Data-Driven Science Vlogging for Connected Learning Anywhere

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Introduction: Social Media in Science Education

Social media can promote formal and informal science education. Student-generated digital media such as chemistry vlogs (“video blogs”; Lawrie and Bartle 2013) have been used for students to express understanding of science concepts and co-create knowledge. When such content is shared on social media platforms like YouTube or TikTok (Hayes et al. 2020), they can facilitate public participation in scientific research and science education (Shirk et al. 2012), effectively turning social media into public spaces for inquiry and learning or even communities of practice for citizen science (Liberatore et al. 2018).

During the COVID-19 pandemic, students and teachers have used social media to create everything from anthropomorphized chemistry videos (Hight et al. 2021) to a virtual biomechanics camp (Burks et al. 2021). However, in most cases, existing social media platforms like TikTok were repurposed for science education. In general, these platforms lack technical features to support deep inquiry and active learning. For example, more than half of science-related videos on TikTok involve demonstrations of *science in making* such as experiments and DIY projects (Zeng et al. 2021), but there is no easy way for the experimenters (i.e., “science vloggers”) to share their experimental data with the viewers for analyses, which is vital for evidence-based reasoning. These original data are typically archived on the vloggers’ computers and not shared with anyone else for further investigations. For the vlog viewers, their experience is typically limited to watching and listening. They have no access to the experimental data, thus no opportunity to develop skills such as using mathematical modeling and computational thinking to analyze data and construct explanations, which are core competencies in science and engineering practices defined by the Next Generation Science Standards (NGSS).

A New Cyberinfrastructure for Science Vlogging

A lesson learned from the COVID-19 pandemic is that we need to build informal science learning environments that are resilient to natural disasters of such scale. This paper describes our preliminary work that transforms social media into a new type of interactive learning environment with data-driven capabilities. Based on the Internet of Things (IoT) technology, this new cyberinfrastructure, referred to as Telelab (Xie et al. 2021, Xie et al. 2022), allows users to use smartphones and accessory sensors to collect experimental data along with videos that choreograph their actions and procedures, anytime and anywhere. Users can choose to upload their experimental data, alongside videos, to the Telelab website to share their experiments with others. They can either livestream their experiments or observations to an audience in real time or create interactive videos that allows viewers to experience their experiments or observations later. Viewers can visualize and analyze published data of an experiment with a graphical user interface (GUI) in their own browsers. As in typical social media platforms, viewers can share, rate, or comment on an experiment. A new feature that distinguishes Telelab from other social media platforms, which is enabled by its data-driven and sharing characteristics as an IoT technology, is the ability for a viewer to reuse the experimental data and conduct their own analyses or even meta-analyses (i.e., analyze a series of experiments--rather than a single one--to examine patterns and trends across the board).

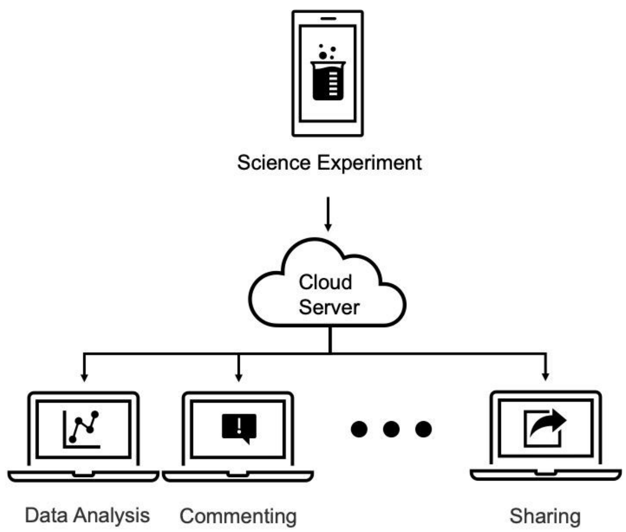


Figure 1. An illustration of the Telelab infrastructure. Student vloggers use a smartphone and accessory sensors to record science experiments and observations. Video and sensor data are saved to the cloud server and shared with viewers, who can use the Telelab web app to analyze experimental data, comment, rate, and share the experiments.

Using a thermal camera attached to a smartphone as an example of the sensing part of the platform, we present three activities to demonstrate how Telelab supports connected science learning through science vlogging in informal settings: (1) garden science: students inspect animals around them to learn about thermoregulation; (2) kitchen science: students observe interactions between common food ingredients to learn about physical chemistry; (3) building science: students inspect public buildings in their community to learn about heat transfer and energy efficiency.

Garden Science: Butterfly Thermoregulation

Beginning in September each year, millions of monarch butterflies travel thousands of miles from Canada to Mexico. While their migration is a spectacle to behold, climate change is posing a threat to these creatures (Bladon et al. 2020). Just like how biologists have used infrared thermography to study how butterflies respond to temperature changes (Tsai et al. 2020), students can also use a smartphone thermal camera to observe butterflies in a garden and discover how they thermoregulate under different conditions.

In this activity, students use the Infrared Explorer, a mobile sensing app as a frontend of Telelab, to control the thermal camera and observe butterflies in the shade (Figure 2a) versus under the sun (Figure 2d). Thermal images of a butterfly show that its temperature is similar to the ambient temperature when it is in the shade (Figure 2b), but its temperature is higher than the ambient temperature when it is under the sun (Figure 2e). When students connect the Infrared Explorer app to the Telelab server, they can record the thermal video along with the temperature data, upload it as an interactive video to the Telelab cloud server, and share their discoveries with anyone through the Internet.

Viewers of such an interactive video can use the shared data to perform their own analyses. For example, one viewer may use the built-in virtual thermometer tool to calculate the exact temperature difference between the butterfly and the surrounding environment. Another viewer may use the area measurement tool instead to obtain smoother temperature readings. Yet another viewer may use the graphing tool to confirm whether the temperature difference persists over time (Figure 2c/f). Rather than being given the conclusion directly, viewers can collect different formats of evidence through their own data analyses to support the claim that the butterflies are *poikilotherms,* whose temperature fluctuates significantly, and that they thermoregulate mostly through behaviors like basking. Such opportunities of observation and analysis, amplified by the Telelab platform, can help viewers investigate what it takes for *ectotherms* (species like butterflies that regulate body temperature depending on the environment) to survive and why certain temperature-sensitive species are particularly vulnerable to climate and habitat change (Bladon et al. 2020).

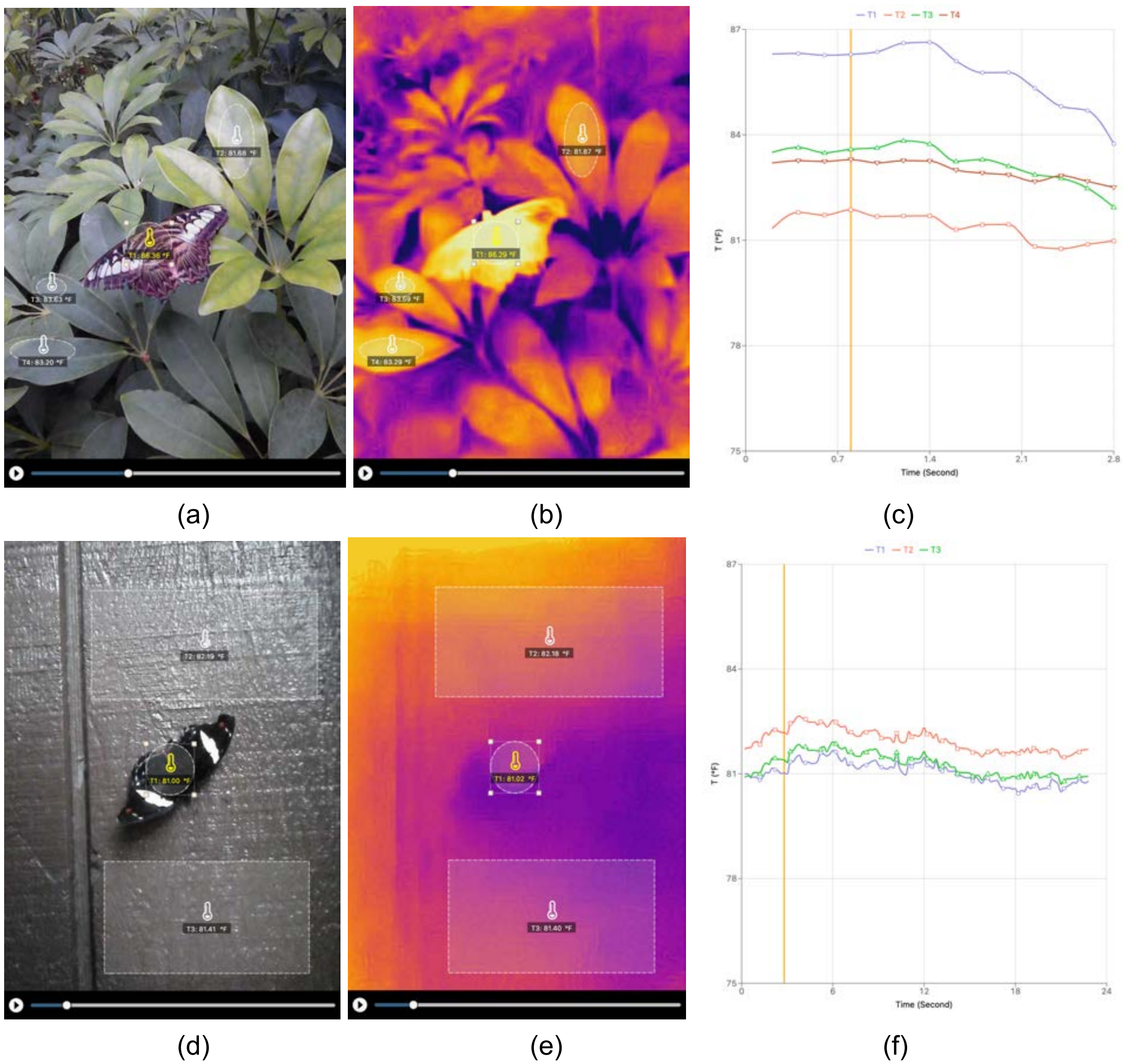


Figure 2. (a) A brown clipper (*Parthenos sylvia*) in a dorsal basking position on top of some plants. (b) Thermal imaging shows that the brown clipper is several degrees Fahrenheit warmer than the ambient when it is basking in the sun. (c) A temperature vs. time graph also shows that the brown clipper is consistently warmer than the environment. Telelab link: https://telelab2.intofuture.org/clip/613f3b10654598002489dd34 (d) A Heliconius butterfly resting on a wall. (e) Thermal imaging shows that the Heliconius butterfly has about the same temperature as the ambient when it is hiding from direct sunlight. (f) A temperature vs. time graph also shows that the Heliconius is consistently at the same temperature as the environment. Telelab link: https://telelab2.intofuture.org/clip/613e491026d4316f2ef6a2e1 (These observations took place at The Butterfly Place in Westford, MA.)

Telelab provides the cyberinfrastructure for anyone to contribute such observational data from anywhere. For example, informal science educators like field scientists working in nature reserves can livestream butterfly observation data and give guest lectures to classrooms all over the world. Students from different geographical areas can also share science vlogs of local butterfly species on Telelab. As creators, they are making personally relevant observations in their own living environment and contributing experimental data to an open science community. As viewers, students can explore the biology of different places that they otherwise might not have access to, connect phenomena that they observe out of school with biological principles that they have learned in school, and contextualize global issues such as climate change by interacting with these science vlogs.

Kitchen Science: Boiling Point Elevation

Social media allows science-related content to be shared and imitated by its community of users, creating *science memes* (Zeng et al. 2021). Just like how coding platforms like Scratch allow novice users to interact with another user's coding project, examine the source code, and add their own edits (also known as "remixing"), Telelab also allows users to interact with science vlogs and perform their own data analyses. Users can even "remix" by tweaking the experimental design, performing their own experiments, and sharing them as new science vlogs. A perfect backdrop for such activities is the kitchen, a familiar place for measurement and experimentation.

For example, many students are familiar with the trick of adding salt to water when boiling pasta, and they may even have some hypotheses about the mechanism behind this phenomenon (e.g., "salt heats up/cools down the water when it dissolves"). Before rushing online for existing explanations to verify their guesses, students can attempt to test them on their own by conducting a simple experiment, where they heat up the same amount of tap water and salted water under the same settings. When students use a thermal camera and the Infrared Explorer app to stream the boiling processes to Telelab, they create an interactive science vlog with rich temperature data across space and time that allow any viewer to participate in the inquiry by constructing their own reasoning. By comparing the temperature changes of salted water and tap water over time using virtual thermometers and the graphing tool on Telelab, viewers can conclude that people add salt to pasta water because this nonvolatile solute elevates the boiling point of water, raises its final temperature, and accelerates the cooking process. If viewers have questions about the experiment design or need any supplementary data, they can also interact with the creator in the comment section (Figure 3).

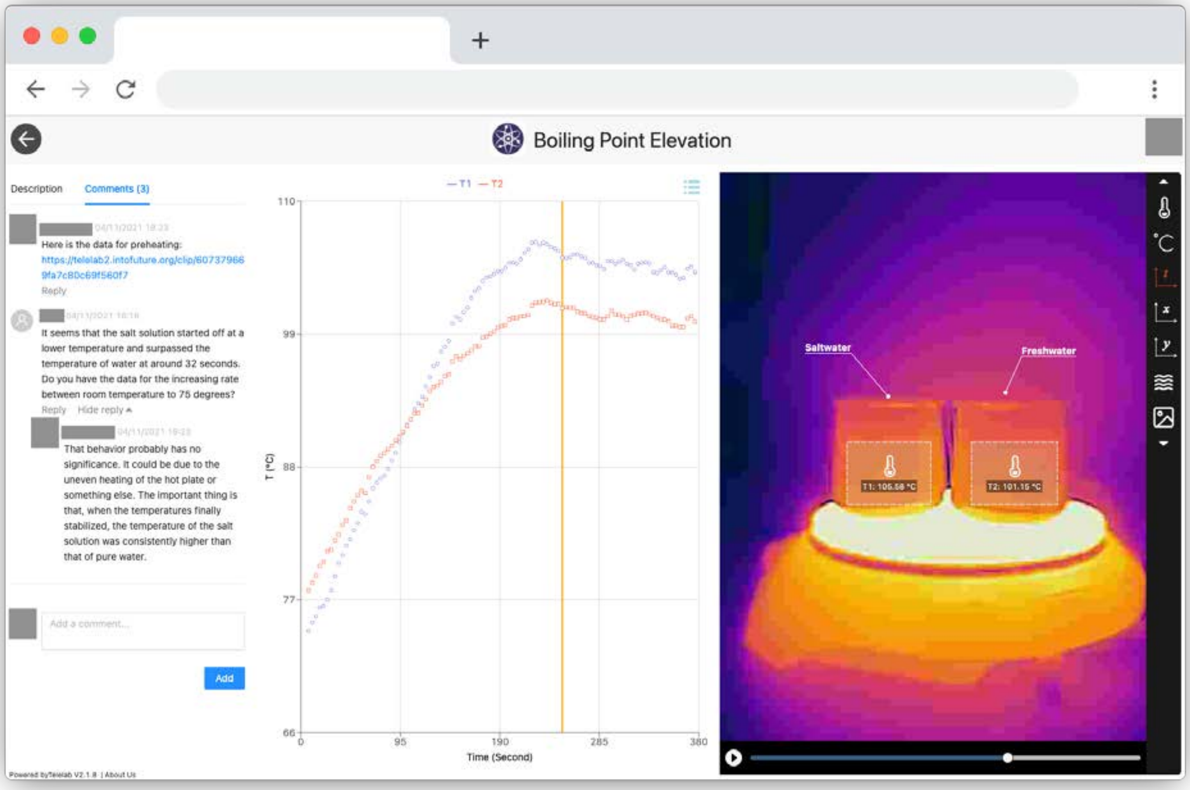


Figure 3. A screenshot of a science vlog about boiling point elevation on Telelab. The experiment uses a beaker of salted water and a beaker of tap water on a hot plate. Viewers can add virtual thermometers to the thermal image and generate a temperature vs. time graph, which shows that the water temperature reaches a higher plateau in the salted water than in the tap water and indicates that salt water has a higher boiling point. Viewers can also discuss the data analysis with the creator in the comment section. Telelab link: https://telelab2.intofuture.org/clip/60737a389fa7c80c69f5a6c2

The shared experimental data allow viewers to not only imitate the kitchen experiments described in the vlogs, but also ask new questions about the phenomena involved. For example, viewers may wonder what will happen to the boiling point if they add even more salt into the water, if they use a different condiment like sugar as the solute, or if they use a different liquid. In this case, viewers can become creators by remixing the experiment design and publishing their own experiments to Telelab (e.g., Figure 4). Their remixed science vlogs will in turn allow other students to perform their own analyses of the temperature data, identify patterns such as slopes and plateaus, and compare different factors that affect boiling point along with the creator. As more students publish their attempts to imitate or remix these kitchen science experiments, they will not only explore a much bigger problem space around the original phenomena than they individually will, but also contribute open experimental data that all students can reuse and analyze.

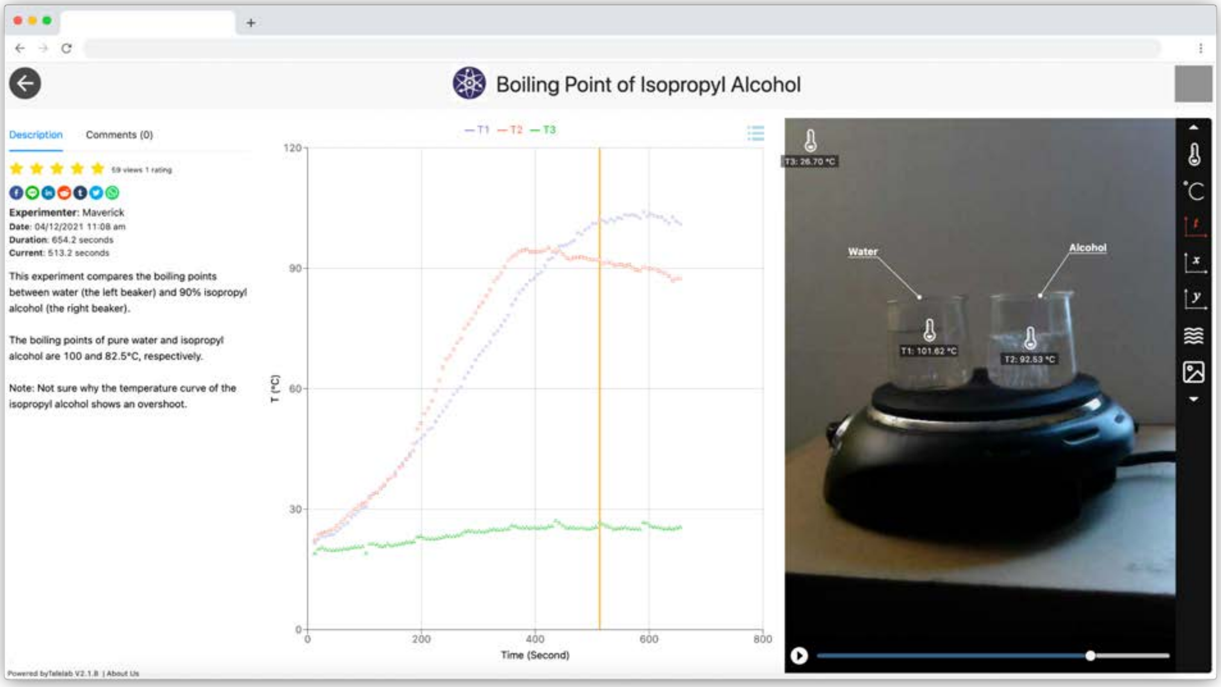
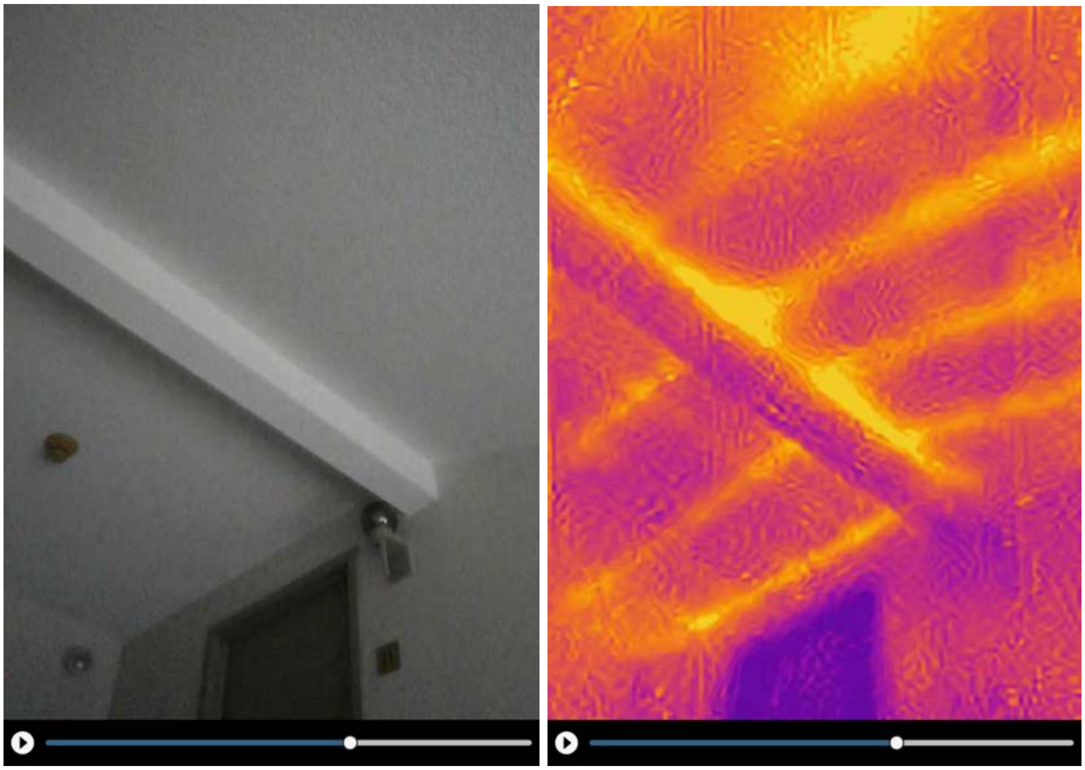


Figure 4. A remix of the previous boiling point experiment that shows the effect of solution type on boiling point. Viewers can use virtual thermometers and temperature graphs to compare the boiling point of water with that of alcohol and conclude that alcohol has a lower boiling point. Telelab link: https://telelab2.intofuture.org/clip/6074625e9fa7c80c69292bd6

Building Science: Energy Efficiency

Buildings consume large amounts of energy to provide heating and cooling, but if a building wastes some of the energy and consumes more than is necessary to maintain a comfortable temperature, then it isn't energy efficient. Energy waste can cause an array of issues from exorbitant electricity bills to urban heat islands, but people are often unaware of its cause - undesirable heat transfer - due to lack of evidence. After students have learned about heat transfer in school, a science vlogging platform like Telelab allows them to apply their knowledge in personally relevant out-of-school contexts such as their own communities, gives them the tools to inspect buildings and streets in their neighborhood for instances of energy waste, and engages them in a citizen science effort to optimize building energy efficiency by eliminating hidden processes of energy waste.

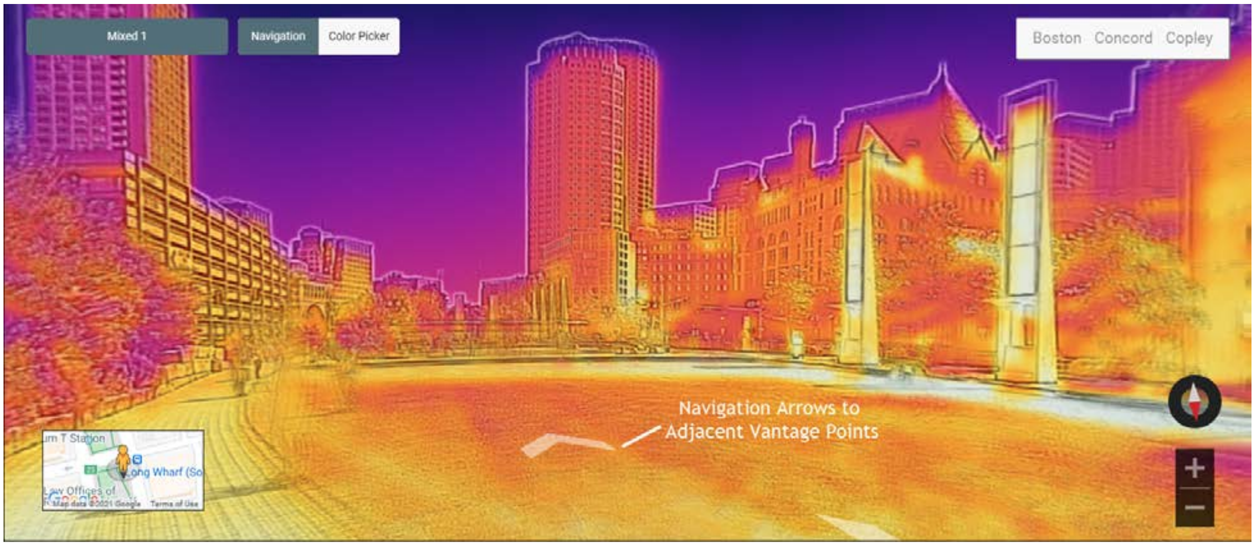
As an example, thermal bridging is a phenomenon commonly found in many wood-framed buildings, where components with a higher thermal conductivity create paths for easy heat transfer between the external environment and the inside of the building and result in energy waste. Students can use a thermal camera to create science vlogs in public buildings by inspecting common locations where thermal bridges are likely to occur, including floor-to-wall junctions and wood members in floors, walls, and ceilings. When they find any temperature differences that indicate thermal bridging, they can use Telelab to share their science vlogs with community stakeholders, who can verify the temperature data themselves and use the thermographic evidence as the basis for retrofitting and remodeling recommendations (Figure 5).



(a) (b)

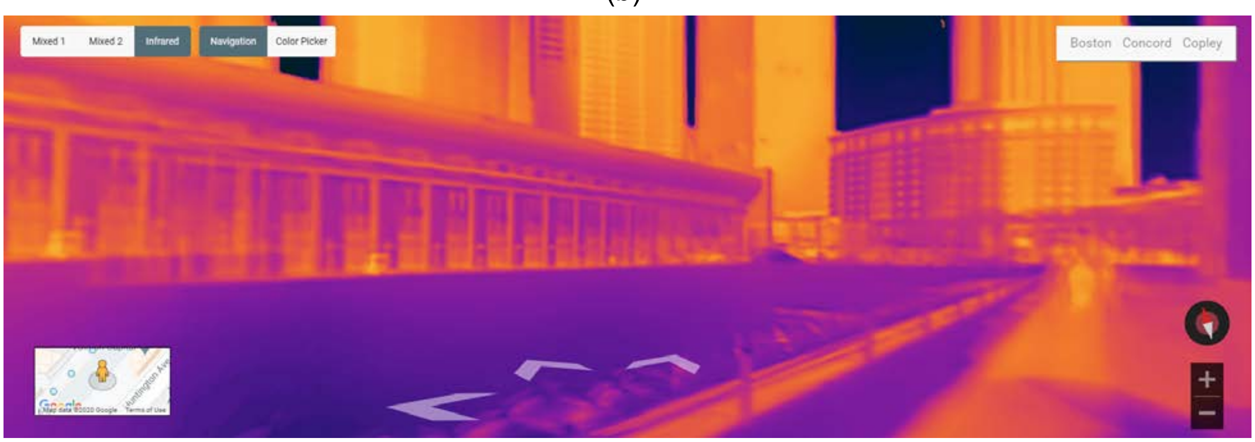
Figure 5. (a) Interior view of a roof with a visible beam during the day. (b) Thermal image reveals that the hidden joists connected to the beam are warmer than the beam during the day and act as thermal bridges. Telelab link: https://telelab2.intofuture.org/clip/615bcb85099b6f0023a4f198

Students everywhere can use thermal cameras to visualize the thermal envelope of buildings and streets in their neighborhood and publish the thermal data as geo-tagged infrared panoramas. The Telelab infrastructure then overlays these panoramas onto Google Maps to create Infrared Street View, a thermal version of Google Street View that allows viewers to identify energy issues around them such as energy leaks and urban heat islands in their living environment. For example, when viewers navigate the energy landscape of their neighborhood or a nearby city (figure 6a), they will notice that the pavements (Figure 6b) and certain building facades (Figure 6c) have a higher surface temperature that contribute to the urban heat island effect, while trees and water features provide patches of cool areas within urban heat islands. These crowdsourced infrared panoramas provide scientific evidence of energy issues that may convince homeowners and building managers to improve the energy efficiency of their properties.



(a)

(b)



(c)

Figure 6. (a) Navigation arrows to adjacent vantage points in Infrared Street View. (b) An infrared panorama of Quincy Market in Boston. (c) An infrared panorama of the Reflecting Pool at the Christian Science Plaza in Boston. Link to Infrared Street View: http://intofuture.org/isv.html

These building inspection activities extend in-school lectures about heat transfer and situate the application of students' knowledge in real-life scenarios that concern the students' personal living conditions. In this case, the Telelab infrastructure integrates three technologies for connected science learning: (1) IoT-enabled scientific instruments such as thermal cameras for observing and documenting hidden processes in everyday life; (2) The integration of a geographic information system (GIS) such as Google Maps that provides a relevant context for students' geographically distributed experiments, and; (3) A social media platform for students to communicate their findings in a visual and interactive way that may generate social impact.

Teacher and Student Feedback

During the development of Telelab, several rounds of professional development workshops were conducted to solicit teacher feedback (Xie et al. 2022). Most teachers liked its ability to support learning everywhere. As a teacher put it, "with this technology, science learning will involve diverse voices from students, about their houses, gardens, and rivers in their community, to name a few. It's more than extended access through online platforms."

In a pilot study during summer 2020, 44 students investigated the concept of reaction rate through a series of kitchen science experiments using baking soda and vinegar and exchanged ideas about different experiment designs (Xie et al. 2022). Analysis of student lab reports showed improved evidence-based reasoning skills. 22 out of 31 students who submitted an exit survey enjoyed using Telelab to visualize hidden processes. According to one student, "I enjoyed seeing the video of what was happening in the reaction and being able to see the graphs of the reaction at the same time."

Conclusion

The COVID-19 pandemic has shifted a significant part of science learning from physical facilities into virtual spaces by force majeure, but a social media platform like Telelab can become a bona fide informal science learning environment that transcends physical boundaries to enable remote scientific inquiry. As an IoT platform, it can also support observations and experiments beyond any physical confinement. When student-generated data are shared through a social media platform, they can transform it into a peer-based learning community, where students recreate and remix the shared content through self-teaching and discussing with other students (Zeng et al. 2021). While the future is still uncertain, the addition of a social media platform for data-rich science vlogging can be an important step towards more resilient, equitable, and accessible science education.

Web Link

Telelab and its curriculum materials are freely available at http://intofuture.org/telelab.html.

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Appendix: Energy Literacy Framework Alignment Table

Essential Principle/Fundamental Concept	Comments
1.2 The energy of a system or object that results in its temperature is called thermal energy. When there is a net transfer of energy from one system to another, due to a difference in temperature, we call the energy transferred heat. Heat transfer happens in three ways: convection, conduction and radiation. Like all energy transfer, heat transfer involves forces exerted over a distance at some level as systems interact.	In the kitchen science activity, students observe that the temperature of beakers increase over time and conclude that energy is transferred from the hot plate to the beakers through thermal conduction.
1.4 Energy available to do useful work decreases as it is transferred from system to system. During all transfers of energy between two systems, some energy is lost to the surroundings. In a practical sense, this lost energy has been “used up,” even though it is still around somewhere. A more efficient system will lose less energy, up to a theoretical limit.	In the building science activity, students observe the temperature difference between the thermal bridges and the environment and conclude that the building is not energy efficient because energy is lost to the surroundings through the thermal bridges.
3.1 The Sun is the major source of energy for organisms and the ecosystems of which they are a part. Producers such as plants, algae and cyanobacteria use the energy from sunlight to make organic matter from carbon dioxide and water. This establishes the beginning of energy flow through almost all food webs.	In the garden science activity, students observe the temperature difference between the butterfly and the environment and conclude that the Sun is a major source of energy for ectotherms like butterflies.