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Published online: 21 Jan 2024.

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Reclaiming the right to look: making the case for critical visual literacy and data science education

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ABSTRACT

As visual cultures scholars have argued, visual expression and aesthetic artifacts largely comprise the modern world. This includes the production of the school as an institution. A critical approach to education therefore must reinscribe students with the ability to see what educational processes attempt to hide and to construct an understanding of the real for themselves. To illustrate this argument, we explore the production of visuality within data science education as one example of how the visual manifests within schools. In response, we propose a visual literacy informed approach to engaging students with data, one that expands beyond contemporary forms of critical data literacy by involving an ontological critique of educational aestheticization. To ground this work, we examine the role of visuality and aesthetics within the implementation of co-designed arts-infused data science projects in four US middle schools. In analyzing interviews with teachers and students, we uncover a series of tensions that reveal the ongoing influence of school visualities alongside the potential for student generated images to amplify their right to look. We therefore argue that critical pedagogies must not only involve reading and critiquing aesthetic artifacts but also engage students in a critique of visuality itself.

Introduction

In his foundational text on the field of visual cultures, Mirzoeff (1999) makes the argument that 'there is now a need to interpret the postmodern globalization of the visual as everyday life' (p. 3). Under this assumption, society is constructed from visuality and all it entails (images, seeing/looking, aesthetics, etc.), as 'forms of visual expression ... reflect the culture within which they have been created while at the same time taking part in shaping it' (Gil-Glazer, 2020, p. 67). Importantly, this understanding of visuality extends beyond a purely ocular definition of the term, as scholars routinely position aesthetics as a constructed

cultural technology with its own embedded power relations (Kellner, 2002; Knochel, 2013; Mirzoeff, 2011; Rancière, 2004). Education, as an institution, represents an example of this contention in large part because of the ubiquity of the visual within schools. The practices of making certain subjects and forms of learning visible or invisible, the production and circulation of aesthetic artifacts, and the privileging of seeing as a means towards understanding all combine to create our modern conception of the school (Prosser, 2007). This process filters into all aspects of schooling as an institution. Defining curricula (Ali-Khan, 2011), manifesting student subjectivities (Atkinson, 2001), and positioning schools in relation to each other and hegemonic discourses (Decuypere & Landri, 2021) all rely on aestheticization and visualizing processes. In this sense, the school emerges as an institution from and through our visual culture.

Although not immediately apparent, the encroaching prevalence of data within schools and the lives of students (Hartong & Piattoeva, 2021; Pangrazio et al., 2022) represents a visualizing process as well. As Decuypere and Landri (2021) argue, the aesthetic technologies used to visualize data do as much work as the data itself, acting on schools and school subjects in ways that data by itself cannot. This happens precisely because data analysis and the creation of data artifacts (i.e. visualizations) represents an aesthetic process: the production of data sets, their subsequent visualizations, and the contexts in which they are placed infuse data with a sense of trustworthiness via visualization (Walford, 2020). Within education, data analysts manufacture the image of a good school through the construction of data visualizations that 'invisibilize' the process of creating these aesthetic technologies (Hartong, 2021). The production of data has also become a dominant process in the construction of the student as a subject, with student identities being increasingly formed through analyses of personal data that occur beyond the students' control (Selwyn et al., 2022). Data thus becomes a means of seeing the student and visuality provides a lens for understanding the function of data within schools.

Drawing on this connection, we use this paper to explore the function of visuality within schools through the example of data science and data science education. This emergent school discipline expands beyond a focus on mathematical computations, incorporating computing and data skills (e.g. managing data sets, producing graphical representations of data) and situated knowledge about data in real world contexts (Acker & Bowler, 2018; Lee & Wilkerson, 2018; Lee et al., 2021). Connecting to our emphasis on visuality, data science educators and researchers routinely foreground the importance of data visualizations, an encompassing term for visual representations of data including tables, graphs, and other graphic portrayals (Lee et al., 2021). Learning about data visualizations involves both constructing the skills needed to understand these aesthetic artifacts and how to create them (Choe et al., 2015; Lee & Wilkerson, 2018; Segel & Heer, 2010). While we recognize the contested place that data science holds within critical education scholarship, especially in relation to the use of data in governing the lives of students (Hartong & Piattoeva, 2021; Pangrazio et al., 2022; Sellar, 2015), the expansion (and ongoing critical positioning) of data science education as a discipline within K12 schools demands further critical inquiry to better understand how the epistemological, curricular, and pedagogical tenets within this field act on students. And, as we will argue here, exploring this process offers insight into how the visual operates within schools

while also providing an opportunity to critically reflect on data science as a disciplinary formation in the first place.

To achieve this end, we first discuss the role of the visual within schools through Mirzoeff's (2011) notion of visuality as a relational and sociocultural phenomenon, one that both obscures extant power relations and produces new forms of power. We then use this frame to consider how Walford's (2020) notion of data aesthetics and data visualizations (as situated, curricular technologies) conceal power relations embedded within knowledge formations, schooling, and education. We construct and further deepen this analysis by grounding our work in the lived experience of students and teachers engaged in what we have defined elsewhere as 'data-art inquiry', or 'a process for building data literacy that draws on inquiry approaches from both data science and the arts' (Matuk et al., 2022, p. 1161). Data literacy, in this instance, includes skills related to gathering, constructing meaning from, and telling stories with data (Matuk et al., 2022; Stornaiuolo, 2020). This approach to data science education engages students in contextualizing and critically analyzing data while simultaneously developing meaning from and communicating new ideas through artistic strategies. We therefore align this work with Gil-Glazer (2020) and other critical visual literacy scholars who argue that engaging students in the production of new aesthetic artifacts, such as the creation of non-traditional data visualizations like data-art, can help develop a critical stance towards the visuality of schools. In doing so, students can reassert what Mirzoeff (2011) describes as 'the right to look', a claim to see what normally gets hidden through the production of visuality. However, this can only occur through a direct critique of the aestheticized dimensions of education, thus necessitating a pedagogical approach beyond merely trading out old aesthetic technologies for new ones. Failing to do so undermines the potential of critical visual and data literacy curricula, reinscribing the kinds of power relations that emerge from common educational practices.

The production of visuality within education

To begin excavating the role of visuality within schools, a crucial (and somewhat self-evident) first step involves defining visuality itself. Beyond merely representing an optical aesthetic or static set of images, Mirzoeff (2011) embraces an active framing of the term by analyzing 'the production of visuality, meaning the making of the processes of history perceptible to authority' (Mirzoeff, 2011, p. 475). Importantly, this understanding of visuality very explicitly roots the visual within the domain of the dominant, a space of authority that renders certain aspects of the social world legible while hiding or completely eradicating those elements that do not benefit those in power. Mirzoeff (2011) goes on to argue that producing visuality involves three steps. First, there is a process of naming, classifying, or categorizing elements of the social world. Second, those in authority separate classified elements and individuals into sub-groups, resulting in a social organization that often reproduces hierarchical power structures. Finally, aestheticization occurs. This practice conceals the power relations that have produced the visual behind an exterior surface. In turn, this aestheticization makes the produced groups and relations seem natural or inherent all along.

As an example, Mirzoeff (2014) contends that the social relations of the Anthropocene have been deeply aestheticized. The categorization of the human and

non-human, as well as intra-human classifications such as first- and third-world populations, have been organized hierarchically with human and first-world populations consolidating power and displacing environmental destruction onto othered ecologies and societies. Mirzoeff (2014) then shows that the aesthetics of imperialism, specifically in relation to the visual nature of the constructed world and its artistic representations, normalized the sources of environmental destruction that reinforce this separation: the landscape dotted with factories, the dark hue of a polluted river, and the material infrastructure that physically isolates those in power from the environmental destruction they cause all fold into the background as everything about the Anthropocene continues to look and feel like a natural or inevitable outcome. In this sense, colonial and capitalist sources of power have produced an Anthropocene visuality through aestheticization and, in doing so, effectively buried their overarching role in destroying the environment.

In his analysis, Mirzoeff (2011) focuses on the aesthetics of 'visual complexes', or interconnected systems of relationships within and to visuality produced by social institutions. But we can extend this notion of visuality into the cultural politics of the everyday through other aesthetic formations. In alignment with Mirzoeff, Rancière's (2004) concept of the distribution of the sensible provides an avenue to understand sociocultural relations beyond institutional and governmental forces that produce the visual. According to Rancière (2004), the distribution of the sensible represents 'the system of self-evident facts of sense perception that simultaneously discloses the existence of something in common and the delimitations that define the respective parts and positions within it' (p. 12). In defining both the common and scarce, the visible and invisible, Rancière (2009) builds on his understanding of the distribution of the sensible to reimagine politics as an aesthetic practice. Politics, in this sense, becomes a process of allowing certain groups, individuals, or ideas to be visible or audible, seen or heard, while denying others the right to do so.

Expanding on this conception of visuality, education researchers have routinely acknowledged the role of aesthetics in the production of curricula and school disciplines. Rudolph (2012), for instance, contends that science as a school subject and the forms of knowledge that define science curricula evolve in part from aestheticization and the creation/circulation of visual imagery. This happens as designers embed epistemological formations, ones that emerge through and gain authority from power relations, within the aesthetics of classroom materials. Perlmutter (1997) uncovered an aligned practice within the production of history textbooks as aesthetic artifacts that, 'in words and images, enact what society deems history ought to look like' (p. 79). This process aestheticizes power relations by naturalizing ownership and control over the production and adoption of these books. Even outside of the creation of curricular materials, Zimmerman (2018) argues that mathematics as a discipline emerges through its aesthetics, with certain visual representations being perceived as inherently more closely connected to disciplinary knowledge. Yet this knowledge exists as a historical construction itself, with certain forms of mathematical thought being aestheticized through various power relations (Harouni, 2015). Visuality as a foundational component of education, understood through this analysis, therefore does not exist as a neutral entity but a productive force that shapes what counts as knowledge and who has access to it

while simultaneously hiding the choices that position select epistemologies as inherent within its curricular formations.

Asserting the right to look through critical visual literacy

The visuality of schools therefore 'manifests the authority of the visualizer' (Mirzoeff, 2011, p. 474) by aestheticizing the power relations that produce, amongst other things, epistemological and curricular formations as self-evident. To counteract this visuality, those being visualized need to reassert their 'right to look'. According to Mirzoeff (2011), 'the right to look is. . . the claim to a right to the real. It is the boundary of visuality, the place where such codes of separation encounter a grammar of nonviolence – meaning the refusal to segregate – as a collective form' (p. 477). In the right to look, a space where subjectivity emerges in gazing at the other as the other autonomously gazes back, the one that looks challenges the authority of visualization by seeing the normally unseen and constructing the image for themselves.

A thread of this notion exists within Freire's (1970) aesthetic practice. Through his method, emancipatory learning occurs as students and teachers critique images that metaphorically reproduce the relationships that define their immediate sociocultural context, imagine an ideal future, and recodify/revisualize the image to embody this idealized social world. Rather than allowing the educator's understanding of the world to dominate this process, the learning community decides together what is seen and unseen in the image and uses that process to visualize a new world (Sanz et al., 2019). In doing so, students produce a countervisuality, a new collection of visual images or aesthetic artifacts that challenge the normalization of power relations within the immediate visual complex (Gil-Glazer, 2020). Within contemporary education scholarship, this process provides a foundation for critical visual literacy, or 'education that enhances understanding of the role and function of images in representation and communication' (Newfield, 2011, p. 84). This discipline builds on Freire's work as students and teachers together unveil and challenge the hidden power relations that produce images and the means through which those images further reinscribe the status quo (Brown, 2022; Errázuriz, 2019; Kellner, 2002).

Beyond working with individual images, however, a sociocultural understanding of visuality emphasizes the role that images play in the production of curricula and schools as legible institutions (Prosser, 2007; Sanz et al., 2019). Aestheticization also produces certain ways of knowing as inherent, thus constructing a distribution of the sensible that extends beyond single images (Woods, 2022). Critical visual literacy attends to this issue by not only critiquing the social production of an image but the production of official curricula and schooling through visuality, creating space for students to challenge both hidden social forces within imagery and the social construction of knowledge as well (Knochel, 2013). The right to look, to demand access to the real and the agency to construct visuality for themselves, is therefore central to critical visual literacy.

Reasserting the right to look, however, proves complicated because the act of aestheticization produces its own logic that seems inherent or natural within acting forms of visuality (Mirzoeff, 2011). Challenging a visual complex thus means challenging the assumed natural order of the world. While accomplishing this goal on a broad scale sits far outside the scope of this paper, Rancière (2009) provides an avenue to challenge

the regime of the sensible (in essence, the local enactment of a visual complex within a micro-community) through the production of and engagement in the arts. The arts, and their embedded metapolitics, provide an opportunity for 'reconfiguring the distribution of the sensible which defines the common of a community, to introduce into it new subjects and objects, to render visible what had not been, and to make heard as speakers those who had been perceived as mere noisy animals' (Rancière, 2009, p. 25). The material artwork invites all involved (artist, audience, and others) to reimagine the relationships that define the micro-community of those engaging with the artistic artifact, collaboratively producing the meaning and politics of the work.

Within the context of education, visual cultures and visual literacies scholars contend that art making and image creation by students can challenge practices of schooling that reinforce discrimination and exclusion (Brown, 2022; Errázuriz, 2019; Gil-Glazer, 2020). The creation of aesthetic artifacts thus produces an opportunity to undermine the regime of the sensible and reclaim the right to look within education. Yet challenging visuality within education through the incorporation of critical visual literacy into the classroom still, in part, reinforces the institution of the school. Even if teachers reimagine their curricula to include the production of new images and visual artifacts as a means towards empowering students, this educational process still occurs within and relies on the institutional structure of the school. But the incorporation of critical visual literacy into formal curricula still holds value. As Gil-Glazer (2020) shows, a visual cultures informed approach to education creates space for students to assert their own humanity and define their own subjectivity within a system designed to negate both. The incorporation of critical visual literacy may not end oppressive aestheticization processes in their entirety, but they can still provide an opportunity for students to reclaim the right to look within an educational system designed for the opposite.

Challenging visuality within data science and data science education

To further illustrate the role of aestheticization and the right to look within schools, we now consider the example of data science education. While any school discipline could serves as a research site, data science's foundational reliance on visualization, as embodied by Walford's (2020) notion of data aesthetics, positions data science education as a particularly fruitful case to consider. According to the author, data analysis technologies (ranging from spreadsheets to tables and graphs) act on both data and social interactions with data by giving shape to this information, a process that aestheticizes data and communicates whether data is 'correct' or reliable through that shape. Importantly, this aestheticization 'entails eliciting, and then concealing again, certain relational patterns from the data sets [analysts] are presented with' (Walford, 2020, p. 212). Here, Walford specifically discusses the process of cleaning a data set where analysts look through collected data, decide which values do not match the shape of the data, and remove those values to create a cohesive data set. Through this process, analysts not only produce data visualizations but they also construct the data's trustworthiness by reproducing an 'aesthetics [of] objectivity' (Walford, 2020, p. 214). But the aestheticization of data does not end there. Visual conventions (the layout of visual objects, the use of shapes and lines, etc.) produce meaning by instilling data visualizations with 'a sense of objectivity, enabling them to

do … persuasive, rhetorical work … and to become valued as explanations of our complex social world' (Kennedy et al., 2016, p. 723). In this sense, the aesthetic components of imagery that collectively produce data visualizations embody specific power relations and infuse these artifacts with the ability to produce meaning, govern, and influence modern institutions (Decuypere & Landri, 2021; Ratner & Ruppert, 2019). The proliferation of these aestheticized artifacts produces a set of social relations, both between individuals and the broader social world. But these aesthetic artifacts also naturalize data's position as an inherent. phenomenon and not a product of individual choices (Walford, 2020).

Returning to the context of education, the aestheticizing power of data provides the foundation for the ongoing datafication of schools. According to Hartong and Piattoeva (2021), school datafication refers to 'the growing influence of data-based policies [and] the emergence of new sites of education data production, centralized databases and new data experts or data mediators' (p. 227) within learning ecologies. As Selwyn et al. (2022) argue, 'students are "seen" by their teachers (and other staff) through the production of digital data' (p. 346) within this educational practice. Yet the generation, collection, and analysis of that data remains entirely outside of the control of students, thus producing an 'information asymmetry' (Brunton & Nissenbaum, 2015) where control over one's own personal data shifts from the student to teachers and administrators. The production of the student as a socially defined (and visible) subject within schools then occurs through the aestheticization of data collection and analysis, with individual identities being seen as inherent to the student despite this process emerging from individual choices made by school authorities about what data to consider and how to best engage that data (Selwyn et al., 2022).

For many scholars, engaging students in data science education represents one possible response to the datafication of schools and other institutions. As Lee et al. (2021) argue, data science education emerges from three separate layers of social relations: student interactions with data, the sociotechnical tools and cultural practices that define the classroom and data science processes, and the socio-political forces (such as race, gender, and class) that dictate what data matters and how it is used. This layered understanding of data science education reveals the encompassing nature of the discipline, enveloping all relationships between individuals through data and to data within aestheticized artifacts. The emphasis on visual technologies in data science education also highlights this connection, as learning how to communicate with, make inferences from, and critique data visualizations represents an intractable part of any data science curriculum (Choe et al., 2015; Lee & Wilkerson, 2018; Lee et al., 2021; Segel & Heer, 2010; Tygel & Kirsch, 2016). Yet critical scholarship within data science education research often falls short of a critique of visuality. For instance, Tygel and Kirsch's (2016) definition of critical data literacy challenges educators to question how data was produced, in turn 'discovering non-neutrality in data: which aspects are exposed by data, and which are hidden' (p. 113). But, as Harouni (2015) attests, this kind of critique questions the content and not the form. Unveiling how data were collected does not equate to questioning the mathematical, statistical, and aesthetic processes that allow for data to be produced in the first place. Critical approaches to data science education can reproduce these shortcomings if they do not engage students in critically examining how data science positions certain subjectivities and ways of knowing as inherent.

To fully and critically engage with the visuality of data science education, Pangrazio and Sefton-Green (2020) advocate for a 'type of data literacy pedagogy . . . [that raises] awareness and critical understandings of data through creativity, visualisation and/or interactivity' (Pangrazio & Sefton-Green, 2020, p. 217). The creation of 'data-art', or creative artifacts that embody students' interactions with and interpretations of data through alternate aesthetic practices inspired by various artistic mediums, provides one example. The creation of data-art helps students find their voice, ask personally relevant questions about data, and see themselves within data sets and data collection processes (Acker & Bowler, 2018; D'Ignazio, 2017; Matuk et al., 2022; Stornaiuolo, 2020). Engaging students in the production of alternate data visualizations, data-art or otherwise, can therefore provide an opportunity to engage a critical praxis where students can critique the aesthetic regimes produced through data and its visualization while simultaneously challenging the aestheticization of data science curricula that occurs within schooling. This creates a theoretical connection between data literacy and visual literacy education via a shared interest in revealing and countering power relations through the production of new, meaningful, and empowering imagery (Knochel, 2013; Pangrazio & Selwyn, 2019). Critical visual literacy thus supports critical data literacy practices as students develop the ability to 'read against' rather than merely 'reading with' visual texts (including data visualizations) (Newfield, 2011). At a broader scale, critical visual literacy can provide a valuable lens to further challenge the visuality of schools. As shown here, this can occur in partnership with data science education, but can (and should) happen within other disciplines as well.

While previous data science education research has proposed educational praxes to critically engage students in the data practices of schools (Acker & Bowler, 2018; Lee et al., 2021; Pangrazio & Selwyn, 2019), a critical data literacy that attends to the personal data of students needs to respond to the aestheticization of and with data. Responding to this assertion, our work focuses on the use of data-art inquiry to challenge the aestheticization behind data visualizations. In doing so, we consider one component among many of generating a visual critique of data with students. While we acknowledge that even the most critical forms of data science education curricula cannot not resolve the issues that result from the reinscription of schooling within formal curricula, Pangrazio and Sefton-Green (2020) argue that the development of critical data literacy still represents a valuable tool in counteracting harmful datafication processes. We therefore build on this research to consider how intertwining critical visual literacy within data science education can further empower students despite these unresolved tensions.

Encountering visuality in middle school data science curricula

To further ground this argument, we turn towards empirical research into the creation and implementation of data science curricula. In this project, we employed a co-design methodology (Penuel et al., 2007) by working alongside four teams of US-based middle school math and art teachers over the course of one year to develop 'data-art inquiry curriculum units' (Matuk et al., 2022), or projects that simultaneously engaged students in data science and art making practices (see Table 1). Notably, we did not design these curricula with the intention of counteracting or interrogating the visuality of schools. Rather, our co-design work with teachers emerged out of an interest in simply using the arts to support students as they

Table 1. Research implementation details.

School	Location	School type	Topic	Data explored	Art medium	Number of Teachers Interviewed	Number of Students Interviewed
Ranier Academy	Medium sized Midwestern city	Public Charter	Chosen by students individually	Publicly available data visualizations collected by researchers	Dance	1 Math, 1 Dance	11
R. Crumb Middle School	Large East Coast city	Public	Friendship	National survey on teens and technology use (PEW research center), researcher generated visualizations from classroom survey	Comics	1 math, 1 visual art	3
Höch Public School	Large East Coast city	Public	Time use	National survey on time use, teens, and well being (American Time Use Survey)	Collage	2 math, 1 English Language Arts, 1 Librarian	0
Bresson Middle School	Large East Coast city	Private, Catholic	'Healthy Neighborhoods'	Publicly available data visualizations from Data2Go.nyc, student generated neighborhood maps	Photography	1 Math/English Lanague Arts, 1 Visual Arts/ Physical Education	4

develop data literacy, since previous studies have shown that arts-infused approaches to data science education often resonate with students who are traditionally marginalized from the discipline or feel intimidated by data (D'Ignazio, 2017; Hannigan et al., 2023). To this end, we acknowledge that our pedagogical approach does not represent a systematic solution to inequities within data science education, as some students may gravitate away from or lack access to this type of curriculum, but instead illustrates one humanistic approach to engaging students within this discipline among many. Each unit involved students responding to personally/socially relevant driving questions by critically interpreting real-world data sets (both pre-existing and student generated) and communicating that analysis through an artistic medium. While these units did incorporate a range of subject specific goals related to various artforms, they all centered on engaging students in critically examining data collection and analysis processes through the creation of alternate visual representations of data. In doing so, we draw inspiration from the creative data science pedagogies described by Pangrazio and Sefton-Green (2020) to help students develop critical data literacy skills (Pangrazio & Selwyn, 2019; Tygel & Kirsch, 2016).

To better understand the experiences of teachers and students within these curricula, we conducted semi-structured post-implementation interviews with all four groups of teachers and students from three schools (with students from one school not participating due to IRB restrictions). We then analyzed recordings and transcriptions through an open and iterative approach to both descriptive and pattern coding (Saldaña, 2015), focusing on moments where participants discussed the various aesthetic technologies in the curricula and their relationships to the data. In doing so, we produced a series of themes (asserting the right to look, aesthetic tensions, and producing countervisuality) that speak to the role of visuality and countervisuality within data science education. Although we had not intentionally designed the study to focus on the visual, the responses from the participants revealed how aestheticization processes shaped the subjectivities of students and the possibilities of learning within these educational contexts. This analysis therefore speaks to the empowering potential of using alternative aesthetic technologies in schools while also acknowledging the reinscription of power relations at the heart of educational aestheticization despite this potential.

Asserting the right to look through critical data literacy

As soon as students in this study began to work with data, they began to claim the right to look. In one example, a participating seventh-grade teacher noticed that students rejected data that did not speak to their lived experience. For this project, the teacher engaged students in exploring publicly available data on time usage before they interpreted/responded to that data through the creation of digital collages (see Figure 1).[1] When looking at tables that showed how people use their free time, a portion of the curriculum that preceded student art making, the teacher noticed that some students

> would say, 'well, I don't do this, my parents don't do this'. One of my students made a comment that there were all these categories and she was like, 'my mom doesn't do any of this, my mom just goes to work. She works all day. This isn't real data'. For her, it wasn't really real.

Figure 1. Student example of a data collage.

Rather than questioning how analysts collected the data or what the data represented, the student's claim that the data 'wasn't real' speaks to a critique of data's visuality. By removing her lived experience, the data loses its claim to truth as the student reasserts their right to look, to see themselves in the data before being removed. Beyond merely exemplifying the role that the right to look plays within curricular artifacts, the quote challenges teachers to understand their role in helping students voice and manifest that claim.

Aesthetic tensions between traditional data visualizations and data-art

Beyond claiming the right to look, we also found students grappling with related aesthetic tensions embedded within traditional data visualizations (graphs, tables, etc.). For example, one eighth grade class worked together to explore the topic of 'healthy places', examining municipal and self-collected data about their neighborhood related to all forms of wellbeing (mental, physical, cultural, etc.) to better understand the challenges and successes of their community in producing a nurturing place to live. Students used photojournalism to communicate their interpretations of the data while simultaneously producing another qualitative data set. Leading up to this process, students created tables and graphs that showed correlations between various aspects of data collected in their neighborhoods. Although teachers asked students to create these visualizations in response to student-generated research questions, one student described their process as follows: 'for my graph, I chose to [compare] high school enrolment and average life expectancy. I just chose what I thought would represent the line best. I chose to use high school enrolment because I thought it would make for a good graph'. This description points to a particular way in which aesthetic considerations drive students' work with data, reinforcing the importance of visual conventions described by Kennedy et al. (2016).
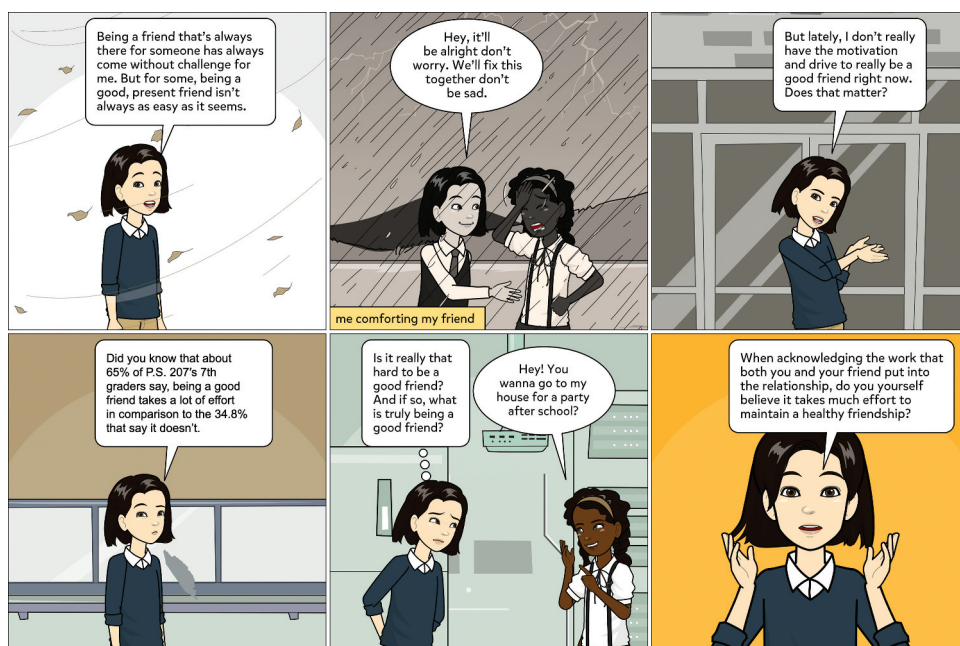
Figure 2. Student example of a data comic.

The student, in essence, decided to explore these variables because of what they thought the graph would eventually look like (i.e. a straight line with both life expectancy and high school enrolment values increasing simultaneously) and not because of an interest in uncovering the relationship between variables. Data aesthetics then in part drive the analysis as the student's intentions lose influence within the visualization.

In another project we developed with seventh-grade math and art teachers, students interpreted survey data collected by researchers from their peers about friendship and compared this new data set to a national survey of teenagers' technology use. Students then used this data to create comic strips inspired by their interpretations of both sets of data, developing skills and knowledge related to data science and comics as a narrative art form (see Figure 2). Reflecting on the project, the math teacher raised an issue with the lack of statistical methods or inferences within students' comics. As she explains,

> the statistical measures, to me, that's the mean/median/mode. A lot of them are just putting in the percentages and what the graph showed. The comic to me is more artistic. I don't know if it has enough of the math in it. I would be curious [to see] a comic from the same graph but a completely different inference that corresponds to the one that they already have.

This critique reveals that the math teacher felt that the comics needed to be more directed towards traditional approaches to data science rather than new approaches to contextualization or meaning making with data. In this interpretation, the comics lose their mathematical value as the aesthetics of the comic shift

In this image I took a photo under the train station. Usually, there is a lot more litter, but they had just cleaned the streets so I couldn't capture that. You can see the stores and mini restaurants on the side. My statement was to tell that during the day the area may seem nicer but it can get worse and worse and much more dangerous at night. We have a high crime rate and that may be because of the quality of the area.

Figure 3. Student example of data-based photo journalism.

away from the aesthetics of the data (becoming 'more artistic'), indicating the curricular importance of data aesthetics even in this non-traditional visual arts context.

Producing countervisuality through data-art

In navigating these aesthetic tensions, data-art provided a means for students to reclaim the right to look beyond simply critiquing other traditional data visualizations and proved foundational for the conceptualization of their work. In the classroom where students explored public health data from their neighborhoods through photojournalism (see Figure 3), one student recognized the opportunity created by this project to speak to a fullness not contained in the graphs:

> taking the photos, I wander the block looking for areas that are a bit nicer and have more vibrant colors. Somewhere nice, but you can tell it isn't the nicest area. You have all these nice stores, you have the train station, but you also have this litter, so having those contrasting things show how the community really is together as a whole ... I think it tells people who don't really understand what it really is for us, to help them learn about how we live every day and to show them that we still work together. I think if you just had [the graph] you wouldn't really understand [our community] completely.

Embedded in the student's description, there exists 'a claim to a subjectivity that has the autonomy to arrange the relations of the visible and the sayable' (Mirzoeff, 2011, p. 474). The graph this student refers to produces a reality that cannot speak to the fullness of their community ('how the community really is together as a whole'), but this student reclaims the right to look at that fullness and embodies that right within her photography, thus aligning with Knochel's (2013) understanding of critical visual literacy as both reading against existing images and recognizing/acting on one's position as an image-maker. Where the original graph reinscribes a dominant visuality, one that reifies what is constructed as true about their neighborhood, the student's photography produces a countervisuality that challenges not only what the data says but the visuality of data science.

While the creation of art can allow students to reclaim the right to look and redistribute the regime of the sensible, this outcome remains far from assured. In the classroom that used comics to communicate and interpret student collected data on friendship, the presence and influence of traditional data visualizations used in this

curriculum occasionally undermined art's ability to allow students to speak and be heard. In essence, reiterating what the data said became more important than using artistic production to develop new interpretations or observations. When the math teacher working on this project asked students to describe how they incorporated data into their comics, she describes how students verbalized this tension:

> [One student said] 'I showed data of the percent of people who find [making friends] easy', but how did you show it? In the visuals that you chose, can you explain why you made certain decisions? [In their reflections,] I wanted them to reiterate what they stated in their comic to describe how they incorporated the data. [One student] wrote something so simple, like, 'I used data from the graphs by using statistics'. What do you mean by that? I don't think they really knew how to answer the question.

In this example, the students use the comic as a vehicle for reporting decontextualized numerical values. How they interpret the data, what they claim outside of that data, or what implications they see in the data do not exist within this work. The comic therefore amplifies the (aestheticized as trustworthy) reality produced through the original visualization.

A similar process occurred in our work with one school that focused on student-choreographed dances based on their explorations of data. In this iteration of the study, students chose topics they wanted to explore. We then curated a series of data visualizations for students to consider as they researched their topic. Students responded to this data by making claims based on this data and choreographing dances to communicate and further explore these claims (see Figure 4). However, as we discussed the choreography with students, we often found that traditional data visualizations dominated the aesthetics of the dance and drowned out the interpretations of students. One student described their creative process of incorporating data into their dance as follows:

> We would physically shape out the graphs, like actually show the ups and downs of it . . . my bent legs are showing how the graph is kind of jagged. And then I go to this [dance move] that is showing how [the graphs] smoothly line up towards the end.

Instead of asserting their own right to look, this quote shows that the aesthetics of the pre-existing data visualizations spoke for the students. The over reliance on the aesthetic components of the data (i.e. the changing slope of the graph) overshadowed the knowledge they could construct from interpreting and contextualizing that data (i.e. what those changing values mean in context or illuminate within the real world). In turn, this approach to creating data-art reinscribes the hierarchical relationship behind data
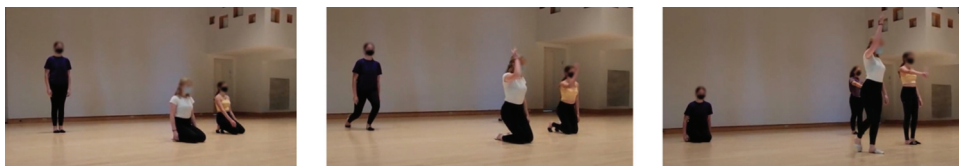

Figure 4. Screen shots of students' data-based dance.

science as a visual complex (Decuypere & Landri, 2021; Ratner & Ruppert, 2019) rather than critiquing it.

However, the students working on this project did not solely replicate the shapes of graphs. In describing a dancer's final presentation that focused on animal extinction, one of the teachers explained this difference as follows:

> She said something about doing some tricks where I curve my back because the graph is curved. But it got deeper. I asked, 'what were the main causes that you noticed throughout the graph of animal extinction and how was that connected into your dance?' And she said, 'the main causes were habitat degradation or change or exploitation. We researched those further and realized that those are all human things, things that we are doing. And we represented that by showing relationships between humans and animals, that we are not respecting them'. So there were a couple different movements showing how humans are negatively treating animal spaces. That was beautiful. Not just, 'oh, I'm curving my back because there's a curve in the graph'.

In this quote, the teacher speaks to both the dominance of data aesthetics and the ability of students to assert their right to look. At times the dancers reproduce the aesthetics of the graph, but in other moments they found an opportunity to assert their own interpretations. Rather than just communicating the data, dance as an alternate approach to creating data visualizations helped them develop a contextualized and situated understanding of the data that allowed for a more personal connection to the topic (representing 'things we are doing' in 'animal spaces'). In turn, the student reclaimed the right to look as they saw themselves in the data and incorporated information, analysis, and interpretation beyond the data visualizations presented to them by teachers and researchers.

Conclusion

As those working within visual cultures and visual literacies research attest, a critical approach to education must involve an interrogation of visuality and the aesthetic technologies that produce curricula, school disciplines, and other institutions of learning (Errázuriz, 2019; Gil-Glazer, 2020; Mirzoeff, 2011). Because our social world emerges through the production of visuality and the circulation of images (Gil-Glazer, 2020; Knochel, 2013), critically engaging visuality and aesthetic technologies in the classroom represents a crucial and often overlooked element of most disciplines. While we acknowledge that situating this work within the context of the school can reinforce the assumed nature of education's visuality, inscribing curricula with 'a theory for critiquing its own tools' (Harouni, 2015, p. 69) can still provide students with a means to reclaim the right to look in the face of official (and aestheticized) curricula and knowledge formations. In line with Gil-Glazer (2020), we argue here that providing students with the opportunity to create their own aesthetic artifacts that embody their own ways of knowing provides one avenue for this reclamation to occur. In doing so, students can rearrange the regime of the sensible by critiquing the assumed inevitability of education's aestheticized outcome and asserting their own place within this visual complex.

However, reclaiming the right to look cannot occur without first intentionally pushing back against the visualization of schools. While our analysis shows that students asserted the right to look and saw themselves within the data included in our co-designed

curricula, the aesthetics of this data also regularly undermined students' ability to critically challenge the embedded epistemological and ontological assumptions described by Walford (2020). Although some students did eventually find opportunities to read against data visualizations, data science as a visual complex restricted students' ability to do so. We therefore argue here that any critical approach to curriculum design must contend with the visuality of schools and the aestheticization processes embedded within that particular discipline. This inherently involves enacting a challenge to the aestheticization processes that produce the official bodies of knowledge that define school disciplines. Within data science education specifically, critical data literacy curricula need to extend beyond merely critiquing methods of data collection and analysis to consider other ways of knowing and being outside of data science itself that, in conversation with data, allow students to construct a more holistic understanding of the world around them. While any number of interdisciplinary approaches to education may accomplish this goal, our study reveals that arts-infused pedagogies provide one (not necessarily guaranteed) avenue for students to reclaim this right to look. Through critical, visually informed pedagogies, students can claim space within the distribution of the sensible, build their identity as an architect of the real, and access their autonomy within aesthetic landscapes.

Note

1. All students consented to their artwork being reproduced in publications.

Acknowledgments

Disclosure statement

Funding

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