

Enlisting Students to Transcribe Historical Climate and Weather Data For Research: Building Knowledge Translation Via Classroom-Based Citizen Science

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Abstract

DRAW (Data Rescue: Archives & Weather) is a citizen science project that asks the Canadian public to take part in transcribing millions of meteorological observations recorded between 1871 and 1963 at McGill University's Observatory in Montreal, Quebec, which was demolished in 1963. We examine how classroom-based curricula can integrate citizen science so youth can learn more about their community via engagement with the local history of weather conditions and impacts. Conducted in March 2018, this research examined knowledge translation during a three-week course module through written reflections, classroom video footage, exit interviews, and a final group research assignment. We worked with 21 students—16- to 20-year-olds enrolled in a social science research methods course at Dawson College, a two-year *collège d'enseignement général et professionnel* (college of general and vocational education) that attracts local students and is a funded part of education in the province of Quebec. We found knowledge translation was facilitated by student engagement with their community's history and appreciation for aiding credible scientific research. Knowledge translation suffered from attempts to include archival records that could be difficult to find, access, and read. Our work showed that citizen science, as a vehicle for community engagement and scientific literacy, requires considerable contextualization, for example, the use of frequently asked questions, tutorials, and blogs for context, and historical context to ensure knowledge translation takes place.

Introduction

Citizen scientists engage in knowledge translation not only by learning new concepts and skills but also by mobilizing their gains to improve their own communities (Cooper, 2016). Knowledge translation, in this definition, refers to the ways research can be synthesized or applied to improve policies or practices whether it occurs through the co-creation of new knowledge or diffusion of new ideas through community engagement (D. Davis, M. Davis, Jadad, Perrier, Rath, Ryan, Sibbald, Straus, Rappolt, Wowk, & Zwarenstein, 2003). We are interested in knowledge translation related to historical weather because it combines translation of science and the capacity to connect individuals to historical aspects of their community. Most historical weather translation happens online where citizen scientists contribute the considerable personpower needed to rescue, digitize, and transcribe the observational meteorological data holdings of the recent past (Ryan, Duffy, Broderick, Thorne, Curley, Walsh, Daly, Treanor, & Murphy, 2018). These holdings remain grossly incomplete because so many remain only in hard copy format or consist of photographed images (Allan, Brohan, Compo, Stone, Luterbacher, & Brönnimann, 2011; Brunet & Jones, 2011). The work of citizen scientists on historical weather records extends the

scientific community's abilities to investigate subjects such as the climate and weather of the recent past while giving citizens the opportunity to acquire basic Earth and climate science knowledge and skills applicable, for example, to planning for the future or voting on major policy decisions (Bonney, Shirk, Phillips, Wiggins, Ballard, Miller-Rushing, & Parrish, 2014).

Youth engaged by our work can situate their community's historical relationship with weather and climate. One hope of our project is that it would connect participants to the lived experience of people of the past and, to a certain degree, consideration of how climate changes may one day shape their own future. Our participants learned about the 1883 Winter Carnival, the weather on the day the first car drove on Montreal's streets, the ways in which cold winter climates enabled travel on rivers, the extremely cold Christmas day of 1896, and the extreme heat wave experienced on August 20, 1884. Our participants learned what life was like and how weather and climate interacted with daily human events. Members of the public have engaged with history in other citizen science projects to improve their community. Roberts, Inwood, and Oxley (2017) worked with secondary students to transcribe the personnel files of all the Australian and New Zealand Army Corps soldiers

who fought in World War I. He has offered other educators lesson plans, guest lectures, and community group talks as encouragement to get involved with his platform where individuals, primarily grade school children, each adopt a soldier.

Lafreniere, Scarlett, Trepal, and Arnold (2017) had university students learn about history by digitizing detailed maps of U.S. cities and towns—originally created by the Sanborn Map Company in the 19th and 20th centuries for fire insurance purposes—to see how their communities evolved and, in some cases, what historical buildings had been lost.

To better understand how communities benefit from working with the DRAW project (see <https://citsci.geog.mcgill.ca/>) and their local history, we adopt a typology of citizen science (Haklay, Mazumdar, & Wardlaw, 2018) in which projects are broken down into three different categories: 1) long-running ecological citizen science projects (e.g., the Christmas Bird Count, which has run annually since 1900); 2) community-based science, for example, the effort by Public Laboratory for Open Technology and Science to document local air pollution; and, 3) citizen cyberscience, for example, projects like those found on Galaxy Zoo (see <http://zoo1.galaxyzoo.org/>) that engage users online in crowdsourcing efforts. These types of projects hold varying potential to impart technical skills, conceptual understandings, and critical thinking abilities in members of a community. Each also possesses the ability to impart an interest in science, technology, engineering, and math (STEM) topics. Citizen scientists have been shown to gain knowledge and skills that help them better understand broader concepts in science (Jordan, Gray, Howe, Brooks, & Ehrenfeld, 2011; Phillips, Walshe, O'Regan, Strong, Hennon, Knapp, Murphy, & Thorne, 2018; Ryan et al., 2018). Many of these

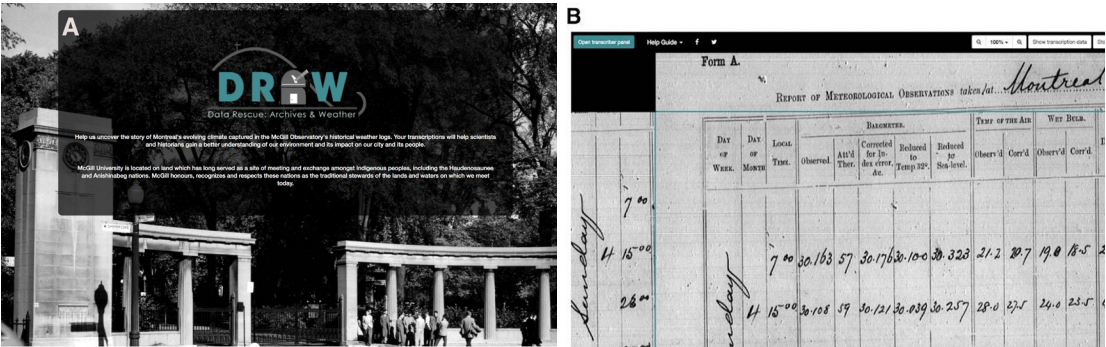
citizen scientists make such gains by helping to measure, observe, and understand basic changes in their environments. Past research has examined how young community members benefit from participating in citizen cyberscience projects (the third in the typology of Haklay et al., 2018) that involve online transcription or image classification. We consider the DRAW project to be citizen cyberscience because it primarily engages users in online transcription.

Knowledge translation facilitated by citizen science that engages the public with their own history can be evaluated by the three “essential components” described by Meinke, Nelson, Kocic, Stone, and Selvaraju (2006, p. 101):

The translation of climate information into real-life action requires 3 essential components: salience (the perceived relevance of the information), credibility (the perceived technical quality of the information) and legitimacy (the perceived objectivity of the process by which the information is shared).

The coupling of crowdsourced, voluntary non- expert citizen scientists with historical climate and weather data transcription represents an attempt to meet each of these components. McGill University’s DRAW project builds partnerships among researchers, Canadian communities, and educational institutions to generate knowledge about historical climate and weather. It asks the Canadian public to take part in transcribing millions of meteorological observations recorded between 1871 and 1964 at McGill University’s former Observatory in Montreal. When transcribed on the DRAW website (Figure 1, A and B) to become machine readable, early weather records such as the McGill

Figure 1.
A. Data Rescue: Archives and Weather Website Landing Page.
B. Random Page Ready for Transcription from the DRAW record.



University observations are useful in understanding climatic variability and change. They document not only changing temperatures and precipitation but hazardous or high impact events such as freezing rain or drought (Slonosky, 2019). When combined with similar records around the world, digitized observations allow for a more detailed understanding of particularly severe or unusual weather events (Brugnara et al., 2015). DRAW participants contribute to making available a dataset that on its completion will be among the largest and most complete climatic records in North America.

We depart from conventional understandings of knowledge translation in several respects. First, knowledge translation is often considered a one-way dissemination of knowledge products from producers to users (Graham, Logan, Harrison, Straus, Tetroe, Caswell, & Robinson, 2006). In contrast, web-based citizen science makes the individual user the producer of actual data used in climate research (Phillips et al., 2018; Ryan et al., 2018). Second, our citizen scientists reclaim their own community's history by examining its past relationship with weather and climate. Third, knowledge translation that takes place in the program described in this study teaches not just about meteorology and measurements but how research was conducted in these disciplines historically and has evolved over time. Our approach contrasts with other citizen science projects that emphasize amateur observations and current scientific practices. Consistent with other citizen science projects, our students can develop skills in numeracy, visualization, graphing, and data analysis and interpretation while tying historical weather records to their own community's history. Many students engaged with their community history by discovering how topics such as air pollution or public health spurred the creation of early weather records.

This manuscript first reviews the literature on citizen cyberscience projects that engage the public with work in meteorology or climate science and the role educational institutions play in knowledge translation. We then investigate how our program implemented at Dawson College worked as a tool for community engagement that ultimately drove climate science knowledge translation in our community. We conclude with the implications for those working to create two-way forms of knowledge translation on weather and climate and the possibilities for citizen science to address

Meinke et al.'s (2006) three essential components for better knowledge translation of climate science.

Literature Review

DRAW represents one of many meteorological-based citizen cyberscience projects (like Old Weather, ClimateWatch, Weather Watch) that are now ubiquitous on the Haklay et al. (2018) typology. However, it is not easy to determine what knowledge translation takes place during citizen cyberscience projects where users may transcribe data alone and at home. This section first reviews the literature on citizen cyberscience projects that engage the public with work in meteorology or climate science. We then examine the role educational institutions play in knowledge translation in their communities and how others have sought to measure knowledge translation both inside and outside of classrooms.

Citizen Science and Meteorology/Climate Research

Citizen science draws upon the rich tradition in climate and meteorological research of trained amateur scientists who did not necessarily specialize in these subjects to investigate the weather around them, its connection to human health, and its influence on human political, social, and cultural events (Slonosky, 2019). Citizen science contributes to knowledge translation by having participants actually contribute scientific data that researchers need, which also makes it potentially salient, credible, and legitimate (Meinke et al., 2006). Our aim in this study was to determine how work with DRAW can assist the translation of knowledge on climate and meteorological research and improve critical thinking about climate change. This aim reflects a socio-environmental synthesis approach that integrates data from both the natural and social sciences to advance understanding of a socio-environmental system like the climate (Wei, Burnside, & Che-Castaldo, 2015).

Engaging the public in hands-on scientific learning on such topics can prepare individuals to think critically about the science behind climate change, with many attitudes forming about scientific concepts when people are students at educational institutions (Simpson & Oliver, 1990). Previous research suggests that "interest in science at age 12–14 years is associated with increased trust in climate scientists in adulthood (mid–30s), irrespective of Americans' political ideology" (Motta, 2018, p. 485). We adopt a definition of critical thinking (McPeck, 1981; Siegel, 1988) where individuals re-examine their own concepts,

attitudes, and identities (Harpaz, 2010) to learn how to discern scientific evidence in public debates. Critical thinking relates to the undertaking of higher-order cognitive tasks that research has shown best improves conceptual understanding of science or the scientific mindset (Krathwohl, 2002). Critical thinking also produces engagement with STEM subjects, particularly when it involves relevant topics from interdisciplinary subjects in the humanities such as historical archival research (Kerski, 2015).

Past research into citizen science has shown its ability to improve community engagement and critical thinking with climate research through tangible hands-on experience (Ryan et al., 2018). Past and current weather citizen science applications, such as the Community Collaborative Rain, Hail and Snow Network (see <https://www.cocorahs.org/>) and OldWeather.org (www.oldweather.org/) underscore the potential of crowdsourcing to engage the public with meaningful learning opportunities and chances to contribute to meteorological research. In cases such as Old Weather, the dataset is being used for climate reconstruction by the 20th Century Reanalysis Project, which provides integrated historical datasets (Compo, Whitaker, Sardeshmukh, Matsui, Allan, Yin, Gleason, Vose, Rutledge, Besemoulin, & Brönnimann, 2011; Slivinski et al., 2019). In contrast, the Data Rescue at Home project exemplifies climate data rescue that uses citizen scientists to transcribe and play a role in safeguarding data for analysis (Allan et al., 2011; Kaspar, Tinz, Mächel, & Gates, 2015). These projects are not alone. Zooniverse (see <https://www.zooniverse.org/>), an online platform that supports almost 100 individual projects, includes projects like the Cyclone Center (see <https://www.cyclonecenter.org/>). The Cyclone Center relies on user-identified patterns in tropical storms to further the scientific community's understanding of these types of storms (Hennon, Knapp, Schreck, Stevens, Kossin, Thorne, Hennon, Kruk, Rennie, Gadéa, & Striegl, 2015).

Educational Institutions and Measuring Knowledge Translation

Projects in educational institutions engage highly motivated students who are ideally placed to bring new technical capabilities home to their neighborhoods and communities. For this reason, educational institutions can serve as a primary source for the diffusion of knowledge where

students, guided by their instructors, learn about historic and scientific research. Through learning, students help to build new processes and social networks for their own communities to learn about and engage with scientific or environmental issues. Observing this phenomenon, Cooper (2016) writes that the “growth in citizen science” signals “a growth in social capital;” social scientists link social capital to communities with “higher educational levels and [that] have better governments, stronger economic growth and less crime” (p. 269).

Citizen science that occurs in educational institutions provides a model for how to improve knowledge translation and unpack the meaning of what it is to do scientific work (Vitone, Stofer, Steininger, Hulcr, Dunn, & Lucky, 2016; Harnik & Ross, 2003). Scientific collaborations with educational institutions in projects like the Global Learning and Observations to Benefit the Environment (GLOBE) (see <https://www.globe.gov>) program engage school communities across the world in research into their own local climate and weather (Mitchell, Triska, Liberatore, Ashcroft, Weatherill, & Longnecker, 2017; Allan et al., 2011). While its complexity can create impediments to teacher adoption, GLOBE students contribute research-quality data using technologies such as the project's website, database, and digital communication tools (Charlevoix, Tessendorf, & Mackaro, 2011; Tessendorf, Andersen, Mackaro, Malmberg, Randolph, & Wegner, 2012). Butler and Macgregor (2003) find that not only scientists guide student learning in GLOBE but also educators, families, and friends who in turn also may gain new knowledge.

Researchers in citizen science often examine the ways in which knowledge translation takes place in informal educational settings. Jordan, Ehrenfeld, Gray, Brooks, Howe, and Hmelo-Silver (2012) asked citizens to help measure whether invasive plant species are more commonly found in forest patches near hiking trails than in nearby forested areas and then tried to determine if “volunteers could apply what they learned to new contexts” (p. 1) as a measure of the translation of knowledge. They found that consideration must be given to “cognitive biases” in “how people learn” when creating and evaluating instructional materials for citizen science (Jordan et al., 2012, p. 20). Cronin and Messemer (2013) reported that “non formal outdoor adult education and structured experiential learning” result in

statistically significant gains in science vocabulary knowledge and science process understanding but only for adults who had collected “more than 30,000 pieces of scientific data” (p. 143). Effective knowledge translation, they conclude, requires citizen science programs to evade the high rates of attrition found in many programs. The proposed virtues of citizen science include its supposed ability to “increase scientific literacy and awareness...fill knowledge gaps and challenge official accounts...drive policy change...[and] build more equal relationships between citizens and scientists” (Kimura & Kinchy, 2016, p. 331). Interestingly, Delfanti (2010) warns that the web tools that constitute citizen cyberscience may alter the meaning of expertise and the process of knowledge production and adds that the political, economic, and scientific institutions investing in citizen science should consider the needs and interests of the actual citizen scientist; otherwise they risk losing their own participants.

Engagement with shared history fulfills this aim by engaging participants in work that relates to their community’s own past and possible future. We departed from traditional citizen science in our focus on having students augment the science by adding in historical newspaper archives and first-hand written accounts. This research gives excellent insight into how knowledge translation occurs when students become citizen scientists who aid in scientific research while building their community’s knowledge of its own history. Their work not only informs scientific research but their own community’s debate about how to manage future climate changes.

Materials and Methods

We wanted to see how citizen science could serve as a medium of knowledge translation that better connects students to their community. We developed a three-week curriculum—or program—that covered meteorology as part of a regularly scheduled social science research methods course. To better have students connect to the community, we augmented the scientific instruction with narratives. Students needed to comb local newspapers and other archival materials from the late 1800s to situate the scientific in the local. Conducted in winter 2018, this research occurred at a two-year institution, Dawson College, which is a component of postsecondary education in Quebec, where students attend five years of high school.

Program Design

Our program consisted of student work both in class and outside of it as they completed their own research. As part of our program, students engaged in group research assignments to learn about historical life or events in their own community. Their transcriptions of historical weather served as the portal for investigation of archival records.

Many students said they were looking to better understand Montreal, the region, or places they had personal connections with. In this way, DRAW connected participants to the lived experience of people of the past and, to a certain degree, people of the present and future. We organized knowledge translation in our program around four specific topics including: 1) Explaining how scientists examine Montreal’s historical weather records, 2) employing scientific research and data transcription skills to evaluate historical sources, 3) explaining how to access historical records and what was the importance of past human social, cultural, and political events, and 4) applying scientific methods involving the use of historical climate records to their own research in class.

The three-week program consisted of out-of-class group research and reading and six 80-minute class sessions. The first two class sessions were hands-on and involved data transcription with DRAW, two were devoted to learning about historical research, and the final two included time for group work with instructors. Students were guided by a course instructor (the third author) and two researchers (the first two authors) in using DRAW and read peer-reviewed book chapters and journal articles about environmental change, citizen science, historical weather events, and climatic changes in Montreal and the Saint Lawrence Valley. As a class, students visited McGill University’s archives to scroll through microfiche readers that contained historical accounts of the time periods from the DRAW record. Groups also engaged with their own community’s history through first-hand historical books, newspaper archives from the local newspapers—*Montreal Gazette*, *Montreal Daily Star*, and *La Presse*—and photographs from the McCord Museum in Montreal, a public research and teaching museum dedicated to the preservation, study, diffusion, and appreciation of Canadian history. During the final week of the program, groups completed their group research assignment. In this work, they attempted to find first-hand historical accounts

that coincided with a day or days in the DRAW record that the instructional team had previously identified. The drudgery of this historical research (as well as data transcription of multiple days in the DRAW record) gave students a chance to consider that there are no shortcuts that will enable them to learn about their own community's shared history or to engage with concepts from climate and weather research.

Assessment of Knowledge Translation

This manuscript evaluates a three-week program where 21 students learned by working with DRAW and completed historical research and assignments outside of class. We chose our length of assessment based upon the tasks students would need to complete. We also considered the relevant literature that suggests that citizen science programs should develop a variety of approaches and lengths of engagement for different audiences (Aristeidou, Scanlon, & Sharples, 2017), with most subject to the differing "temporal nature of volunteers' motivations and participation practices" (Rotman, Hammock, Preece, Hansen, Boston, Bowser, & He, 2014, p. 110).

Our methods highlight how interactions occurred in our classroom and contributed to high levels of engagement with our four outcomes for knowledge translation. Demographically, our group ranged from 16–20 years old, with 13 women and eight men. Ethnically, our class was diverse with students who were Caucasian (3), Latino (11), African Canadian (1), Asian (4), Pacific Islander (2), and Indigenous (3). All lived in Montreal or one of its nearby suburbs, with most feeling they were slightly better off or about the same in terms of wealth as peers.

Data Collection

All of our data collection methods were approved by the appropriate McGill University and Dawson College research ethics boards (McGill University Research Ethics Board File #444-0418 and Dawson College Application ID #180129). Whereas students may have had an incentive to take part in work with DRAW as part of their normal class activities, their participation in this research was fully optional. At the start of class, the researchers (the first two authors) explained that their course instructor (the third author) would never see any of the research materials or who took part. Researchers would not receive any graded materials used in the

research until well after the course concluded. Three students opted not to take part in the research but completed all elements of the coursework.

Four research instruments (see Supplementary Materials) enabled insight into how students interacted with instructors, each other, and DRAW and archival materials (e.g., community newspapers). The first topic we examined was how scientific knowledge translation occurred (using video recordings); second, whether historical research facilitated this translation and also was translated itself (using a group research assignment); third, whether participants displayed critical thinking (using written reflections); and finally, how knowledge may have diffused beyond Dawson College to the wider public (using exit interviews). While not discussed in this manuscript, the pre and post exams included in our Supplementary Materials Sections 5–7 confirmed knowledge translation occurred over the time our program took place.

Co-coding of written reflections and exit interviews as well as co-grading of group research assignments involved the lead author and a co-coder or co-grader in a process from which a measure of inter-rater reliability was calculated for each. A standard process for coding was followed (Johnson & Christensen, 2008) that involved: 1) the lead author and co-coder determining codes or rubrics together, 2) the first item being coded or graded with each item discussed, 3) three subsequent items all being graded then being discussed, and 4) the remainder of coding or grading taking place individually.

Disagreements at any stage were noted and used to calculate the inter-coder or inter-grader reliability statistics for each instrument. Table 1 displays Cohen's Kappa values calculated for each research instrument where a measure of intercoder or intergrader reliability was determined. All were within research standards (Krippendorff, 2004).

Table 1. Cohen's Kappa Reliability Values

Research Instrument	Cohen's Kappa Value (K)
Group Research Assignments	0.872
Exit Interviews	0.897
Written Reflections	0.917

Notes: To complete each statistical test we used SPSS Version 20.0.0. To assess the validity of our instruments on a few measures, we also used the free software, jMetrik.

How scientific knowledge translation occurred (video recordings). We recorded 67 minutes of classroom video footage spread across 27 separate shots of student groups in each lab and class session. Much as those studying how community members might engage with each other on local policies through town meetings or focus groups, our analysis focused on how students engaged in groups with historical data and research. We sought to determine how knowledge translation occurred in the classroom by employing three categories of coding about group engagement, including the level of engagement with coursework, the dynamics of how groups engaged and any technical issues that impeded group engagement. We applied definitions for classifying community engagement to the classroom used by Sinha, Rogat, Adams-Wiggins, and Hmelo-Silver (2015). Our adapted definition classifies each moment when students remained on topic while working with peers, instructors, or DRAW and the microfiche readers at McGill University.

Translation of historical community knowledge (group research assignment). In group research assignments, students were given instructions to transcribe a unique weather event in the DRAW record before conducting historical research into that event in archival records held by different institutions in their community including Dawson College and McGill University. The purpose was to determine how student community members learned about the relationship between human historical events and weather and climate, and how this provided ways to engage the public in learning about climate and meteorological science through DRAW. Groups also were presented with a list of possible events they might choose contained within DRAW. The written group research assignments (11 in all) were graded using strict rubrics and a co-grader to ensure the reliability of our grading procedures (see Table 1). Rubrics included the nine parts of the assignment and were graded at three levels of achievement based on students' ability to relate meteorological data to actual historical events and the present places where they took place.

Critical thinking with DRAW (written reflections). Students were asked to write individual and group reflections before and after

the four class sessions, with the fourth reflection completed as a group. We examined 68 reflections to determine how engagement with historical research about their own community triggered critical thinking in students.¹

Diffusion of knowledge beyond educational institutions (exit interviews). The 16-question interview protocol was drafted, discussed by the authors (excluding the third author), tested for clarity, and revised during multiple stages. The protocol consisted of three main sections on students' reflections on citizen science and DRAW, students' engagement with their community (inside and outside of class) during coursework, and students' new appreciation of their community's relationship to weather and climate. Eleven students were randomly selected for exit interviews, as was the main course instructor (third author, who did not take part in conducting the research or discussing any of its research instruments).²

Results and Discussion

In this section we examine program results on four main topics in relation to each of our research instruments.

How Scientific Knowledge Translation Occurred

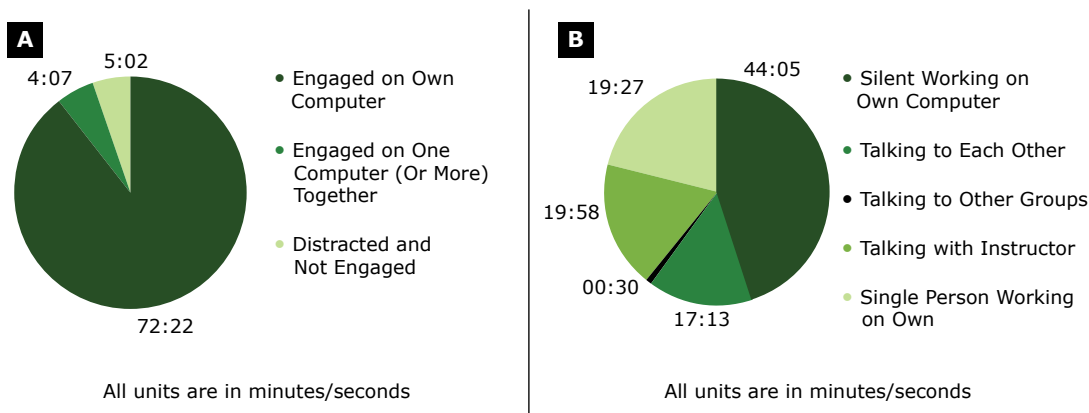
We sought to determine how students used DRAW as a vehicle to engage with their community's history and contribute to science that will help them decide the community's future. Our video recordings enabled observation of engagement when students worked with DRAW and during which they completed their group research assignments using historical documents online or microfiche readers. Much as social scientists study town meetings or focus groups, our analysis focused on group engagement dynamics. Figure 2 shows the various ways students engaged with technology and members of their classroom community.

The first set of four videos consisted of introductory work with DRAW. Students first participated in a lecture and discussion on citizen science. In the second class, they were introduced to DRAW. Videos of both indicate the level of engagement prospective citizen scientists have when they arrive at the DRAW project's website. Students utilized DRAW silently on their own

¹In total we employed 43 unique code categories across each of the four written reflection days, collected 8 codes applied to the first reflection, 17 to the second, 6 to the third, and 12 to the fourth. All coding was done using Saturate App (see <http://www.saturateapp.com/>), a tool that enables qualitative coding of responses by a human online. Some individual responses were coded multiple ways.

²All interview response coding was also done using Saturate App.

Figure 2. Students divided time while (A) engaging with course technology and (B) with each other, instructors, and others. Knowledge occurred in two primary forms: when working on their own or chatting while transcribing and while engaging within groups and with instructors. Totals are 67+ minutes because of multiple shots analyzed separately.



individual computers while only spending one tenth of the recorded time talking with each other. In this small amount of time, students were often overheard talking about the difficulties in manipulating the rectangle used to identify which sections of the DRAW page had been completed after transcribing observations.

In the next set of videos we evaluated the success of the program’s archival research components. During these class periods, groups ranging from one to three students chatted with instructors and within their groups, often while working on their own computers. On rare occasions, individual students chatted with other groups. Students more frequently shared computers or pointed to a group member’s computer work while discussing work. Instructor interventions helped students understand how to interpret data, find historical resources for a group research assignment, pose hypotheses, or analyze their data (both from DRAW and their archival research). Transcribed data was reproduced in the group research assignment and then students were required to plot several graphs from the data they transcribed.

Salience, or the perceived relevance of the science, proved essential to sustaining engagement after students transcribed data. Video records indicated that group work with historical research was essential to sustain engagement after the first time they used DRAW. As we will see again in the next section, salience was shown through high levels of filmed engagement with work where students researched an event in their own city’s history that was tied to historical weather and climate records. In video recordings and exit

interviews, students pointed out that, compared to other courses, this course allowed them to actually “do” research.

Translation of Historical Community Knowledge

Groups were asked to transcribe a specific page in the DRAW record and contextualize it with archival research on a social, political, or other human event at the same time. Group research assignments provided a quantitative indicator of how both scientific and historical knowledge was translated to students through engagement with their own community’s lived experience with climate and weather.

The quality of student work varied greatly. We scored this translation by how well groups found sources of community knowledge in the archival resources. Our highest scoring group (89%) wrote about Montreal’s 1883 Winter Carnival when the first ice palace was constructed and the impacts of weather and climate on this event. Their work included finding a detailed account of this event in the *Montreal Daily Star*, now defunct. Our lowest scoring group (16%) focused on how an extremely cold Christmas Day in 1896 impacted animals and did not answer many of the assignment questions. In an era in which students expect such an easy user experience in terms of availability and searchability, it was by no means easy to figure out how to search microfiche. Through their experiences during the search, groups learned that the act of looking for historical newspaper accounts could both be tedious and fascinating. They then applied their findings to create a map that helped to identify key locations in Montreal where their historical events took place. This helped students

to connect with specific people and places from their own city's history and also connect past to present through shared geographical spaces.

An excerpt from one group's assignment highlights the knowledge translation that occurred and exhibits a high level of clarity, support for any suppositions using historical evidence, and accurate descriptions of possible relationships between human activities and the weather events transcribed from DRAW data:

It is likely that during the winter of 1883 in Montreal, there was a very low mean temperature and that this temperature was fairly consistent. These conditions would have been necessary in order to keep the ice palace intact. Apart from making this possible, the extreme cold would surely have affected the residents of Montreal, especially since the Winter Carnival was held outdoors. It is likely that reaching the site would have been more difficult and that people would have to be dressed using many layers and not be able to stay outdoors for very long.

Not all groups wrote so clearly, supported their ideas, or concisely identified relationships. Irrespective of citizen science, the challenges students faced can easily be underestimated in a program that constitutes a first exposure to scientific and historical research. An example of this concerned a group that investigated the extreme heat on August 20, 1884 but instead focused on the type of clothing during the time period that would have made the population more vulnerable to extreme heat. They wrote about individuals living where the plumbing was poor who might suffer from dehydration; whereas others could suffer during a time before air conditioning and of very large families.³

Conducting background research to adequately understand their topic was difficult for many groups, who struggled in finding adequate archival references from historic (and sometimes now defunct) newspapers. Several groups forgot to include this section or neglected to cite any sources. The historical element to this particular program created an additional barrier for the students, both in locating sources (one group did not realize that

in the 19th century, news would not be available instantaneously and so failed to look for newspaper articles on the day after the event they were interested in) and in basic background knowledge on social and living conditions during the era of the DRAW record.

A program designed around DRAW resulted in knowledge gains for our students although not on every topic. We saw no improvement in conceptual understandings of how historical meteorological methods could result in error. Indeed, the concepts of error and uncertainty were outside the scope of this brief module. In reviewing our instructional approach, we realized that groups scored worse on topics such as these that coursework did not address directly. Students may still have encountered these ideas because the scientific process, like the history of a community, can be messy. The credibility of our citizen science means students were exposed to this messiness (and inconclusiveness) of the scientific process. This exposure also meant our students appreciated how scientists communicate findings and what they considered to be errors. Students learned how the original scientists gathered data, which involved tasks such as recopying measurements, modifying the data (such as reducing observed pressure to mean sea level in the original 19th century documents) or transcribing others' data. This meant DRAW helped to spark students thinking about how historical meteorological research processes might compare to modern ones.

Critical Thinking with DRAW

In structured reflections, we asked students to consider what they had learned, either weather, history, citizen science, or about the DRAW project specifically. This helped ascertain our success in making concepts accessible. Our reflections identified what students learned about citizen science (Reflection 1); how students felt about DRAW itself (Reflection 2); whether they understood how climate and weather impact human society (Reflection 3); and how well archival research into their own community's history helped learning (Reflection 4). Table 2 summarizes the responses to each written reflection, the number of codes we applied to analyze common responses among students, and the major topics written about in each.

The first reflection asked students to express the most important thing they learned about DRAW and citizen science. Half of the students

³ It is important to note that the lack of clarity in assignments might have been because not all of the students in our class spoke English as a first language. Some were primarily French speaking.

mentioned the idea that “normal” or “untrained” people could contribute to science in citizen science. One respondent captured the sentiment of the majority, noting, “The public is a large population and therefore the data transcription can happen more quickly. The data is important because it can help us predict climate and weather trends.” The two-way flow of knowledge and data was central to responses as well. Half the students focused on the importance of contributing to real scientific research related to “environment” and “climate” or “weather” issues. Six focused on DRAW’s potential to educate the public or “create awareness.” But our students were naive about how DRAW data would be used, particularly the nuance in using this data to predict future climate or weather. Most students did not see the complete DRAW records or how scientists use them. As one respondent wrote of this data’s use:

Because we could prevent certain periods.
Example: If every five years there is a huge period of cold and snow, we could prevent it and get prepared in advance.

The second reflection evaluated whether the DRAW website user interface facilitated knowledge translation. In terms of how their interactions with the DRAW website shaped their learning, most students reported they learned about data transcription. A few expressed details beyond pure functionality: They felt they had learned about meteorological symbols or data notations, the

usefulness of DRAW’s data, or an interesting historical fact such as who founded the McGill University Observatory.

The third reflection asked students to write their own exam question to triangulate whether the group research assignment and lectures effectively translated knowledge about the human relationship to historic weather or climate. Example questions included, “How were lower class citizens in Montreal in the 19th century affected by extreme cold?” “How can a heat wave impact people today where they live?” “What is the impact of climate and weather on our lives?” “What are the factors that can affect people in different classes or locations when considering extreme weather events?” Student-generated questions suggest that group research prompted students to think critically about impacts on the lived experience of people in the past and future. Citizen science in this context not only helped teach about the observations recorded in DRAW itself but also about how weather and climate impact their community.

Our final written reflection examined how student archival research into their own community history helped to translate knowledge. Half of the groups agreed that historical archival research represented the most difficult part of their work. Three student groups found data transcription with DRAW difficult because the original record’s cursive handwriting or meteorological symbols were hard to read. Three responses invoked the excitement of tying historical weather and climate

Table 2. Written Reflections According to Four Response Factors
*(These reflections were completed by each group instead of individual students.)

Written Reflection Number	Number of Reflection Responses Collected	Number of Codes Applied to Reflection	Common Responses
1	18	22	Untrained public can contribute to DRAW; the public make real contributions to scientific research.
2	20	21	DRAW website teaches data transcription, meteorological symbols and data notation.
3	19	10	Student written exam questions demonstrate connection of DRAW weather record to history of community.
4	9*	10	Work with historical archives was hardest part of Group Research Assignment; excitement over research into own community history.

data to their own city’s history. One group expressed this well in their reflection writing, “I find it interesting to research the culture of Montreal in the 19th Century, and I will enjoy seeing the difference between the climate of Montreal in 1883 to the climate today in 2018.” Other groups responded that enjoyable parts included “teaming-up” to work as a group, having hypotheses connected to data and research from the real world, the act of transcription being enjoyable, and satisfaction

with the idea that DRAW helps scientists to complete their work.

Overall, students were engaged by the idea of citizen science and the ability to contribute to actual scientific research. They also demonstrated understanding of the human relationship to climate and weather. Learning was not perfect; some students failed to ascertain from DRAW or their instructors how researchers make use of the transcribed data. Most found work with their own community's past engaging and information about historical weather and climate interesting. The classroom experience demonstrates the importance of contextualization for translating scientific knowledge. DRAW was initially designed as a stand-alone citizen science website where users could transcribe weather data at home with minimal support. In a course setting, occasionally students made suppositions in their group research without supporting evidence (e.g., that people develop diseases due to temporary, localized bad air quality; that the omission of diseases from a historical account meant that none occurred; or that rich people could completely escape the effects of poor air quality). Even though inaccurate, these hypotheses revealed the inception of critical

scientific thinking and indicated that knowledge translation in the students' research suffered primarily from their inexperience at supporting arguments scientifically or the instructors' lack of emphasis on these skills. A formal classroom setting differs from public usage in that these misperceptions can be corrected by instructors.

Translation of Knowledge Beyond Educational Institutions

We examined 11 exit interviews conducted with a subset of the students. Our interviews solidified the finding that exposure to historical climate and weather data (for the first time) opened students' eyes to how scientists conducted research and how they could contribute to science. Exit interviews reinforced the written reflections in demonstrating that knowledge translation was facilitated by tighter connections between the DRAW transcription work and its use in research and in policymaking (especially related to the issue of climate change). Table 3 organizes interviews by the number of respondents who spoke about the topics of interest in this study.

Students felt that DRAW revealed what climate researchers did and how complex the research could be. Not all agreed that DRAW was the most

Table 3. Interview Topics by Times Participants Discussed
Specific Subject and Total Number of Participants Who Commented

Interview Topic/Related Interview Protocol Question Number(s)	Number of Interviewees Who Commented (out of 11)
Complexity of climate and meteorological research / 1 and 7	11
Relationship of DRAW to climate change / 5	11
Learned something new in course module / 2	11
DRAW teaches public about history / 6, 14, 15 and 16	11
DRAW teaches public about climate and meteorological research / 6	11
DRAW website easy to use / 10	11
Transcription is relaxing / 10 and 13	8
DRAW aids hands-on learning / 13	8
DRAW not completely hands-on / 9	1
Handwriting and symbols in DRAW record difficult to read / 9	11
DRAW record contains inconsistent notation / 9	9

effective medium for translating knowledge about climate change, even if students did feel those who use the website would learn about climate and weather. One student said:

It's hard to take it, to connect it with climate change when you're only transcribing [a] specific time because then you're not really comparing it or contrasting it to other dates or like now, so you don't think about that while you're doing it.

Another said:

I feel like if you want to learn more about it then you should. If it's not something that you are really focused on then I don't feel like you need to learn as much about it as we did.

This pointed to the need to contextualize citizen science with other material (FAQs, background information) or other activities (e.g., feedback mechanisms, forums).

Interviewees related their own learning with DRAW to climate change. They commented that they, themselves, were “strong” on the issue of climate change, that “people need to get more educated,” and that DRAW provided “proof.” An example was:

I do believe that DRAW would gain from talking about climate change a bit more because then it would...reach out better and it would give an incentive for people to see the climate change. Maybe they'll say, “Oh, really, that happened; this is how it was back then and this is how it is now.”

We asked if interviewees felt their work in our course module taught them something new. All did, with many mentioning this multiple times. New ideas included citizen science, data transcription, meteorology, and historical climatology. One student commented:

I had never actually thought of [climate and meteorological research] before this class, like I had never been introduced to it. So everything that we've been doing, like transcribing the data and even just looking at the booklets with all the climate in it, I've never seen that before.

Some interviewees felt DRAW would help the public learn about its history or learn about the work of climatologists and meteorologists. A student commented:

Montreal is a very diverse city, so I think it would be interesting for people who come here, and for people who've even grown up here, to know historically. And I guess part of that is the climate because there was lots of extreme weather—heat or snowstorms—that affected the population a lot.

Another said:

I basically learned that anyone could be doing [this] kind of thing. I always thought it had to be Bill Nye the science guy kind of people. I didn't know that a normal person could be useful to actually do stuff and that really shocked me.

Finally, a key component of knowledge translation that extends beyond classrooms or workshops (where instructors or others can help facilitate work with DRAW) is the website itself and its accessibility to users online. On the positive side, interviewees' comments focused on the clarity of instructions provided by DRAW (including the video tutorial) and the site being easy to use. Even despite difficulties reading old records, most students enjoyed a transcription process and website that they described as “relaxing” and “therapeutic” to use. The salience of the knowledge translation with DRAW included the hands-on nature of the transcription process. One noted that:

When I talked to other students who are in research methods classes, they're not actually doing research and they're not actually participating. So, it is a more interactive class and you go to class and you're like, “Oh, I'm actually going to do something, I'm not just going to sit and take notes and like listen to lectures.”

On the negative side, there were comments about the DRAW meteorological record containing difficult-to-read handwriting and symbols. Not all interviewees agreed with the idea of DRAW being totally hands-on either, with one saying:

I think that this project, it's more on your own and you're on the side and you do it and it goes on the Internet. Instead of actively going to take the measurements and just helping, it's just transcribing, instead of doing like photography with birds. I think that I feel a bit more disconnected from the research.

Students talked about the difficulty in transcribing with DRAW including when the original observers had inconsistencies in their notations such as multiple observations being recorded on the same time label or encountering new or unique symbology that DRAW researchers themselves had not seen. The legitimacy of this type of citizen meant students encountered challenges in their own research assignments. We exposed students to the way the data was recorded in the original records. The DRAW data came in 15 different logbook formats, with up to nine sub-daily observations containing as many as 47 variables per observation. Formats changed as observational standards evolved (Kingston, 1878). Students encountered observations that were crossed out (a supervisor in the observatory reported in the margins that he surmised the observer had made up the data to avoid getting out of bed). Times appeared in the dates area; symbols were in the wrong place. Cursive handwriting was a persistent challenge to interpret. The goal was to replicate the reality of historical weather data and not to make scientific data collection easy. As we discuss in the next section, the credibility of work with DRAW meant students confronted real challenges in their research assignments. At the same time, actual facts about the people of Montreal's relationship to historic weather and climate were translated for the community.

Conclusion

As the program progressed, researchers saw how citizen science could be a vehicle for engagement with a shared community history and, in some cases, sustain engagement with meteorological data transcription. We conclude with the need to contextualize citizen science when it is used as a means for climate science knowledge translation. Work with Dawson College students helps, in this way, to inform the larger DRAW community, which consists of members who work with public audiences, community groups, and

school districts. Our research examines how knowledge translation of climate science can be considered an issue of salience, credibility, and legitimacy (Meinke et al., 2006). We used citizen science as the medium for this translation and deployed it in a classroom setting during which climate scientists and social scientists interacted with students. Here we draw conclusions, explore their implications, and then examine future directions for this research.

First, while researching their own history and working on actual science proved engaging and salient for students, most students also felt archival records on their topic (accessed through microfiche reader at McGill University and Dawson College) were difficult to find, access, and read. In an Internet age of easy, freely accessible, and immediate discoverability, students are not trained to use archives that are not online. In our knowledge translation, we must take care not to make assumptions regarding discoverability and findability (e.g., that individuals will understand the data is not at someone's fingertips).

Second, the credibility, or the perceived technical quality of a project that develops two-way translations of knowledge in citizen cyberscience projects like DRAW, requires considerable contextualization to ensure knowledge translation. This includes the use of FAQs, tutorials, and blogs for context, including historical context. The need for this contextualization has been found elsewhere in the citizen science literature (Sieber & Slonosky, 2019; Garbarino & Mason, 2016).

Third, the legitimacy, or perceived objectivity of the translation process, helped us sustain engagement and provide contextualization to the transcription work students did with DRAW. Students who transcribed records and completed historic research connected both to the wider DRAW community and to members of the public concerned with matters of policy related to climate, weather, and historical conservation. Their contributions not only meant engaging with these disparate audiences but also learning new skills from the social and natural sciences. These skills might enable students to play an active role in the community where technical abilities or critical thinking might be highly valued or needed.

Finally, our study uses the classroom to examine knowledge translation through citizen cyberscience that can often be difficult to study

when users are alone and at home. This research offers insight into the potential for projects such as ours, particularly when the public becomes engaged in the process of recovering knowledge about their community's historic relationship with climate and weather. The legitimacy, or perceived objectivity, of the translation process, helped us sustain engagement and provide contextualization to the transcription work students did with DRAW.

Future Directions

Our results help to determine how well the coupling of citizen science through DRAW with archival research in the humanities translates knowledge about weather, climate, and historical meteorology. The citizen science represented here engendered engagement in the history of the community in which students lived. This points to some important implications for future research. While archival research can be difficult for students to access, steps to addressing this concern are readily available. During the course of creating our program, we searched for records. This search led to discussions with the editor of *The Montreal Gazette*, who wanted advice on how to make their archives public as a means for preserving them. Future curricula developed as part of the DRAW project can utilize such partnerships and might (in response to comments in exit interviews) better tie student transcription with DRAW to the ways in which community members engage scientific researchers and policymakers in decision-making. Although we have since replicated this course, we expect to collect and analyze more results than from just two iterations before we generalize important findings.

This study also indicates the role of knowledge translation and citizen science in relation to climate change where scientific research remains highly technical and obscured by political debate. Two-way forms of knowledge translation that benefit citizens as well as scientists (Graham, et al., 2006; Delfanti, 2010), even when they occur strictly online as in citizen cyberscience, would do well to ensure the type of contextualization found in this course module. This contextualization can be integral to sustaining public engagement in future projects that like ours not only require crowdsourced efforts but also seek to build two-way forms of knowledge translation.

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■ 1. Group Research Assignment

DRAW Module: Final Assignment (15%)

Course: Research Methods–Section 07

Instructor: [Instructor Name]

Semester: Winter 2018

Background

You've now learned how to transcribe data using the Data Rescues: Archive and Weather project (<https://test.citsci.geog.mcgill.ca>). You've also learned about trends in Montreal's historical climate and how human social, political, and cultural processes can often relate to climate or weather. For this module's final assignment, you will now put together these two skills to conduct your own research on the relationship between weather and human processes in the City of Montreal in the late 19th century. This assignment involves working in a group of two or three and each group will choose their own topic to study.

Instructions

1. Select a topic from the handout provided and let me know the topic that your group has chosen. Each group will have to work on their own topic, so some topics may not be available if other groups have already selected them.
2. Write a hypothesis where you make predictions about the influence of weather on your chosen social event, if you chose this category of topic, or the effect of the extreme weather event on Montreal in general, if you chose this category of topic. The hypothesis should be a paragraph in length and include specific predictions about societal responses to weather on that date. Complete the topic development exercise on the assignments section of Lea by the end of class on April 5th and save a copy for your records. You only need to submit one copy per group—include the name of your partner(s) on the document that you submit.
3. Complete a transcription of DRAW data for the date that your group selected (*see bottom of document for instructions to access a specific date.) Print and save your completed work for inclusion when turning in your final assignment. If this will help your analysis, copy and paste your transcribed data into an Excel sheet (provided to convert the values to modern scientific units). Complete two graphs showing the change in two weather variables over the event time frame. Use an appropriate graph format (line graphs or histograms are often best for time-related data) and paste these graphs into a Word document. Beneath each graph discuss the trend/pattern shown in a paragraph (i.e., one paragraph per graph). Include comparisons between the weather on this date with what is typical.
4. Conduct background research into either a) the risks associated with the type of extreme weather event you have chosen, or b) particular details of the social or political event that your group selected. Summarize your findings in two or three paragraphs (200–300 words) beneath your answers to the first section. Consider using websites from government agencies, universities, historical archives, and the print collection in the Dawson (or any other library) to develop your answer to this question. Some potentially valuable sources are included on the topic handout sheet.
5. During your visit to the McGill University Archives, search the microfiche collection and find coverage for the event corresponding with your date in The Montreal Gazette archives. Save a PDF or JPEG of at least one article that provides coverage or mention of your event and paste this into your assignment.
6. Use Google Earth to identify locations in Montreal that are pertinent to your topic (e.g., locations mentioned in sources that you found, places that you believe were at strong risk due to extreme weather, etc.). Use the placemark and/or polygon tool to identify these locations and then save and insert a Google Earth view into your assignment. Write a summary of this event beneath the Google Earth image that is 200–300 words in length.

7. Revisit your research question and tentative research hypothesis and discuss what you have found in comparison with what you originally predicted in 150–200 words.
8. Write a paragraph conclusion describing challenges in the research process for your group and describe anything that was particularly interesting, surprising, or otherwise of note that you discovered in your research.
9. Complete a cover page and a works cited page in APA formatting. Use size 11 or 12 point, Times New Roman and 1.5 or double spacing.
10. Submit a digital copy of this through Lea by the end of the day on April 19. A 5% penalty will be applied if it is not complete by midnight on April 19, with an additional 5% for each day of lateness thereafter.

*To access a transcription page for a specific date on the DRAW website, click on “transcribe a page” in the centre top, then click on “my transcriptions”; scroll all the way down; there’s a button at the bottom which says “view all transcribable pages” (it’s well hidden!)

■ 2. Group Research Assignment Rubric

1. Topic

- 2–Clear well-articulated topic as it connects to climate/weather or DRAW.
- 1–Topic not entirely clear or connection to climate/weather or DRAW a little unclear.
- 0–No clear topic or connections to climate/weather or DRAW.

2. Hypothesis

- 2–A well-developed paragraph that makes a clear and accurate prediction about: 1) the influence of weather on the chosen social event, or 2) the effect of the extreme weather event on Montreal in general. The paragraph includes multiple specific predictions about societal responses to weather on the date.
- 1–A well-developed paragraph that makes predictions about: 1) the influence of weather on your chosen social event, or 2) the effect of the extreme weather event on Montreal in general. There are minor inaccuracies in the way the relationships are described, the influence of weather on social events, or on a few details. There may also be parts of the paragraph where the response is not entirely clear or specific. Their response includes a few specific predictions about societal responses to weather on the date.
- 0–The paragraph is not well-developed or does NOT contain clear or accurate predictions. The group may NOT have understood the relationship between the events and their particular weather record or has left out important details or other significant information in relation to their topic. Their response does not include multiple specific predictions about societal responses to weather on their date.

3. DRAW Transcription

a. Converted Data

- 2–The data converted is the correct/appropriate data and is displayed in a way that is clearly visible.
- 1–The data is correct but as imported into the assignment submitted, it might be hard to clearly read. It may also contain some inappropriate data with the correct data.
- 0–Incorrect/inappropriate data or completely unreadable import into the assignment.

b. Two Graphs

- 2–The assignment includes two graphs with clear titles, axis labels, data labels (if needed) and a good choice of graphs that accurately represent the data. They must have two different variables.
- 1–A poor choice of type of graph is made for either of the two graphs or the graphs don’t include key elements that are important to understanding what is displayed. Minor errors in representation of the data in the graph.
- 0–The graphs are illegible or not included; or the data is inaccurately represented.

4. Appropriate Background Research

- 2–The assignment contains a 2–3 paragraph literature summary (200–300 words in length that clearly states either: 1) the risks associated with the type of extreme weather event you have chosen, or 2) particular details of the social or political event that your group selected. The assignment includes AT LEAST three sources that may be from websites from government agencies, universities historical archives, and the print collection in the Dawson (or any other) library (including any listed on our topic handout sheet).

1–The assignment contains a 2–3 paragraph literature summary (200–300 words in length) that clearly states either: 1) the risks associated with the type of extreme weather event you have chosen, or 2) particular details of the social or political event that your group selected. It may contain minor inaccuracies, misstatements, or other unclear parts. The assignment includes AT LEAST two sources that may be from websites from government agencies, universities historical archives, and the print collection in the Dawson (or any other) library (including any listed on our topic handout sheet).

0–The assignment contains a literature review that is less than 200–300 words or 2–3 paragraphs and doesn't clearly answer either of the prompts above. The section may contain major inaccuracies, misstatements or other unclear parts. The assignment includes one or fewer sources.

5. Newspaper or Other Historical Document

2–The assignment includes a clear, easily legible newspaper or historical document.

1–The assignment includes an unclear newspaper or historical document.

0–The assignment does NOT include a newspaper or historical document.

6. Map

2–The assignment contains a clear map with a well-developed paragraph that clearly explains what is contained in it AND its relationship to the topic the group has researched. Locations are clearly identified on the map and relate directly to the group's topic.

1–The map contains minor inaccuracies or the paragraph is unclear in places explaining what is pictured in the map. Locations are mostly clear, but perhaps not specific enough.

0–The map has major errors or the paragraph is unclear. The locations are not clearly delineated or the explanation of them in the paragraph is unclear.

7. Conclusion

2–The original hypotheses are restated clearly and answered as to whether they were rejected or supported. They used real evidence from their own research to support their conclusion.

1–The original hypotheses are restated but they are not all clearly rejected or supported.

0–It's unclear what the original hypotheses were or whether the group rejected or supported them.

8. Challenges

2–The group wrote a clear paragraph articulating well thought-out challenges they faced and how they dealt with them.

1–The paragraph is clear but the challenges are not well thought-out or the way they faced them is not included.

0–The paragraph is unclear or doesn't clearly include challenges and how the group faced them.

9. Cover and Works Cited Pages

1–Gave references

0–Did not give references

■ 3. Written Reflection Prompts

Class Session One Reflection

In one sentence, write down the most important point you learned about citizen science today.

In 1–2 sentences, describe why it might be important to have the public transcribe data with the Data Rescue: Archives and Weather project.

Class Session Two Reflection

First, divide your sheet of paper into two sections: "Pro" and "Con."

Write a list of features from DRAW that you think fit in each section. (These can be things we discussed about the site or anything you noticed today.)

Next, in one sentence, write down the main thing you learned about DRAW.

Class Session Three Reflection

Today your group was asked to think about how climate and weather may relate to human social, cultural, and political processes.

Write an exam question on this topic. It may be open-answer, essay, or multiple choice.

Class Session Four Reflection

Write down the research question you will investigate for the module final assignment. Generate a tentative research hypothesis—a paragraph in length—that includes specific predictions of the influence of weather on your chosen date on social, cultural, and/or political aspects of Montreal.

In one sentence, write down what parts of your research with DRAW or McGill University's archives might be most difficult.

In a second sentence, write down what parts you think you will most enjoy.

■ 4. Exit Interview Protocol

Please note: Students who took part in interviews previously signed a consent form for all of the research they wished to take part in during our research (including the exit interview.) This form contained all of the relevant information for informed consent and about the \$20 CAD compensation students were given for taking part in an interview. In our protocol, we also reminded them of important elements of their informed and voluntary consent when taking part in an exit interview.

To be read by the interviewer: We are interested in knowing more about how you felt about the Data Rescue: Archives and Weather (DRAW, <https://citsci.geog.mcgill.ca>) course module. In addition, a few questions will ask about your background. This interview should take 20–30 minutes depending on the length of your responses.

We are interested in any of your views. Please remember, there are no correct answers to any of these questions. You may also stop this interview at any point should you wish to do so.

Questions on Climate Science/DRAW/Citizen Science

1. Previous to this class, did you feel like you understood the research methods of climate scientists? How about those of historical climatologists?
2. Name two scientific research ideas you learned during the DRAW module. Was there a specific part of the course that you found useful in learning these concepts? If the student needs guidance, suggestions include 1) class lectures, 2) the module assignment, 3) in-class exercises/discussions, 4) reading, 5) work with DRAW in lab.
3. Do you think citizen science constitutes a real research method for scientists who are working to examine climate/weather data? How do you think it differs from other forms of citizen science?
4. Who do you imagine might be the audience or user for this data? In what ways did you learn this data might be used during the DRAW module?
5. Did work with the DRAW project alter your views of climate research, specific scientific processes, or issues related to climate and weather?
6. What do you think the average person learns when they transcribe data for DRAW? How could this learning be improved?
7. How much did this experience change your view of what scientists do when undertaking scientific research on climate or weather? In what ways?

Questions on Working with DRAW

8. Do you think DRAW would benefit from being more explicitly linked to studies of climate change? Why or why not?

9. What do you think were the greatest challenges in working with DRAW? Were any parts of the website/transcription process difficult for you to use? Did you need to take breaks?
10. How do you feel your own transcription process went? Was it difficult to stay focused? Read handwritten records? Do you think you made any errors? Did you find it easy or hard to find your place on the page of a handwritten document?
11. How would you change the DRAW website to make it more accessible to the general public?
12. Despite difficulties you had, if any, do you feel this was a worthwhile activity? Why or why not?
13. What did you like about transcribing these records for DRAW? What did you dislike?

Questions on Humans and Climate/Environment

14. During the DRAW module, what did you learn about Montreal's historic climate as it related to important political, social, and cultural events taking place?
15. Do you think it's important for Montreal/Quebec residents to be aware of this data and their history? Why or why not?
16. How do you think Montreal/Quebec residents should be engaged with this project? What types of events or outreach efforts do you think would be successful?

■ 5. Pre/Post Exam Analysis

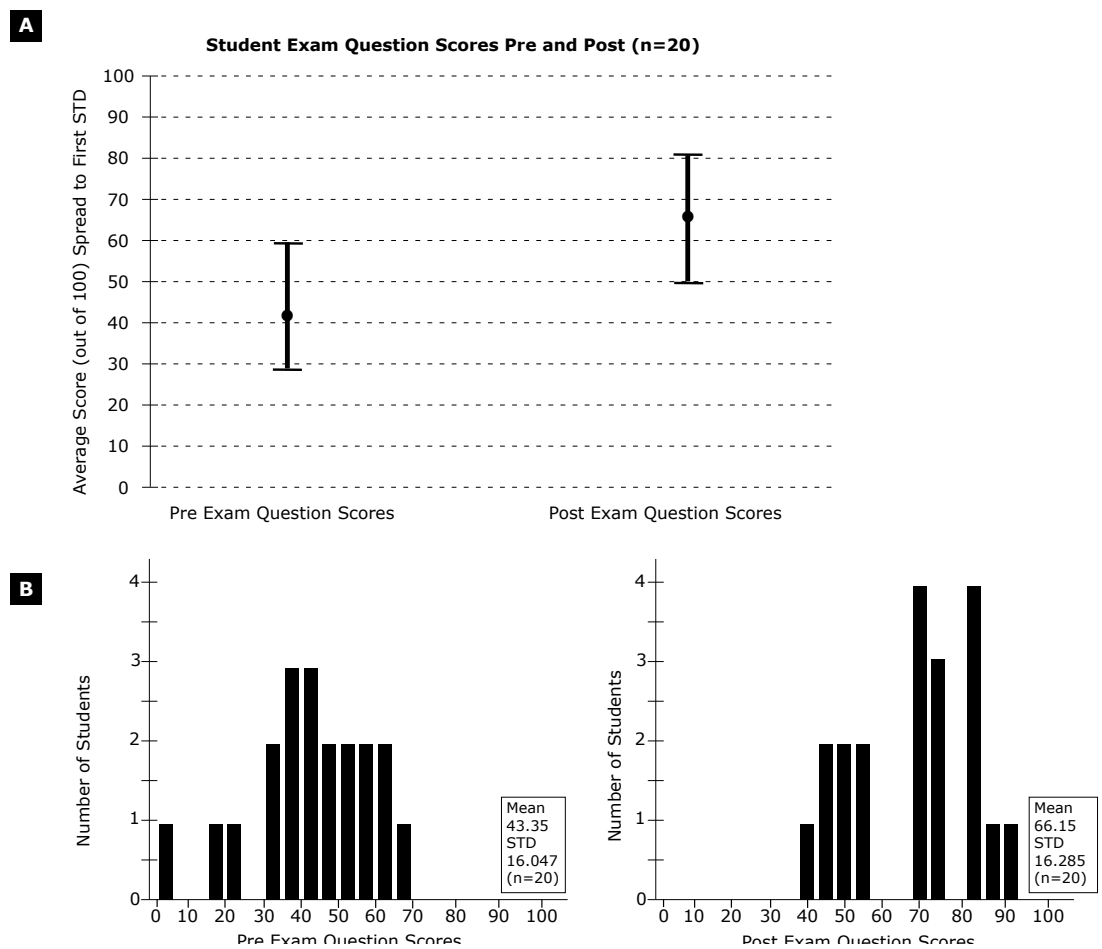
While not reported on in this manuscript, we include a measure of knowledge translation we captured from our course using pre- to post-exam questions. We correlated each of the multiple choice and short answer exam questions to specific learning outcomes of our course. Each of the bolded numbers in parentheses at the end of exam questions following are correlated to learning outcomes reported in this manuscript. We also include a figure reporting on how student scores changed from before and after our course.

Our pre/post-exam questions allow us to look at knowledge transfer quantitatively. It enables us to examine conceptual learning gains qualitatively in the form of eight short answer questions. Pre/post-exam question scores were graded out of a total possible score of 100 points. We designed pre/post exam questions that included five multiple choice (4 points each) and eight short answer questions (10 points each) with equal numbers of questions in each section aligned to each learning outcome.

The quantitative results from our pre/post-exam questions and group research assignments identified which pieces of knowledge were transferred during our course module. The instructional approach that included DRAW resulted in a significant increase from before the instruction to after. (Supplementary Materials Figure 1.) Our five multiple choice questions assessed (both pre and post) whether students had knowledge of who originally recorded weather at McGill University's Observatory, the relationships between climate, weather, and human events, and what students knew about the scientific process and sources of error. Most students improved in identifying a climatic event that impacted human society (12 out of 20), the backgrounds of people who recorded the original meteorological data (16), and how scientists communicate findings (16). On the post exam, the class struggled to identify an example of a specific human event being tied to a single incident of weather (14 out of 20) and in defining the idea of a climate reconstruction (14).

In the short answer section, individuals did well naming their own examples of human events that were impacted by extreme weather or climate. However, students continued to do poorly at identifying the common traits held by such events—perhaps because this concept needed to be better stressed by instructors in relation to the phrasing of the question. A typical full credit response included: “Generally, humans tend to adapt to intense climatic/weather events by staying inside and being cautious (e.g., ice storm, snow storm, etc.) or by evacuating the area affected (e.g., heat wave so people go up North or flooding so people leave city”). Students did demonstrate conceptual understandings of citizen science, meteorological research as represented by DRAW, and sources of error in the observations. Individual students showed learning gains in terms of identifying ethical concerns with citizens participating in research, the benefits/drawbacks of citizen science to scientists, and in writing their own hypotheses that DRAW could be used to answer. (See Student Exam Question Scores next page.)

Supplementary Materials Figure 1. Pre and post exam question scores (n=20) allow quantitatively whether knowledge translation took place during our course module. (A) Paired-samples T-Test was used to determine whether there was a statistically significant mean difference between the pre- and posttest score averages for the group (n=20). Students scored better on the posttest (66.15 ± 16.285) in comparison to the pretest (43.35 ± 16.05), a statistically significant increase of 22.80 (95% CI, 16.39 to 29.22) points, $t(19) = 7.439$, $p < 0.0005$, $d = 1.66$. The effect size for this change could be considered large (Cohen, 1988). (B) Distributions of scores indicated that while no students scored above 70 points (out of 100) on the pre exam questions, almost half the class did (n=9) on the post exam.



6. Pre/Post Exam Questions

Section I: Multiple Choice Questions (2 points per question answered)

- During the time period 1874–1900, historical climate and weather data records were taken originally by whom at the McGill University Observatory? (1.1)
 - Trained amateur scientists
 - Doctors
 - Professors and students
 - Lawyers
 - Scientists
- An example of a specific human event being tied to an incident of weather or climate: (3.1)
 - Use of frozen waterways for wintertime transportation of goods and peoples
 - Riots over the Boer War at Laval University being quelled by a wintertime blizzard
 - Montreal residents escaping to suburbs and rural areas to escape summer heat waves
 - Social activities being planned during wintertime when residents returned to Montreal
 - None of the above

3. An example of trends in climate being tied to broad human cultural patterns includes: (3.2)
 - A. People still came to celebrate during the Queen's Jubilee despite heavy rain and inclement weather in Montreal
 - B. Riots over the Boer War at Laval University being quelled by a wintertime blizzard
 - C. Floods, high food prices, and political turbulence leading to the 1917 conscription crisis
 - D. Social activities being planned during wintertime when residents returned to Montreal
 - E. None of the above

4. When a scientist takes part in publishing papers based on the data found in DRAW, he or she is undertaking what part of the scientific process: (4.3)
 - A. Formulating hypotheses
 - B. Skepticism
 - C. Communicating findings
 - D. Citizen science
 - E. All of the above

5. If a scientist utilizes historical climate records to find inaccuracies in the instrumental temperature record or confirm periods of warming/cooling, he or she is: (4.2)
 - A. Conducting climate reconstruction
 - B. Calibrating their model
 - C. Confirming anthropogenic climate change
 - D. Conducting improper research
 - E. Re-checking data from proxy or reanalysis data

Section II: Short Answer Questions (5 points per question answered)

Answer each of the following questions. Your answer to each question should be a paragraph (50–75) words in length.

1. What are two ethical concerns that had to be addressed in order for you to participate in the DRAW project? How did the researchers address those concerns in their research design? (2.2)

2. What are two potential sources of error in the measurement of the original climate data? (1.2)

3. Based on your participation in the project, what are two potential sources or error in the digital transcription of McGill's historical climate data? (1.3)

4. Describe the pre/post questionnaire format using concepts of survey design discussed in this course. (2.1)

5. What is the type of sampling method used for the questionnaires in the DRAW project? Discuss one advantage and one disadvantage of this sampling method. (2.3)

6. Discuss two traits common in human events that coincided with some climatic or weather related event. (3.3)

7. Write a hypothesis you expect to be true about Montreal's past climate. Explain in a sentence whether DRAW could be used to prove or disprove this hypothesis. (3.4)

8. Take a position: Explain how citizen science research may 1) improve or 2) decrease the accuracy of scientific data. Justify your argument in one or two sentences. (4.1)

■ 7. Pre/Post Exam Questions Short Answers Rubric

Question One

2–Any two of: 1) Informed consent; 2)Anonymity of responses; 3) Voluntary; 4) Instructor and researcher separation of roles; 5) Students could choose to participate in different parts of research (not all); 6) Risks of taking part in this research; 7) Students can leave the research at any time; and 8) At the conclusion of the research, all data will be destroyed.

1–Any one of the above.

0–None of the above.

Question Two

2–Reasonable explanations for human or instrumental error from historical meteorology (i.e., student recorder slept through, misinterpretation of weather, misunderstanding of data entry, the technology not being as accurate historically, gaps in the record or the historical materials due to non-collection of data).

1–Only one of the above.

0–Nothing that is reasonable and/or fits within those broad ideas above.

Question Three

2–Anything that's reasonable and related to the transcription process (i.e., entering the wrong date with a row), entering incorrect information, hard to read handwriting, misinterpretation of symbols, human error due to lack of training.

1–Only one of the above.

0–Nothing that is reasonable and/or fits within those broad ideas above.

Question Four

2–Any answer that correctly describes measurement of knowledge and attitude change from pre (before the intervention with DRAW) to post (after the intervention with DRAW).

1–Any answer that contains elements of the right answer above but not the full right answer.

0–Missing any element of the right ideas above.

Question Five

2–Any answer that denotes that it is non-random sampling because we worked with a specific population intentionally (advantage). One disadvantage is it makes this only quasi-experimental and a sample that may not be generalizable because it was not randomized.

1–Some element of the right answer above.

0–None of the right ideas above.

Question Six

2–There are climate or weather conditions that directly impact human behavior (e.g., storage of food, going home to shovel, travel methods, events planned, displacement to the countryside during summer heat waves, illness). Or any answer that gives two examples that include these attributes.

1–Only one of the right answers above.

0–None of the right ideas above are encapsulated in the answer.

Question Seven

2–Any reasonable hypothesis about the DRAW record that it actually could be used to answer.

1–An answer that is mostly reasonable but has some kind of flaw in reasoning or might not be answerable by the DRAW record.

0–Nothing is right about the answer either in its reasoning or ability to be proven/disproven by the DRAW record.

Question Eight

2–A clear direct statement for/against citizen science's impact on scientific data. At least two sentences that justify the position taken.

1–Only one sentence of justification or some unclear position statement, but enough elements of a correct answer above to warrant one point.

0–No correct elements of the right answer above.