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Re-Shape: A Method to Teach Data Ethics for Data Science Education

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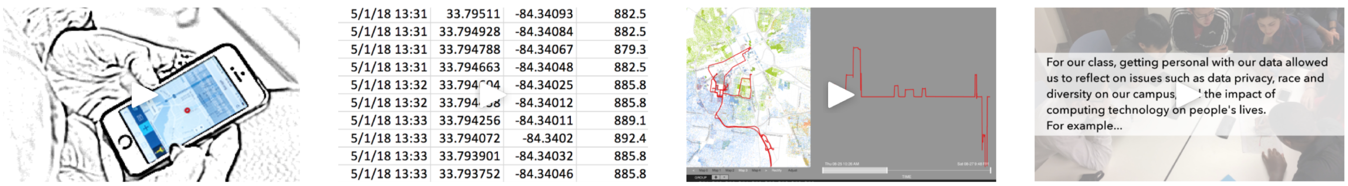

(1) Personal Data Collection (2) Data Processing (3) Collaborative Visualization (4) Reflection

Figure 1. Summary of Re-Shape method. Re-Shape builds upon the idea of cultivating care through open-source tools and activities that allow students to collect, process, and visualize their physical movement data in ways that support critical reflection and coordinated classroom activities about data, data privacy, and human-centered systems for data science.

ABSTRACT

Data has become central to the technologies and services that human-computer interaction (HCI) designers make, and the ethical use of data in and through these technologies should be given critical attention throughout the design process. However, there is little research on ethics education in computer science that explicitly addresses data ethics. We present and analyze Re-Shape, a method to teach students about the ethical implications of data collection and use. Re-Shape, as part of an educational environment, builds upon the idea of cultivating care and allows students to collect, process, and visualize their physical movement data in ways that support critical reflection and coordinated classroom activities about data, data privacy, and human-centered systems for data science. We also use a case study of Re-Shape in an undergraduate computer science course to explore prospects and limitations of instructional designs and educational technology such as Re-Shape that leverage personal data to teach data ethics.

Author Keywords

Data ethics; care ethics; data science education; information visualization; data literacy; data privacy; computer science education; re-shape; interaction geography slicer

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CSS Concepts

Human-centered computing ~ Human computer interaction (HCI); Visualization; *HCI theory, concepts and models; Visualization application domains*

INTRODUCTION

From IoT infrastructures to health systems, data has become central to the technologies and services that HCI designers design and develop. Moreover, the ethical use of data in and through these technologies should be given critical attention throughout the design process. For example, as O'Neil provocatively demonstrates, when the ethical use of data is not central, algorithms and data science systems can be used as "weapons of math destruction" that promote inequality and undermine democratic decision-making [36]. For many years, HCI designers and researchers have acknowledged the significant need for research to inform ethical design practice [30] with some recently proposing novel concepts such as ethical mediation to guide future design education and formal educational practice [15]. Likewise, within the computing education community there has been a recent surge of work focused on teaching ethics in ways that are applicable and scalable across CS education contexts [1, 6, 8, 12, 53]. However, there is little ethics education research in computer science that explicitly addresses data ethics.

In this paper, we build on recent calls for pedagogical research on design instruction as a foundational area of inquiry for HCI [60] and suggests that teaching data ethics should be a more central issue for HCI researchers, who are uniquely positioned to develop instructional designs and educational technology to teach data ethics. Particularly, we present and analyze Re-Shape, a method to teach about the ethical implications of data collection and use. Re-Shape, as part of an educational environment, builds upon the idea of *cultivating care*, a feminist approach to ethics that aims to engage students with a concept of responsibility to the other, interdependence, and attentiveness to vulnerability and inequality in the socio-technical systems we design. Re-Shape utilizes existing open-source data collection and processing tools, a version of a geovisualization tool called the interaction geography slicer (IGS) that we have built and also make open-source in this paper, and a set of learning activities that bring feminist care ethics to undergraduate computer science courses. These tools and activities allow students to collect, process, and visualize their physical movement data in ways that support critical reflection and coordinated classroom activities about data, data privacy, and human-centered systems for data science. Particularly, students are confronted with the idea that they are the "other" within systems that use and may exploit personal data and are prompted to think about what care they desire or demand from these systems.

We disseminate this method of teaching data ethics through a web platform that we also make available in this paper and will continue to expand in the future. Currently, this web platform includes instructional videos for teachers and students, links to activities and tools, examples of Re-Shape used in different classrooms, and class discussion questions, guides, and assignments. This platform is available at: **https://www.benrydal.com/re-shape**

In this paper, we also contribute a case study of Re-Shape in an undergraduate computer science course to explore prospects, limitations, and next steps of instructional designs and educational technology that leverages personal data to teach data ethics. Altogether, our work extends recent work in HCI that translates an ethic of care to pedagogical contexts [45] by providing students with opportunities to make choices with and through data that support chosen values and enhance modes of caring [62].

We begin by reviewing relevant research. After this, we provide an overview of a multi-year design-based research project that led to the development and current design of Re-Shape. Using qualitative methods, we then conduct an analysis of Re-Shape using empirical data from a computer science ethics course with 40 undergraduate computer science students at a large, public research-intensive university. Findings from this analysis subsequently frame a discussion where we explore the prospects and limitations of instructional designs and educational technology that leverage personal data to cultivate an orientation to care in students' future professional work with data.

THEORETICAL FRAMEWORK

Embedding Ethics in Computer Science

Our work is informed by a growing body of research in computing education concerning computer ethics. This work is motivated by widespread calls for computer scientists to better engage with the ethical dimensions of their work and is increasingly supported through conferences such as the ACM conference on Fairness, Accountability and Transparency as well as initiatives that span academia and industry such as the Mozilla Foundation's Responsible Computer Science Challenge, an effort to integrate ethics with undergraduate computer science training in innovative ways [29].

In particular, we draw from researchers and teachers who are developing new and meaningful approaches to embedding ethics in computer science classrooms. These approaches typically focus on the development and use of (a) case studies or modules designed to fit specific CS content areas (e.g., computer vision, machine learning) [6, 8, 46], (b) creative approaches to teaching computer ethics, for example, through science fiction, autobiographies, embodied activities, or project-based learning approaches [1, 4, 53], (c) game-based activities such as role-playing games designed for large computer science courses [29], and (d) activities that leverage ACM's Code of Ethics.

Though this body of work remains in its infancy, Skirpan et al. summarize one theme important to our work in this paper: Namely, "Discovering novel and engaging methods for training responsible engineers that do not sacrifice learning technical skills will continue to be a central problem for CS curriculum design" [53]. Equally important to our work, there is little research on ethics education in computer science that explicitly addresses data ethics. Our work in this paper builds on existing calls for pedagogical research on design instruction as a foundational area of inquiry for HCI [60] and suggests that teaching data ethics should be a more central issue for HCI researchers, who are uniquely positioned to develop instructional designs and educational technology to teach data ethics.

Care Ethics & HCI

Many of the previously reviewed approaches to embedding ethics into computer science classrooms typically teach ethics at the scale of individual decision-making and communicate ethics through abstract concepts of rights, virtues, or consequences (e.g., utilitarianism, Kantianism, virtue ethics, social contract theory). In contrast to such approaches, our work in this paper builds upon *an ethic of care*. An ethic of care in HCI is a feminist approach to ethics that is concerned with concepts of shared responsibility and attentiveness to the interdependent nature of inequality and vulnerability that are embedded in our socio-technical systems [13, 20, 21, 28, 56]: Notably, an ethic of care finds being in relation, not individualism, as ontologically basic to ethical decisions [34]. More than just concern or thoughtfulness for others or a certain issue, care brings a notion of belonging or attachment as well as responsibility to decision-making that extends beyond oneself [34, 58]. Seminal feminist science and technology theorist, Puig de la Bellacasa, writes in *Matters of Care* that in order to think with an ethic of care, we must engage in "thinking-with," which she describes as a relational way of thinking that creates new patterns and layers of meaning out of previous multiplicities [39]. This activity of "thinking-with" is what we seek to create through Re-Shape; using Re-Shape, students engage in thinking-with data collection and visualization technologies, their personal movement data, other students, historical legacies of oppression, etc.

Thus, we situate our work within the growing body of work in HCI concerned with examining the relation between an ethic of care and HCI (e.g., to design systems that hold central notions of identity and the self, equity, empowerment, diversity, social justice, agency, and fulfillment) [see 57]. We were particularly inspired by recent efforts in HCI to translate an ethic of care to pedagogical contexts through service learning courses for graduate ICT programs [45] as well as work highlighting the need to develop an ethic of care in the practice of data science by providing students with opportunities to make choices with and through data that support chosen values and enhance modes of caring [62]. Altogether, our work in this paper translates an ethic of care to teach data ethics in ways that support critical reflection and coordinated classroom activities about data, data privacy, and more broadly, human-centered systems for data science.

Leveraging Personal Data to Support Learning

Our effort to translate an ethic of care to teach data ethics through Re-Shape also draws from a growing body of research that suggests leveraging data about one's own activity or "personal data" provides powerful ways to engage learners across a variety of disciplines, including computer science. For example, as Lee describes within a statistics education context, "Personal activity data (PAD) obtained from activity trackers has the potential to stimulate thinking about statistics in a way that other forms of data, even other real data, cannot. Because the data come from the students' own activities, they are intimately familiar with them and able to reason about patterns and variations in the data based on their own experience" [23, 24, 41, 47, 63, 64]. Similarly, Hautea, Dasgupta and Hill illustrate within a social computing context novel designs for children that engage youth in critical data science by leveraging public data about children's own learning and social interactions online [16].

Our work leverages physical movement data (e.g., GPS traces collected from cell phones) to support students' personal reflection about their daily lives in ways that are inspired by Deborah Lupton's scholarship on sociomaterial configurations of personal and digital data [26]. Namely, she contends that personal data is agentive and relating to and making sense of our own data provides us with alternative ways of knowing about and reflecting on our world. We also draw from work that highlights how new digital mapping and dynamic, geovisualization tools provide ways for learners "to get personal with data" or more specifically, link personal reflections about their own data with broader societal issues represented by aggregate data in forms such as interactive, digital maps [18 also see 37, 42, 43, 44, 55]. Taken together, our work leverages personal data and develops new tools that can support teaching data ethics in ways important to the technologies and services HCI designers design and develop.

RE-SHAPE DEVELOPMENT & DESIGN

Development

We developed Re-Shape through a multi-year design-based research project that initially began through work with pre-service social studies teachers (i.e., teachers in training) at a small, private research-intensive university teacher preparation program. This early work aimed to develop tools and activities to support primary goals of the National Council for Social Studies [33] regarding citizenship education. These goals included introducing pre-service teachers to geospatial technology and instructional designs they could use to teach public history in ways that used data to foreground anti-deficit approaches to teaching public history that allow students to explore how places and communities have multi-faceted meanings and histories [33, pg. 181]

As part of this work we conducted a series of pilot studies embedded in teacher education coursework and programming at this university. These pilot studies iteratively tested and evaluated a variety of existing and new (developed by us) geospatial data collection and visualization tools and activities. In particular, we evaluated to what extent particular tools and activities provided pre-service social studies teachers with opportunities to learn about and reflect on how they could incorporate emerging geospatial and data science technologies to teach students how public history is not simply a set of facts but rather involves contested and multi-faceted meanings and histories [27 also see 9, 17, 32]. For example, this relational perspective on teaching public history entailed providing teachers with opportunities to study their own physical movement and other forms of personal data such as social media data over large-scale open data sets about their local urban environment in order to explore their own personal relations to the multi-faceted meanings and histories of particular places and communities. During these pilot studies we collected a variety of data to inform our work including pre/post surveys, detailed audio and video data of classroom activities with pre-service teachers, and assignments submitted by teachers.

Conversations with computer science faculty and our own engagement with the Mozilla Foundation's Responsible Computer Science Challenge highlighted the broader applicability of Re-Shape to ethical and responsible computer science education and efforts to translate an ethic of care into HCI educational contexts [45]. As a result, we began further evolving, testing, and implementing Re-Shape in university computer science and HCI classrooms at a large, public research-intensive university across a variety of courses. In particular, we explored how Re-Shape could provide highly technical, data-driven, and experiential learning opportunities through which students were confronted with the idea that they are the "other" within systems that use and may exploit personal data and were prompted to think about what care they desire or demand from these systems. We iteratively tested and evolved the design of Re-Shape in four human-centered computing courses, one of which was an ethics course required of all computer science majors. In two of these iterations we collected pre/post surveys, detailed audio and video data of classroom activities, and assignments submitted by students. Moreover, our future plans over the next year include collaborating with four other universities to embed Re-Shape in social studies and computer science classrooms.

Design

As summarized previously, Re-Shape is a method to teach data ethics that is comprised of 4 steps: (1) Personal Data Collection, (2) Data Processing, (3) Collaborative Visualization, (4) Reflection. In the following, we describe in detail each of these four steps and the design of open source tools and activities students engage with in each step. These steps are typically completed by students over two separate class periods to provide enough time for students to collect their personal data, which in this case is their physical movement data. However, as we discuss at the end of this paper, this method is very flexible allowing teachers to adapt this method (e.g., by shortening or lengthening activities) in ways that best fit their own teaching and classrooms.

Step 1: Personal Data Collection

Students begin by downloading an application on their smart phones to record their physical movement as a GPS trace. Currently, we strongly recommend and link to a free, award winning, and established application that is available for iPhone/Android called ViewRanger™ developed by Craig Wareham and Mike Brocklehurst. In contrast to the majority of other similar tools (e.g., running or jogging apps, other custom research tools), ViewRanger is intentionally designed a) to make data collection visible and experiential (i.e., users decide when to use the application and are aware when it is running on their phones) and b) to allow users to own, download in various formats, and control their data. As we later illustrate, these design features are critical to student learning.

After downloading ViewRanger, students record at least 2 days and if possible 1 full week's worth of their physical movement data. This recording can be continuous or students can selectively choose when to record their movement. After they have recorded their movement, students save their movement as tracks in ViewRanger. We recommend students save and begin a new recording or track each day they collect their data. These tracks can then be uploaded or synced within the application to ViewRanger's online platform where students can subsequently download and view their tracks as GPX files, a common data format for reading/encoding geospatial data.

Step 2: Data Processing

Before or during a subsequent class period, students use a well-known, free platform called GPS visualizer developed by Adam Schneider to convert their GPX files from ViewRanger into a more standard comma separated values (CSV) file. GPS visualizer provides open, powerful, and straightforward ways to process and convert many types of geospatial data. By converting their physical movement data to tabular data, or a CSV file, students who are unfamiliar with geospatial data are able to discern meaning from the data, prior even to any visualization. Typical geospatial formats such as GPX and shapefiles do not offer the same level of human readability that tabular data does. Moreover, students are also able to read and view their data in many standard programs such as Microsoft Excel. Importantly, as our work later in this paper will demonstrate, these data processing experiences are novel even for undergraduate computer science students who have rarely viewed their personal data in a machine-readable file format previously.

Step 3: Collaborative Visualization

A central aspect of Re-Shape is a class devoted to collaborative visualization of students' physical movement data (e.g., typically done in small groups of 5-7 students). Prior to our work, existing tools to support the collaborative and dynamic visualization of physical movement data were either quite limited or too expensive for classroom contexts. For example, ESRI products, while extremely powerful, did not support the types of dynamic, collaborative, and interactive visualization important to our work while expensive space-time cube systems such as GeoTime were impractical for classroom use. Thus, we developed a dynamic visualization tool to support collaborative visualization of physical movement data. This tool, adapted from our prior work in museum as well as classroom contexts, is a simplified version of the interaction geography slicer (IGS) [47, 48, 49, 50]. We make this tool available as both a web and desktop application that can be visited/downloaded through the Re-Shape web platform. The web application, developed by Cody O'Donnell, provides ways for teachers and classes to immediately use the IGS while the desktop application uses the Processing Programming Language and Unfolding Maps Library [31, 40] and supports an expanded set of visualization operations and larger data sets.

This version of the IGS allows students a) to import students' physical movement data from Step 2, b) view their data not only over space but also over time and in multiple 2D and 3D representational forms, c) study their movement over different interactive digital maps and photographs of maps (e.g., historical urban planning maps) that they can import and quickly “georectify” (i.e., scale to/superimpose on an interactive digital map) within the IGS, and d) dynamically interact with their physical movement data in a variety of ways (e.g., animate, rescale, group/select). Figure 2 aims to convey some of the dynamic and collaborative qualities of a class using the IGS.

Figure 2. A class uses the interaction geography slicer (IGS) to collaboratively visualize and interact with their physical movement data over different digital maps and in multiple 2D and 3D representational forms.

Figures 3 and 4 provide screenshots of the tool in use that more specifically highlight its technical features. For example, in figure 3, a student has displayed their movement as a red path on the left over a racial dot map (color on the map indicates race, see [5]) and on the right over a timeline. In the timeline view, the y-axis corresponds to the vertical dimension on the map. Moreover, the student has selected a period of time (approximately Thursday-Saturday) on the timeline and thus, only movement during that period is shown in both views. Figure 4 shows the same students’ movement in the IGS in a 3D space-time cube format where time extends upwards. For example, tall, vertical lines of movement in space-time indicate no movement (e.g., often when this student is sleeping over this 3-day period). Notably, students also visualized and interpreted their movement over a 1938 map of redlined districts to consider historical legacies of exclusion. Together, these figures also show aspects of the IGS’s interface. For example, the bottom left of each figure shows how multiple map layers and student movement paths are organized as well as group tabs that can be used to group movement paths in separate tabs for comparative analysis.

Prior to using the IGS in class as part of Re-Shape students should read a framing article to help center their analysis and discussion. For university students, we recommend Kwan’s work that re-presents the post-September 11 experiences of Muslim women in the USA using critical geography perspectives [22 also see 25, 54] as well as Lupton’s theory-building text on how encounters with personal digital data alters how we know, sense, and perceive out in the world [26].

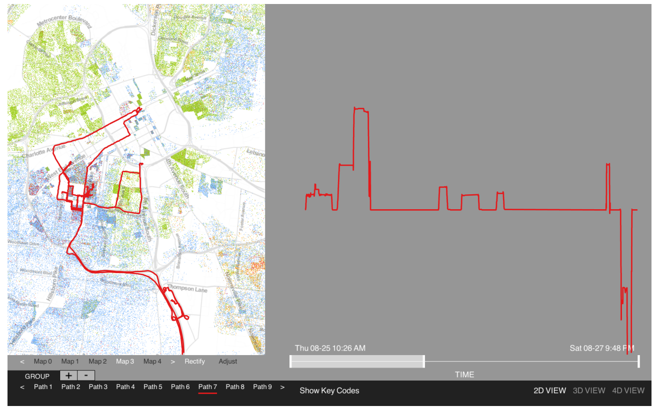

Figure 3. Screenshot from the IGS showing a student’s movement (red path) on the left over a racial dot map (color on the map indicates race) and on the right over a timeline (approximately Thursday-Saturday), with the vertical axis corresponding to the vertical dimension on the map.

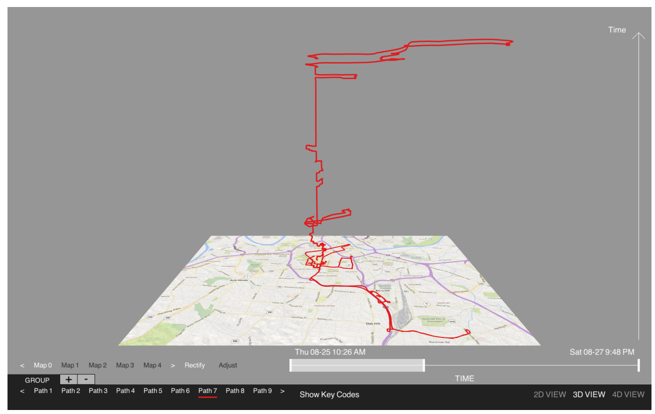

Figure 4. Screenshot from the IGS showing the same student’s movement in a 3D space-time cube where time extends upwards (e.g., straight lines extending upwards in time indicate when the student is not moving).

Additionally, students who are willing, share their data through a private file sharing service such as Firefox Send (https://send.firefox.com) with their groups and/or teacher (i.e., so that all physical movement can be viewed from a single computer either as a class or more typically, in small groups). We emphasize that teachers should never require their students to share their data or visualizations of their data with others during these activities. In our work across multiple universities, the majority of students are excited about sharing and visualizing their data together with only a few in each class “opting out.” All should be able to participate in activities whether they choose to share or not share their data.

The prior descriptions highlight the flexibility of the IGS and also how teachers can develop their own instruction around the tool (e.g., teachers can have students find or create their own base maps and import them into the IGS as interactive map layers).

Step 4: Reflection

Following a class centered around the collaborative visualization of their physical movement data in the IGS, students reflect on their personal data and experiences. This can be done either through a subsequent class discussion or through an assignment. We have developed assignments and sample discussion questions for different disciplines that are available on the web platform we make available in this paper. For example, the discussion questions for computer science include: Describe what it felt like to collect and be able to see and interact with your own physical movement data? What does your physical movement data tell you about you? What things had power over your movement - increasing your mobility or decreasing it? What is your relationship to your local geographic context? What other forms of data about you might be more informative and why? Finally, to what extent are you your data?

RE-SHAPE CASE STUDY

In this section we demonstrate the impact of Re-Shape on student learning during an undergraduate computer science ethics course with 40 computer science students. To study Re-Shape, we collected detailed audio/video records of classroom activities. Students also provided feedback through pre/post surveys, and assignments served as a third, important source of data. Our analysis in this section focuses on student assignments, which responded to the questions described above in step 4. While other data continue to inform our work in important ways (e.g., advancing the IGS interface), assignments provided the most meaningful and visible way to understand and assess students' learning and experiences as a result of Re-Shape.

As part of the assignment, we also encouraged students to create a map-based representation using tools of their choosing including basic visualization tools provided by ViewRanger (at this time, we had not made the IGS available beyond class activities). We have included a few students' representations in figure 5 to demonstrate the types of representations students produced.

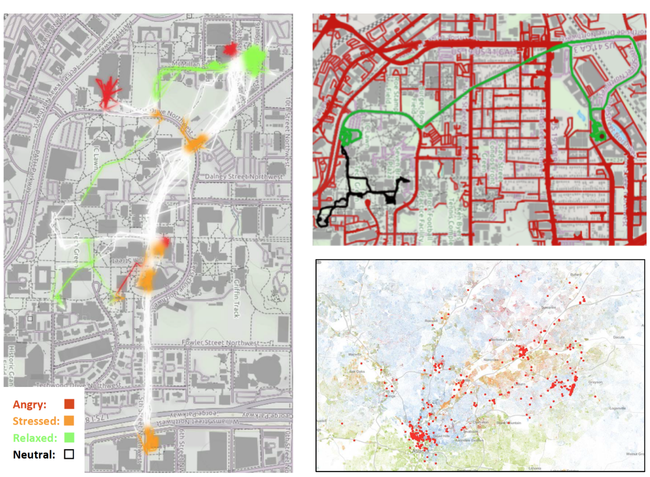

Figure 5. Representations from 3 student assignments.

For example, the left image in the figure shows a student highlighting their movement across campus using color to indicate where on campus they feel particular emotions. The top right image shows the variety of paths one student felt they could take to travel across their university campus in red and one green path that represents the path they typically take due to safety concerns. The bottom right image shows a student plotting data from their Google location history over a racial dot map of their local environment.

We used a grounded theory approach [7, 14] to analyze and assess student assignments for evidence of learning. This approach was appropriate both with respect to the types of data we collected and also to our goal of developing better questions to inform future work in this new design space. Our analysis focused on developing broad categories from this data. We met weekly as a research team to iteratively analyze this data and agree upon codes and categories from this data. Our coding focused on our interpretations of how students experienced and learned through Re-Shape. Initial questions that guided our analysis included: What types of experiences have CS students had around personal data? What types of reflections does physical movement data support? How do visualizations of mobility support students to reason about their own data and consider an ethic of care in their future professional work? To what degree does data collection and/or visualization enhance students reasoning about their own data and important ethical or societal questions? Do students develop a notion of an ethic of care through these activities? Importantly, our analysis of learning was less focused on content acquisition and more focused on illustrating the quality of students' experiences and how students' stance towards data and identities or their attentiveness to vulnerabilities that may be exploited through data-based technology may have changed subtly or significantly through Re-Shape. Put differently, our analysis of learning is informed by socio-cultural and social practice approaches to studying learning that align with our theoretical framework and approach to integrating an ethic of care in a teaching context.

ANALYSIS & FINDINGS

Four primary themes/categories about student learning through Re-Shape emerged from our analysis of student assignments.

Theme 1: Novel Data Experiences

We typically assume computer science students have intimate and detailed knowledge about data. However, throughout our analysis of student assignments students consistently described how their experiences with data through Re-Shape were novel.

Sixteen students explicitly emphasized that they had previously never collected or studied personal data. For example, one student wrote, *"Collecting data about myself was nothing short of revealing. I do not actively monitor any data related to myself such as number of steps I take in* *a day or hours of sleep so this was a novel experience to me."* Similarly, another student wrote, *"Gathering and reflecting on my location data in class was something I experienced for the first time. Even though my location data is publicly available through applications like google maps, facebook, weather channel and many many more; it was the first time that I got to talk about it and reflect on it face to face with other people."* Still further another student wrote, *"Prior to collecting my data in this class with ViewRanger, the closest I had ever come to gathering any of my own data was fitness tracking with an Apple Watch. However, this was the first time I actually took a deep dive into my own data as I had never taken a second look at my fitness statistics despite religiously collecting it."*

In contrast, seven different students described how they had collected personal data but had never visualized personal data. For instance, as one student described, *"Gathering data about myself felt inconsequential at first as I already use countless technologies that rely on my sharing personal information daily. Once I was able to visualize my movements over that one day, however, I felt like these few numbers latitude and longitude pairs on a map revealed so much about me. I felt able to scrutinize my life in a very intimate, personal way."* Similarly, as another student described, *"I have become so entrenched in modern technology that collecting the data about my movement felt rather natural. I am always used to Google Maps tracking my location, but I will say seeing my daily movement was eye-opening as it gave me a broad reflective perspective on myself."*

The majority of other students described how studying their data in collaboration with their classmates provided new experiences that were critical to their own learning. For example, as one student wrote, *"Initially upon reviewing my movement data, I thought nothing of it. It seemed like a harmless exercise that did not reveal much about me. The discussion that my group and the class had changed how I thought about my personal data."* Similarly, another student shared, *"Initially, I found that analyzing my data did not result in any thought-provoking insights. However, after I identified patterns in the data, compared it with other students' data, and generated my visual, I realized the data revealed a great deal about me."*

In summary, 37 of 40 students found their experiences with data through Re-Shape novel to differing degrees. The 3 students who did not find this assignment novel collected a very small amount of personal data, which highlights the potential challenges associated with approaches and assignments that leverage personal data collection. Likewise, our analysis suggests Re-Shape provided experiences that a) allowed students (future computer science professionals) to directly confront personal data for the first time and b) disrupted students' conventional views about data in ways that provided them with new understandings about the quality and detail of personal data collected through applications they use in their daily lives. Altogether, this theme demonstrates Puig de la Bellacasa's concept of thinking-with, as students used Re-Shape to deepen their understanding and experience of data.

Theme 2: Empowering vs. Unsettling Data Experiences

Re-Shape was intentionally designed to provide learners with ownership of their personal data and opportunities to safely and collaboratively reflect on their data in ways that are not provided by the majority of technologies they use in their daily lives. Our analysis revealed how these design features led to a tension that was visible in all but five assignments. Namely, students highlighted a tension between empowering vs. unsettling data experiences distinctly visible in 23 students' assignments. For instance, the following piece of writing from one student summarizes this tension: "*Observing and interacting with my own data felt both empowering and unsettling. On one hand, seeing my own whereabouts and patterns across several days gave me knowledge of my daily habits. Seeing my movement data in front of me made me feel capable of planning out future days. I also felt the need to explore areas that I may otherwise avoid. At the same time, noticing the accuracy and speed at which my phone can track my location made me think deeply about the types and quantity of personal data we afford to technology companies [...] This feeling was spurred by my realization of the high level of detail that exists in the location data that my phone collects."*

With respect to empowering data experiences more specifically, one student wrote, *"Now instead of having some data scientist who works for one of the apps I use analyze and interpret my data I was able to analyze it myself."* Likewise, another student illustrated, *"ViewRanger on the other hand made my mobility easily accessible to me and never tried to hide the fact that they were tracking my location. Having this access made me feel as if I was in control of my own data."* Still another student wrote, *"Taking the wheel and encharging myself with my own data gave me not only an interesting outlook on data collection as a whole but also gave me a chance to introspect a portion of my life."*

With respect to unsettling data experiences, as one student summarized, "*As I observed and was able to extrapolate patterns from the tracking data I was looking at I felt more and more vulnerable to the strangers whom I trust with my data as I realized that tens if not hundreds of software applications out there similarly manipulate data about my life with a potential to learn things that are actually very personal and that I would be reticent to hand out details about to friends."* Similarly, as another student wrote, *"During this course, interacting with my personal mobility data was very eye-opening and surprisingly unnerving. Although I was aware that location services on my iPhone give many apps access to my whereabouts, seeing my movements tracked brought another layer of awareness into how intimate insights about my patterns are given to* *complete strangers. This data provides a detailed view of my life and provides much context about who I am, what I value, who I interact with, and what I do."*

In summary, providing students with ownership over their data through new types of data collection and visualization technologies and activities led to both empowering and unsettling data experiences. These experiences in turn caused students to consider how personal data is and could be collected and used through technology and by companies they and other people interact with in their daily lives. Notably, both the transparency of ViewRanger as a data collection tool and the possibilities for dynamic and collaborative interactive visualization provided by the IGS were critical for students to have these experiences. Likewise, this theme resonates with the analysis by Kaziunas et al of practices of care through personal health data tracking; through engaged ethnography, they surface a similar tension where users feel both empowered and burdened by data. Parents explained how access to data brought both anxiety and relief in managing their children's blood sugar. This reveals the complex and often invisible impact of datafication in our society.

Theme 3: Experiencing Data Privacy

Nearly all student assignments touched on ideas we interpreted as issues related to data privacy with 16 assignments explicitly mentioning the term data privacy. This was a goal of Re-Shape, but our analysis here also highlights how Re-Shape provided distinctly unique and important ways to experience data privacy that contrasted with students' conventional understanding of data privacy and also typical ways data privacy is taught in computer science courses.

For some students, the act of collecting their own data resulted in reflections about data privacy. For instance, as one student characterized, *"Although I'm all-too familiar with the fact that large amounts of my personal data are continuously being tracked by large technology companies, I found that purposefully recording my movements allowed me to really be in touch with the effects a lack of privacy can have on one's life."* For other students, the process of dynamically visualizing and analyzing their data provided opportunities to reflect on data privacy. For example, one student wrote, *"While I found the tracking itself to be non-invasive, the analysis afterwards revealed many concerns I had not yet considered."* Likewise, as another student described, *"By collecting and visualizing my data during this course I felt quite concerned about how much my data, even anonymized, could be used to deduce my entire life. While I had previously known about the possible conclusions that could be drawn from my data, I had not used visualization tools to see this in action."*

Importantly, as a result of these experiences, many students stated that their beliefs about data privacy had changed. For example, as one student wrote, *"Due to the obtrusive nature of the ViewRanger app and the realization of the extent to which seemingly innocuous data can be exploited, I feel that I have taken a different stance on data collection upon completion of this activity."* Likewise, another student wrote, *"Personally, I didn't worry about my data privacy. My belief is that if you are on the internet, you forgo your privacy. However, after looking at my own data, it feels unnatural to have access to this."* Furthermore, another student wrote, *"Although the assignment may have been disconcerting at times, it forced me to get closer to issues of privacy which I've never deeply contemplated before."*

Finally, one student provided a unique and detailed characterization of data privacy important to our work in this paper. As this student described, *"When asked to share our location data with the class, I opted out. At the time, this was very rational thinking. I live alone off campus. I'm a small female. I don't want people to know where I live and when I'm home. After discussion, I realized this was a ridiculous line of thinking, as I rarely opt out of giving apps on my phone access to my location. Anyone who gained access to that data would know everything about my whereabouts. Pair that information with my social media presence, search history, and payment history and someone looking to do harm would have a comprehensive amount of information to do so. It is interesting that I was more concerned about 30 or so of my peers viewing my data but have ignored the many companies that have access to even more information than that. This exercise has made me rethink who has access to my data."*

Altogether, our analysis suggests that Re-Shape provided students with experiences that both raised awareness about data privacy and may have altered some students' views about data privacy. Notably, both the process of collecting and visualizing data through novel tools was critical to embodying personal data in ways that led to unique and meaningful experiences with data privacy. This theme demonstrates how students engaged in care for technologies and for users through the concerns they attached to questions like who gets to know when I am home and who gets access to my data.

Theme 4: Situated Knowledge & Responsible Caring

While at times in their assignments students engaged deeply in complex societal dilemmas about data privacy, cultural belonging, vulnerability, and oppression through surveillance technologies, much of the reflection assignment content included detailed descriptions of their movement. While it is tempting to dismiss content in the reflection assignment where students describe their daily routine, these descriptive paragraphs provide essential space for students to develop what we saw as a fourth theme, situated or grounded knowledge and responsible caring. Situated knowledge is objective knowledge constructed from a specific and partial perspective [34, 58]. According to the feminist theorist, Donna Haraway, we can only find a larger vision when we are grounded in some particular place. We submit that Re-Shape offered an explicit process for students to explore their situated knowledge through personal data collection and visualization of their physical movement data. Subsequently, students were able to explore and discuss their visions and insights into ethical computing and consider technical tools as modes of responsible caring.

We found evidence of this process of cultivating and articulating an ethic of care in many student assignments. First, students demonstrated ways in which they personally used their data tracking technology to achieve certain value-laden outcomes. For example, one student revealed, *"while tracking my data, I frequently felt the urge to spend less time working in my room, and instead work in the library because it would make me look like a better student."* Moreover, another student began to describe awareness of data tracking by the application in use: *"The time during which I tracked my location was interesting. I'm sure that there are apps that are tracking my location without me realizing it. So that made the experience with the ViewRanger app stand out. Not only was I consciously recording my tracks, the app was constantly reminding me that it was actively tracking my location at the top of my phone screen."* Finally, there was evidence of students recognizing who is potentially most vulnerable and not cared for by large technology companies, as in the following excerpt, *"this makes me uneasy about big companies like Google who have access to this data for millions of people. It can easily be manipulated and be used maliciously to target different races or predatory ads to children."* Here we see not just a recognition of personal vulnerability in data privacy, but also thinking in solidarity with others who may be particularly vulnerable to data surveillance. As mentioned, fostering this attentiveness and solidarity through shared vulnerability is key to Tronto's theory of caring democracy.

Altogether, the quotes above and across each theme highlight the depth of students' reflections about their data and class experiences. Importantly, these reflections are a critical first step for students to begin to develop visions and insights into ethical computing and to also consider technical tools as modes of responsible caring.

DISCUSSION

In summary, our work in this paper builds on existing calls for pedagogical research on design instruction as a foundational area of inquiry for HCI [60] and suggests that teaching data ethics should be a more central issue for HCI researchers, who are uniquely positioned to develop instructional designs and educational technology to teach data ethics. We began by highlighting the need for ethics education research in computer science that explicitly addresses data ethics. Subsequently, we illustrated the development and design of Re-Shape, a method to teach students about the ethical implications of data collection and use. We used a case study to demonstrate how Re-Shape impacted student learning in one particular computer science course. In particular, we illustrated how students were confronted with the idea that they are the "other" within systems that use and may exploit personal data and as a result, began to consider what care they desire or demand from these systems. On one hand, we suggest our results are significant because they illustrate the utility and scalability of Re-Shape and more broadly, of instructional designs and educational technologies that leverage personal data to teach data ethics in ways that are relevant to technologies and services HCI designers design and develop. On the other hand, we suggest our results highlight significant limitations and next steps in this early work. We focus our subsequent discussion on exploring the educational and technological prospects, limitations, and next steps for Re-Shape and other instructional designs and educational technology that leverage personal data to teach data ethics.

Educational & Technological Prospects, Limitations & Next Steps

From Personal Reflection to Principles of Care

Our work in this paper offered students opportunities to develop a grounded sense of their own data and learn about the risks associated with being made visible. These experiences in turn allowed students to begin to consider principles of care. However, future work needs to make the connection between personal reflection and principles of care more explicit and more strongly in line with specific principles of care such as interdependence. We suggest three potentially fruitful ways HCI researchers could do so either through efforts to extend Re-Shape or other types of approaches that leverage personal data to teach data ethics.

First, we see significant value to developing assignments and activities that allow students to see others' data that is very different than their own. In our current work for example, we have begun to partner with local high schools to allow both our students and high school students to simultaneously collect and collaboratively visualize their physical movement data in ways that highlight similarities and dramatic differences in their data [10]. This in turn leads to richer and more diverse understandings of how surveillance technologies and data science systems differentially impact people (e.g., college students, historically minoritized populations) who live in the same geographic context. Likewise, we are working with students and other universities in different cities to create repositories of personal and open data sets that can be used by teachers and students to draw comparisons between themselves and others across urban/geographic contexts.

Second, future designs should also better incorporate ethical frameworks prior to collecting and visualizing personal data in ways that allow students to use specific concepts to make personal data experiences more relational. For example, making Lupton's concept of an "human-data assemblage" or other concepts from feminist scholars such as Aristea Fotopoulou understandable and usable for students before collecting and visualizing their own personal data (as opposed to after through reflection) may provide ways to put into practice specific principles of an ethic of care during class discussions and assignments.

Third, future work needs to develop ways to translate students' experiences with data to imagined futures of work concerning ethical computing and technical tools as modes of responsible computing. Namely, activities and reflection should be further designed to allow students to examine, for example, how technologies they are developing in other courses or encounter in their daily lives consider or do not consider ethical values and qualities of caring practices.

Infrastructures for Sharing Personal Data

As described previously, allowing students to draw comparisons between their own data and other data was critical to our work. However, such efforts at scale will require exploring and developing technological infrastructure to support the comparison of personal data in new ways that respect student privacy and contribute to building classroom community. Such infrastructure includes: developing tools for teachers and researchers to share (and in certain cases prevent the sharing of) different types of personal data within and across classroom contexts in ethical and safe ways, exploring what types of personal data (e.g., physical movement data, social media data) are able to be shared to best support specific connections and conversations about principles of care, and making repositories of data sets available to support meaningful forms of comparative analysis across different classroom and geographic contexts. Notably, there may be some contexts where designs such as Re-Shape that leverage personal data and the sharing of personal data are not appropriate or alternatively, simplified versions may be more appropriate. For example, a simplified version of Re-Shape uses only ViewRanger's visualization capabilities in ways that do not require students to share their personal data. In summary, future work needs to explore and understand how activities centered around personal data can best be designed and used by others to build classroom community and align with contemporary discussions about student data privacy when teaching data ethics [see 2].

Transparent Data Collection Tools

Our work highlights the value of data collection tools such as ViewRanger that make learners aware that they are collecting data in ways that subsequently cause them to more deeply consider their personal data and how it was collected; their values and decisions made visible through personal data; and how the process of data collection impacts different people positively and negatively. Such tools are rare as most data collection technology aims to automate the data collection process and make it invisible to students and citizens, often to monetize personal data for advertising purposes. Put differently, while the idea of "transparency of a system" has long been a topic of HCI work [35, 51], our work highlights how it may be necessary to expand notions of transparency in terms of data in contemporary systems. We thus suggest that developing data collection tools which make the collection of personal data visible and experiential for students is a rich design space for HCI researchers. This design space aligns with existing citizen/data science initiatives in HCI [3, 11, 38, 59, 61] and may offer opportunities to integrate data ethics into a variety of highly technical computer science courses.

Visualization Tools to Get Personal with Data

There are few tools like the IGS that are customized for specific pedagogical settings and support the rapid, dynamic and collaborative layering of personal data in relation to open data sets in ways that, as Kahn succinctly describes, allow students to "get personal with data" [18 also see 19]. We suggest that developing such visualization tools is a fruitful design area for HCI that is necessary to expand work in this paper. As our work shows, visualization plays an important role in enabling students to take an active role in their data, through which they become more inclined to care about the data and consider the implications of its existence. Extending Kahn's ideas, we suggest the focus of such tools should be developing domain-specific capabilities (e.g., interaction techniques or visualization operations for social studies instruction) that allow students to make personal connections with large-scale data sets through collaborative analysis of their data.

CONCLUSION

Our work extends existing work to show why teaching data ethics should be a central issue for HCI. In particular, Re-Shape illustrates one method to teach data ethics in ways relevant to the technologies and services HCI designers design and develop. We emphasize there are other approaches, and we invite HCI researchers, designers, and teachers to explore and further develop instructional designs and educational technologies to teach data ethics, particularly designs and technologies that leverage personal data to cultivate care in the practice of data science.

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RESEARCH ETHICS

Throughout our work we worked closely with institutional review boards (IRB) at two universities to conduct research in ways that benefited students, student learning and respected the privacy of students during activities that leveraged personal data. We emphasize the necessity of conducting research that leverages personal data to teach data ethics that works with local institutional review boards, the contexts of specific classrooms or universities, and current ethical guidelines provided by the CHI, CSCW, IDC and related communities.

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