people "circling around a topic," who avoid the internet, and whom she presumes are more "organized, more ordinary (…) [and who] focus on educational stuff." Kelly admired Ariel's use of symbolism, and was surprised at how it differed from Ariel's typically conventional artwork.

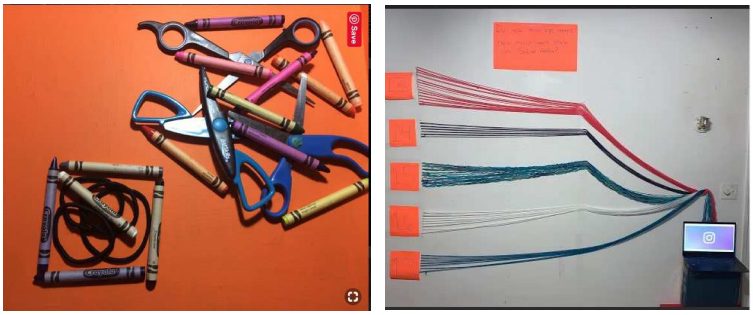

Figure 1. Data sculptures from Ariel (left) on the impacts of the internet, and Yamil (right) showing teens who "disagree" with the statement "Do you think age impacts how much teens share on social media?" by age.

Yamil. Based on his pre-test, Yamil had difficulty evaluating the quality of data, and making accurate claims based on graphical representations of data. He began his data sculpture by seeking relationships in the Pew data that he believed would be interesting to a wide audience (pre-teens and parents). He chose to communicate the relationship between young people's age and their attitudes toward sharing personal information on social media. He first tried using clay to represent this relationship, but when he could not accurately scale his sculptures to the data, he abandoned this medium in favor of yarn. He pinned the yarn to a wall, distinguishing age groups by the yarn's color, and mapping the number of strands to the number who disagreed with the claim.

Kelly, who shared that Yamil was one of the more creative students, noted surprise at the resemblance of his artwork to a canonical graph. At the same time, Yamil had misinterpreted the data set in multiple ways. His title, "Younger age group reveal more personal information on social media," suggests that Yamil believed the data to be about how much information teens share, rather than teens' perceptions of how much others share on social media. Moreover, the decisions he made for practical reasons seemed to have led to misrepresenting the data. More specifically, instead of showing each of the 1,060 survey respondents, Yamil transformed and filtered the available data, reinterpreting the Likert scale as a binary yes/no question, and representing only the respondents who disagreed with the focal statement. By representing only a fraction of the sample and using sums rather than percentages, he overlooked the fact that 80% of 13-year olds actually believe that people share too much personal information. It seemed that Yamil's expectation that "older kids know more" (as in, they know better than to share personal information online) prevented him from recognizing his misinterpretation.

Discussion and significance

In exploring how teachers and students experienced an arts-based approach to data literacy, we found that students generated unique questions, negotiated relationships between data and materials, and made claims that attempted to go beyond the data. Ariel conveyed meaning through the color, shape, and organization of materials, while Yamil used an unconventional material (yarn) to construct a conventional representational form. Both students ultimately drew on personal beliefs rather than on the data as evidence to support their claims, a difficulty identified by Hug & McNeill (2008). By examining their process, artifacts, and reflections, we identify opportunities to better support students' informal inferences through art-making.

First, while Kelly and Bruce both highlighted the chance for students to pursue their interests through this unit as an opportunity, students struggled to communicate personal perspectives that were also grounded in data. Ariel and Yamil incorrectly interpreted data when pursuing questions that were personally interesting to them, rather than develop new questions, answerable with the data available. This shows the difficulties of working with data as an artistic material, that is, in negotiating its affordances and constraints for communicating a perspective to an audience. The mandated asynchronous format limited the discussion that teachers would have facilitated to address such issues. To scaffold students' sense-making, future iterations might incorporate tools and routines of authentic artistic practice, such as with tools such as peer and public (Soep, 2005), wherein students can iterate on their ideas, examine their biases, and test their artistic choices.

A second challenge was in defining data art. Yamil made a functional data art sculpture, offering his audience a tool for discovery by attempting to represent the data objectively. Ariel, on the other hand, made an expressive data art sculpture, connecting her audience to the topic through a feeling or concept. Both students showed difficulties in making and communicating informal inferences about data, either being unable to go beyond the data or using data as little more than inspiration. It is essential to support reflection on how choices about data skew toward either extreme, and to support students in iterating toward the center. In future, we will find ways for students to create personal connections with broader social patterns found in data.

This study highlighted the opportunities in an arts-based approach for allowing students to make inferences that give data personal and social meaning. It also emphasized the need to ensure that students are grounding their interpretations in evidence. Findings will inform future research and design on arts-based data literacy and art at the middle school level.

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