

Connecting Youth Using Arctic Mystery-Themed Kits

Karina Peggau¹, Jason Cervenec¹, Evan Van Tassell², Angus Fletcher², Sue Hogan³, Emily Kridel⁴, and Ellen Iverson⁵

¹Byrd Polar and Climate Research Center, ²Department of English, and ³OSU Extension, The Ohio State University, Columbus, OH; ⁴Stratford Ecological Center, Delaware, OH; and ⁵Science Education Resource Center, Carleton College, Northfield, MN

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ABSTRACT: Climate change is affecting Polar Regions at a greater rate than other parts of the planet and bringing information about Polar Regions to learners in informal settings is an integral part of increasing polar literacy. Inspired by escape rooms and mystery-themed materials that have increased in popularity over recent years and necessitated by disruptions during the pandemic, the Arctic Mystery engaged youth in small groups by challenging them to work together to make claims based on evidence and reasoning. This CSI-style kit features Arctic ecology, geography, and local connections as well as scientific data, research materials, and field research as content through which youth solve the mystery of a scientist's disappearance. Preliminary results from virtual user-testing indicate high engagement throughout the six-session program. Further testing is required to determine whether the kit is associated with gains in self-reported scientific identity, fascination in science, and valuing science. The kit's versatile format may be successful in other formats, including asynchronous and in-person settings.

INTRODUCTION

According to the Intergovernmental Panel on Climate Change's (IPCC) Sixth Climate Assessment Report, humans have had an unequivocal impact on the Earth's warming atmosphere, ocean, and land (IPCC, 2021). *The Lancet* Countdown categorizes climate change as the greatest global health threat of the 21st century (Watts et al., 2020). Changes occurring in the Arctic are considered "iconic" indicators of climate change. In particular, sea ice extent in the Arctic Ocean has declined substantially since 1979, reaching lowest post-winter extent on record in April 2021. Overall, the Arctic warms more than twice as fast as the rest of the world; for the 8th consecutive year, average air surface temperature in the Arctic was at least 1°C above the long-term average (Moon et al., 2021). These changes have significant ecological, social, and economic impacts on the region.

Addressing the challenges of climate change is a global effort which involves cooperation. Yet, in the United States,

less than 20 percent of teens claim they are "very well informed" about the causes, consequences, and solutions to global warming; only 27 percent claim they learned "a lot" about climate change in school; and only six percent of teens claim global warming is an "extremely important" issue to them personally (Leiserowitz et al., 2011). To preserve and defend the role of science as part of a social system for establishing objective truth, we all need to have greater awareness for practices that we have long taken for granted, including the role of transparent dialogue and expectation for observable evidence (Rauch, 2021). Engaging teens and underserved youth in scientific inquiry and connecting them to climate research can be difficult to integrate in a traditional school day. Therefore, polar literacy programs offered outside of school time could provide more time to grapple with content in a hands-on setting and develop a greater interest in the polar regions, climate change, and STEM (Krishnamurthi et al., 2014).

With this awareness, the project team created the Arctic Mystery with the aims of increasing polar literacy, promoting scientific thinking, and building science identity by engaging young learners in scientific inquiry and polar research in informal education settings. Inspiration for the format of an Arctic Mystery Kit stems from the popularity of exit games or escape rooms, in which a group of two or more individuals use clues to solve puzzles and accomplish tasks in a themed environment within a finite amount of time. This genre of entertainment, which expanded and matured in the latter part of the 2010s (Sugar, 2019), offered a chance for teams of adults to earn personal satisfaction and bragging rights. Companies emerged to offer these experiences at a cost of approximately \$30 per person for one hour, with some praising the team-building opportunities. Recent publications demonstrate a growing interest in escape rooms within education, possibly exacerbated by the need to innovate during the COVID-19 pandemic, in disciplines as diverse as mathematics (Stohlmann, 2020), engineering (Gordillo et al., 2020), pharmacology (Smith and Davis, 2021), and health sciences (Boysen-Osborn et al., 2018; Dittman et al., 2021; Frederick and Reed, 2021; Sanders et al., 2021; Spears et al., 2021; Valdes et al., 2021). Teams have sufficient experience to have recommendations for optimizing the development and refining process (Eukel and Morrell, 2021).

A similar fascination with puzzles and mysteries struck the middle school, high school, and higher education science education community in the mid-2000s with the airing of the television sensation, CSI and its subsequent spinoffs (Mardis, 2006; Yanowitz et al. 2010). Although CSI shows tend to oversimplify the methods used and time required to solve a crime, it is important to acknowledge that they still increased public interest in forensic science and solving problems. In fact, not only did forensic science course offerings expand, but classroom lessons and units were re-designed to learn content, develop skills, and establish habits of mind with the backdrop of solving a crime. Examples of units and lessons abound in biology (Kurowski and Reiss, 2007) and chemistry (Marle et al., 2014; Meyer et al., 2014), but also in areas such as informal STEM education (Yanowitz, 2016). Well-developed materials simulated the process of solving a mystery by encouraging students to gather data, weigh evidence, synthesize solutions, and communicate their findings. Students responded favorably to these mystery-inspired materials (Klopfer et al., 2005) and the format might have had other ancillary benefits such as diversifying the perception of who does science (Jones and Bangert, 2006).

Puzzle and mystery boxes, that may be purchased to complete individually or with a group, have become more readily available. A number of these were a source of entertainment during the COVID-19 pandemic, with

different levels of difficulty, themes, and formats (Austin, 2021). Some of the boxes stand alone, whereas others are part of serial installments.

Research suggests that puzzles and mysteries of this type can train students to perform inductive thinking and to create and test hypotheses in more scientific ways (Fletcher, 2021). This is particularly true when students are transported into fictional environments, where they feel more empowered to make predictions and more motivated and eager to tackle tricky situations or challenging tasks (Liu et al., 2011). It has been shown that inductive reasoning, and particularly the ability to form predictions about past and future events, is a key skill both in performing general tasks and in the construction of scientific knowledge (Sternberg and Kalmar, 1998; Holland et al., 1986). Fictional mysteries can thus be an effective tool in STEM education by prompting students to develop, test, and adjust hypotheses, which are invaluable skills in scientific thinking.

METHODS

Advent of the Arctic Mystery. When a series of in-person learning materials were developed for youth in autumn 2019 and winter 2020 as part of the NSF-funded Polar Literacy Project (PLP), the Arctic Mystery was outlined as a discrete, culminating challenge that would allow youth to demonstrate what they learned in an engaging format. Since the PLP targets informal education where youth can make free choice to participate, both being fun and hands-on are prerequisites for effective materials (Krishnamurthi et al., 2014).

With the team's attention on other materials, the Arctic Mystery was labeled a "15% project" - inspired by the projects at Google and 3M that are not necessarily part of a team members core job responsibilities but that they explore with fifteen percent of their time (Coyne, 2001). Like many 15% projects, the Arctic Mystery was interesting and appeared to connect with the larger project but did not dovetail with all the other materials. The team deemed it high risk/high reward if the team could make the format work. Little did we know in early winter 2020 that the Arctic Mystery would soon fill a critical role delivering programs. The Arctic Mystery format was well-suited for the remote and virtual learning that would soon dominate the education landscape with the COVID-19 pandemic, while also being amenable to in-person instruction that would subsequently return. The kit is intended for middle school aged youth in a group setting, where individuals work together to discover clues or 'evidence' that leads to new information about the polar regions or the whereabouts of a scientist and their data. Like a traditional escape room, facilitation is kept to a minimum, except for providing hints or necessary content knowledge when teams encounter a roadblock.

Arctic Mystery Narrative and Materials. In this narrative, youths act as “detectives” to solve the mystery of a missing scientist in the Arctic. The kit is broken into six sessions. Each session lasts between one and one and a half hours.

In the first session, youth are detectives-in-training solving the disappearance at a remote cabin using only two cartoon drawings and a brief background story as evidence. The first session focuses on teambuilding and practicing argumentation by using evidence and warrants to make claims (Hillocks, 2011). For the next five sessions, youth have “graduated” to detectives and are working to solve the mystery of a scientist, Perm A. Frost, who disappeared in Alaska. To uncover the whereabouts of Perm and the animal associated with her disappearance, youth must identify relevant evidence from the Arctic climate, geography, and ecology, and from the scientist’s belongings, and use this evidence to construct claims. The evidence provided to youth and objectives for each session are listed in Table 1.

At the conclusion of the mystery, Perm is found alive having injured herself pursuing the “suspect” animal who ran off with her backpack. Resolving the mystery in this fashion was appropriate for the middle school aged youth in the target audience. Time is devoted to discussing safety considerations for working in the field, such as packing the “Ten Essentials,” which includes a light, map, and first aid (The Mountaineers, 2020); traveling with a team; and alerting others to your intended itinerary.

Session Materials. During each session, youth are presented with a cover letter from the FBI that lists the evidence included in the session and the objectives to be accomplished. This letter serves an essential organizing role for each session and is consistent session to session. The letter and additional materials are distributed in a sealed envelope. Additional materials vary but include guidebooks for Arctic ecology or wildlife; maps of Alaskan ecoregions, regional airports, counties, or topography; images and forensic lab results from the crime scene; data from the scientist’s desk, computer, lab notebook, field equipment, or journal; and miscellaneous evidence, such as animal collar coordinates, information on how to use a pH meter, and an airplane ticket (Figure 1.0 – 1.6). Many of the materials can be used to solve the mystery; however, some materials may be useless or are presented in an earlier session and need to be referenced again. User testing has also found that youth perform their own research online and bring additional information to solve the challenges. Likewise, most objectives can be “solved” using more than one line of evidence, creating multiple routes to success, adding to the value of group dialogue, and allowing facilitators to challenge advanced groups to create “systems of evidence” based on multiple pieces of evidence supporting a claim. Although there is some linearity to the Arctic Mystery narrative, youth are encouraged

Table 1. Evidence and objectives for each session of the Arctic Mystery.

Session	Evidence	Objectives
0	- Detective Letter - Background story - Crime Scene Images	- Establish a team name - Determine who is missing and other individuals - Describe the events that transpired
1	- AK Ecoregion Map - AK State County Map - Map of Airports - Plant Field Guide - Pages from Perm’s Journal	- Determine which ecoregion Perm traveled to - List the counties within that ecoregion
2	- Wildlife Field Guide - Plane Ticket - Airport Weather Data	- Find which airport Perm traveled to - Figure out when (date/time) Perm arrived - Eliminate one suspect
3	- Erosion Data (Payne et al., 2018) - Animal Tracking Coordinates - Nuiqsut Topographic Map - Cryptograph - Instructions for using a pH meter	- Locate Perm’s campsite - Unlock laptop - Eliminate one suspect
4	- Blank AK Map - Campsite Images - More Journal Pages - Local News Reports - Weather Data	- Find what time Perm went missing - Eliminate two suspects - Select evidence to be sent to the forensic lab
5	- Perm’s field notebook - Images from field sites - Scat sample analysis - Fur sample analysis - Saliva DNA analysis	- Determine which animal is associated with Perm’s disappearance - Identify Perm’s location

to share their claims and reasoning to provoke discussion and inspire new ways of addressing the challenges. In fact, youth regularly introduce viable lines of evidence, drawing from both materials within the kit and external sources they sought on their own, that the project team did not anticipate.

Implementation. The Arctic Mystery was tested in a virtual format, with materials distributed in advance via the mail

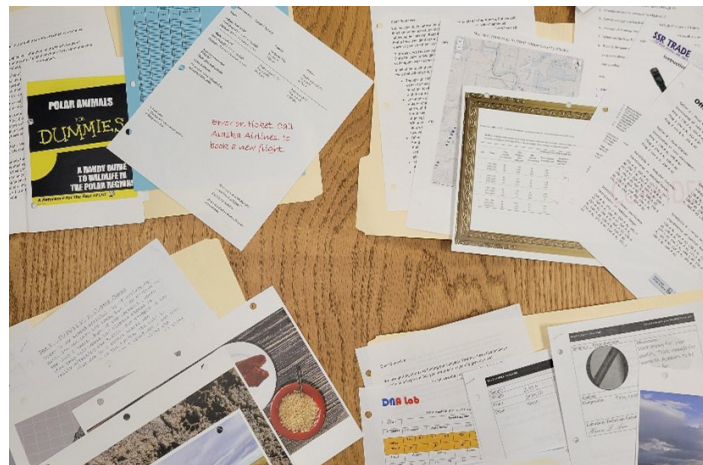


Figure 1.0. Full Kit: The entire Arctic Mystery is composed of six sessions with images, notes, booklets, and other 577 evidence for youth to explore.



Figure 1.1. Session 0: Images of both the inside and outside of the cabin.

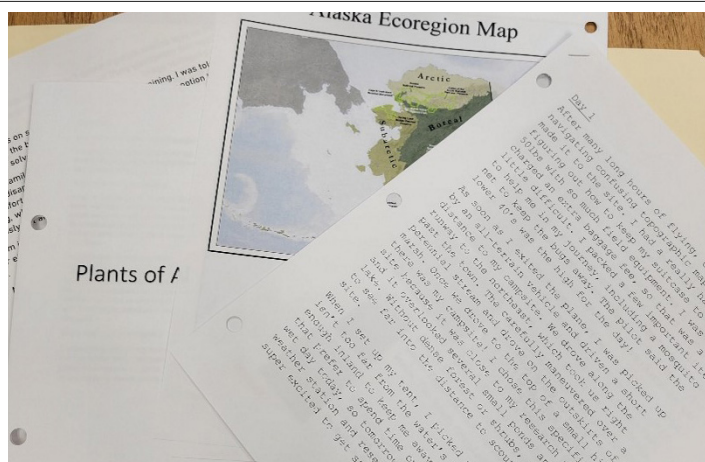


Figure 1.2. Session 1: The case of the missing scientist begins, starting with an excerpt from Perm's journal.

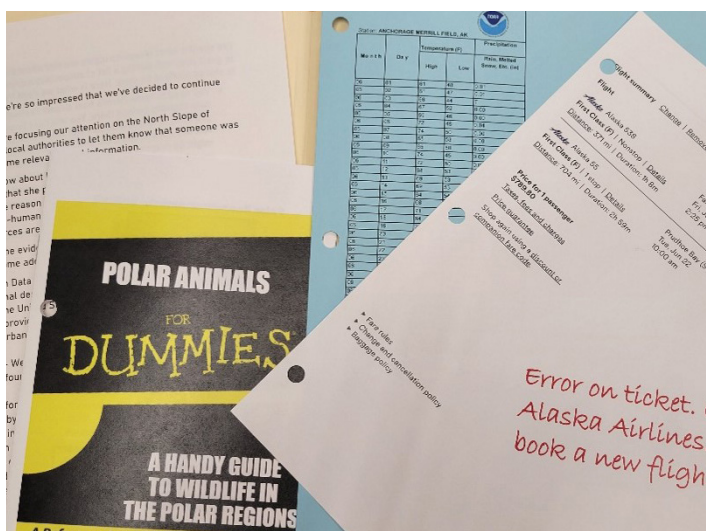


Figure 1.3. Session 2: Youth determine which town Perm is in and are introduced to the suspects.

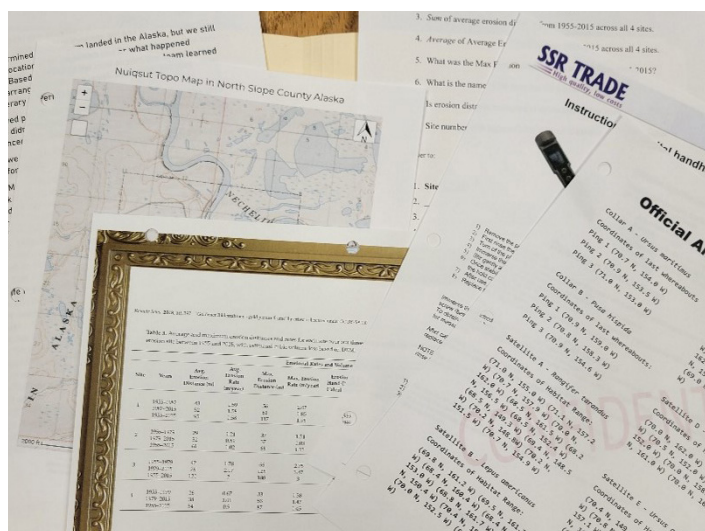


Figure 1.4. Session 3: In addition to locating her campsite, youth explore Perm's research in hopes of discovering her laptop password.



Figure 1.5. Session 4: Search & Rescue officials send details from Perm's campsite and youth get a closer look at the contents of Perm's laptop.

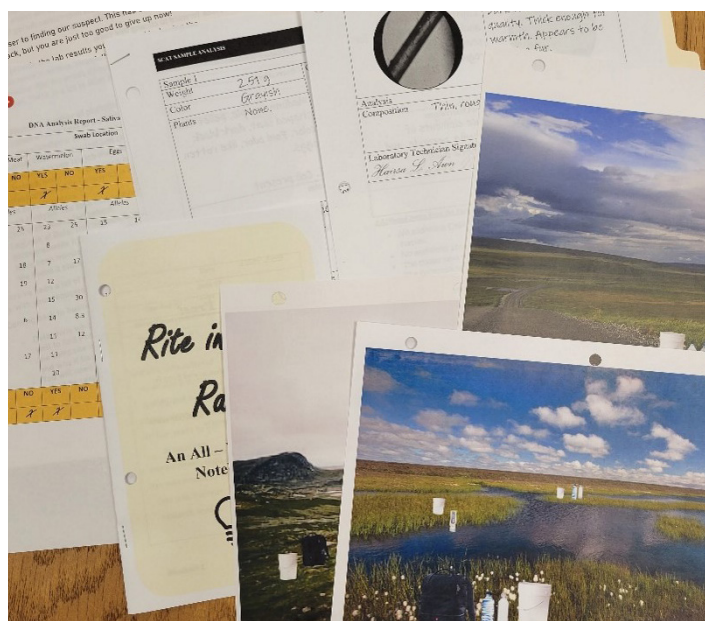


Figure 1.6. Session: Forensic results and a lab notebook yield information about Perm's location and the animal associated with her disappearance.

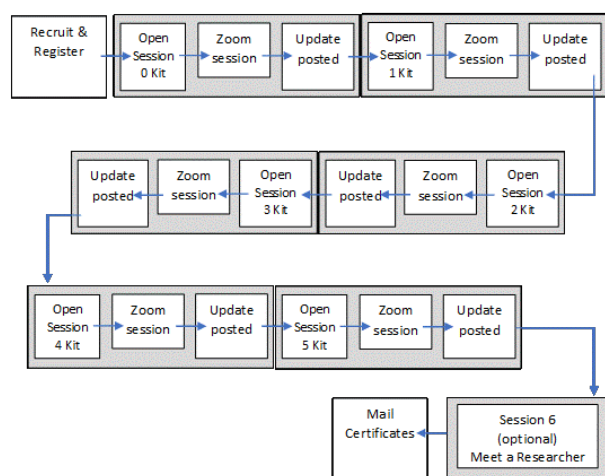


Figure 2. Each session includes three parts: opening and processing materials, discussion with peers over Zoom, and receiving updates a few days later. Accessing the materials in advance allowed youth to process the information at their own pace, and delayed results allows youth to refine their answers after the Zoom meeting.

and synchronous session occurring weekly as outlined in Figure 2.

In the first iteration of the program, session envelopes were mailed to 14 youth weekly. User testing found that distributing all sessions in one package, with each session sealed in clearly labeled envelopes, was preferred as it was lower cost, easier for project staff, and less likely to face unpredictable mail delays. At the conclusion of each session, youth were invited to open the subsequent session's envelope in a collective big reveal. While youth were not obliged to work on the kit independently, they were invited to peruse the materials in advance, and some reported spending at least one hour outside of scheduled meetings to work on the kit (Iverson et al., 2021).

Synchronous meetings on Zoom were divided into five parts as shown in Figure 3. The three parts with all youth participating in a large group alternated with two parts with youth in small groups using breakout rooms.

Each breakout room had a group of eight to ten youth and at least one facilitator, such as a teacher, camp counselor, or project staff member. Youth roles including leader, timekeeper, reporter, and encourager were established within each group. Groups were set larger than would normally be done in person because some youths were quieter online, and none were required to turn on their video. Therefore, facilitators needed to encourage quiet youth to participate – the chat function was a particularly welcoming space for some youth – and deploy methods specific to virtual programs such as chat bombs, where all youth would type their response and wait to hit enter at the same time to view all responses at once. Group roles were changed weekly.

In each session, teams were asked to draft a “report” that answered each of the key objectives by creating a claim us-

Estimated time of approximately 75 minutes

4 minutes	Welcome and music
2 minutes	Pre-session survey (depending on the week)
2 minutes	Recap of the previous week
25 minutes	Small team breakout rooms 1
7 minutes	Midpoint check in as large group and share out
25 minutes	Small team breakout rooms 2
5 to 10 minutes	Regroup as large group, discussion, Q&A, and post-session survey

Figure 3. A large group opening (8 minutes), a mid-point check-in (7 minutes), and a closing. Between the large group segments, youth spend most of their time working in small groups to discuss the materials, the session's challenges, and how to move forward with solving the mystery.

ing evidence and rules/reasons, as shown in Hillocks (2011). In small groups, facilitators are asked to “disappear” as much as possible, allowing the group to navigate the Mystery together. If the conversation diverged or the group became stuck, facilitators are given a list of session-specific “hint” questions to nudge the small group discussion. The hint format is popular with many of the free-choice puzzle and mystery boxes now available commercially, including puzzle books (example in Treat and Cabarga, 2003), so that participants can be given clues when they are stuck without divulging the entire solution. Facilitators were also asked to remind team members of their roles, invite quiet individuals to the conversation and chat, and help the team clarify their answers and reach consensus. Small group discussions and mid-point check-ins advance the entire group conversation toward reaching a solution when individuals and groups, respectively, have slightly different information.

During the mid-point check-in and large group closing, each group shared their findings and which evidence they used. The focus was not just on their claim, but the evidence that was useful, why that evidence was useful, and how the group arrived at consensus. In addition to offering opportunities for youth to formally communicate summaries of their team's findings and allowing knowledge to emerge from youth rather than facilitators, these exchanges enabled information flow between groups.

A few days after the session, youth received a digital update from the FBI via email and Padlet, informing them what evidence was useful and telling them which claims were correct. This step ensured that none of the teams were left behind in the narrative, delayed gratification about finding the “right” answer, and maintained the role of the facilitators as not having the answers to give (these answers always came from the FBI introductory letters or updates). This strategy also gave youth extra time to explore their theories outside of the general meeting time and support the notion that alternative explanations are possible. After the final session, the large group watched a video of Perm thanking teams for their efforts to find her. This video served as the final update. In addition to synchronous meetings, youth had an opportunity to engage with the Mystery and each other asyn-

Table 2. Steps of the 5E's Learning Cycle and their application within the Arctic Mystery.

Engagement	The Arctic Mystery narrative is engaging to a young audience. During the first team meeting, facilitators set the scene and describe the story of a scientist going missing in the Arctic. Finding the scientist was a large motivator for small groups and individuals – many of whom began developing theories after completing the first two sessions. The scientist's disappearance left many questions unanswered, including "How did this happen?", "Where are they?", "What can I find out about this?"
Exploration	Each packet contains a variety of documents, maps, booklets, images, or other evidence which could be used to locate the scientist. Youth can peruse the materials independently on their own time or during small group meetings. During the meetings, teams develop strategies for solving the problems using the evidence they were given, then each strategy is implemented. Youth who viewed the materials in advance could guide the discussion or provide input based on their experience with the materials. Youth could find additional materials on their own, such as books or online resources. Small groups typically work through one or two prompts before the time ends.
Explanation	Between the two breakout sessions, a large group meeting breaks up the discussion and allows groups to share their findings thus far. During this period, small groups convey their current theories by describing how those theories were developed and which evidence was most helpful. After each small group reports their current findings, teams might adjust their findings or find new useful evidence during the second breakout session.
Elaboration	During the second breakout session, small groups draft a brief report which lists their claims (e.g., the penguin is not associated with Perm's disappearance), the evidence used to make the claim (e.g., the penguin lives in the southern hemisphere), and the rule or reasoning for their claim (e.g., Perm disappeared in the Arctic, which is in the northern hemisphere, far away from any zoo or wild penguins). Groups use their prior knowledge and context clues in the materials to support their arguments.
Evaluation	This happens in two moments: during the final large group discussion and at the beginning of the next week. A summative large group discussion provides closure for small groups at the end of each day. Here, small groups share their final thoughts or conclusions with other teams, and teams provide feedback and discuss the materials amongst themselves. The feedback report containing the correct answers to each challenge was released a few days later. This report is also read during the opening of the next session. After the report is shared, youths are invited to ask questions or return to the previous week's materials to review and understand the reasoning behind the report.

chronously using a social media-like virtual bulletin board, Padlet. While there needs to be a way to communicate with facilitators asynchronously in case an envelope is missing an item or a youth is going to be absent, the bulletin board was not used as extensively as anticipated and is not seen as essential.

The Arctic Mystery capitalized on the 5E Model of Instruction, as outlined in Table 2. Also known as the "5Es", this research-based model is designed to help students learn fundamental concepts in five phases: engagement, exploration, explanation, elaboration, and evaluation (Bybee et al., 2006). The phases are implemented in a sequence to guide instruction and give youths an opportunity to grapple with the content before synthesizing their learning. This learning cycle was an essential ingredient to our work and measured

in the Polar Literacy Project Kit Development Rubric, found in the Appendix.

Facilitator resources have been developed, focusing on how to engage youth in effective dialogue and key questions that nudge youth toward solutions, without resorting to a focus on specific right and wrong answers. In addition to print materials, web links/QR codes provide facilitators with easy access to support videos for each of the sessions.

Data Collection and Kit Refinement. Throughout the design process, the Arctic Mystery was reviewed by internal staff and a graphic design student to check for readability, simplify materials for a younger audience, and present the materials in a format that was easy to print at a low cost. Test materials were produced and reviewed for accuracy, style, and ease of use.

Facilitators. After its development, the Arctic Mystery kit was vetted again for accuracy, engagement, and modularity during collaborator meetings and individual feedback by project partners. The kit was also reviewed a second time for cohesiveness, navigability, and accuracy by project team members. This included completing the objectives as youth would while checking that instructions were clear, materials were easy to read, content was aligned with the Polar Literacy Principles (McDonnell et al., 2020) and that assigned tasks were manageable.

Recommended revisions included simplifying data sets and maps. For instance, the legend for the Nuiqsut topographic map and the airport weather data were simplified by removing information irrelevant to the kit. Simultaneous additions were made to the kit, including a few pieces of extraneous information and two more animal "suspects," so that youth would have some pieces of evidence that they could clearly say were irrelevant. Feedback also led to the creation of the FBI letters that accompany each session and provide a predictable source of objectives and list of evidence within the kit's theme.

After the first pilot, further revisions were made at the recommendation of Marilyn Sigman, an Alaskan educator and long-term resident who has travelled extensively within the state. Noteworthy recommendations included considerations for the Indigenous people and culture in Nuiqsut, the importance of subsistence in the region, and the costs and logistics of bringing in resources from outside the community. This feedback was included in the kit in the form of a journal entry, which described Perm's visit to the town.

The narrative for the Arctic Mystery centered around a scientist making multiple mistakes that lead to her disappearance, including traveling independently to an unknown location without notifying colleagues or the local community, not carrying radio equipment, leaving food out in the open, and not having a bear-proof container for food storage.

Table 3. Youth demographic data and program structures for two user-testing events.

Program Description	# Participants	# Of Days Attended Mean (Median) of Max	Grade Range	% Female	% URM (Underrepresented Minority)
Fall 2020 – youth recruited via Southeastern Ohio outdoor education camp	14	3.86 (4.00) of 6	6 – 8	57.1%	unknown
Spring 2021 – youth recruited via Central Ohio 4-H special interest club	17	6.89 (8.00) of 8	6 – 8	35.3%	11.8%

While these features of the narrative were necessary to make it both plausible and compelling to youth, Marilyn recommended taking time to unpack the irresponsibility of these actions and how they are unlikely to occur with practices that researchers currently employ in the field. The second iteration of the kit included an opportunity to discuss field safety and mistakes Perm made during her expedition, including a visit by an early-career polar researcher who has conducted fieldwork.

The project team collaboratively developed a rubric for the larger Polar Literacy Project, against which any materials would be measured. The Arctic Mystery was scored against this rubric as is shown in the Appendix.

Youth. The Arctic Mystery was formally user tested on two separate occasions, once with 14 youth in Fall 2020 and once with 17 youth in Spring 2021. Fall 2020 user testing targeted youth in Southeastern Ohio but extended to youth in other locations, including Colorado and California. Spring 2021 participants were part of a 4-H Special Interest (SPIN) Club in Central Ohio. While additional user testing was planned, complications with the COVID-19 pandemic and youth fatigue with virtual programs resulted in cancellations and delays.

Demographic data were collected from participants who provided consent and is represented in Table 3. Both user tests were held virtually, with session materials mailed in advance and synchronous sessions held via Zoom.

In both pilots, surveys were used to collect data measuring the following metrics: fascination in science, science identity, valuing science, and engagement. Youth were also asked to complete an end-of-event survey designed to assess their overall interest in program activities, including strengths and weaknesses and the amount of time that they devoted to the materials outside of the synchronous sessions.

The following metrics were measured at the start and end of each program: Fascination in Science, using the Fascination in Science subscale of the Science Learning Activation Survey (Chung et al., 2016a); Science Identity, using four items from Cole (2012); and Valuing Science, using the Valuing Science subscale of the Science Learning Activation Survey (Chung et al., 2016b). The eight-item Fascination in Science scale measures youth positive affect and interest towards science and curiosity about the natural world (e.g., I wonder about how nature works). The eight-item Values in Science scale measures youth perceptions of importance of

science in its utility towards personal goals (e.g., Thinking like a scientist will help me do well in all of my classes) and to society (e.g., Science makes the world a better place to live). Using a sample of 2,903 6th and 8th grade students, Chung et al. established reliability on the Fascination and Values scales (Cronbach's alpha of .86 and .83, respectively) and validity of these scales (using Exploratory Factor Analysis followed by a Rasch Model of Fitness). The Science Identity scale measures to what extent youth self-identify as science people with goals and attitudes that characterize this identity (e.g., I am interested in pursuing a career in a scientific field). Cole established reliability (Cronbach's alpha of .93 and .91) and convergent validity (assessed by correlating science identity with the number of science activities that youth reported participating in or enjoying) and divergent validity (assessed by correlating science identity with three other forms self-identification used such as musical person or athletic person) from a sample of 206 youth enrolled in a museum-sponsored program. The eight-item Engagement in Science Learning Activities survey (Chung et al., 2016) measures youth focus, participation, and persistence on a task in terms of their behavior, thought processes, and affect. Using a sample of 2,600 6th and 8th grade students, Chung et al. established reliability (Cronbach's alpha of .80) and validity (using Exploratory Factor Analysis, Structural Equation Modeling, Confirmatory Factor Analysis, and Rasch modeling).

RESULTS

Given the small sample sizes at the individual program level, quartile analyses were not feasible for science identity, fascination in science, and valuing science. Youth responses to the surveys were averaged and paired together. As shown

Table 4. Paired averages on pre- and post-surveys for science identity (on a five-point scale ranging from 1 “not at all true” to 5 “really true”), fascination in science (on a four-point scale ranging from 1 “NO!” to 4 YES!), and valuing science (on a four-point scale ranging from 1 “NO!” to 4 YES!) for two user-testing events.

	Identity	Fascination	Valuing
Fall 2020	4.06/4.06 (n=4)	3.58/3.66 (n=3)	3.58/3.6 (n=6)
Spring 2021	3.3/3.4 (n=9)	3.04/2.99 (n=11)	3.12/3.21 (n=10)
OVERALL	3.53/3.65 (n=13)	3.16/3.14 (n=14)	3.29/3.35 (n=16)

in Table 4, youth reported slight, though not statistically significant, gains in science identity, fascination in science, and valuing science across both user tests. Overall, youth reported the greatest gains in science identity, with the average self-reported score increasing by 0.8 points on a 5-point scale.

Engagement surveys were administered after each session beginning with day two (session 1) of the Mystery. In Spring 2021, youth completed two additional days of programs, including a climate data activity and project representing their data findings. Average engagement by day was measured for both Fall 2020 and Spring 2021 programs and reported using a four-point scale where 1.0 indicated low engagement and 4.0 indicated high engagement. Self-reported engagement was greater than 3.0 throughout the Arctic Mystery program (days 2-5), as reported in Table 5. Across the two programs, averaged scores were well above the mid-point, indicating high engagement.

Engagement varied by program. Due to the virtual format, youth had opportunities to disengage by avoiding the next session's activities, however, facilitators observed strong engagement for those who did attend sessions. For quieter youth, engagement appeared to increase under the following conditions:

- when opportunities to participate were anonymous or low stakes (e.g., when youth were asked to participate in anonymous polls or to share their responses in Zoom's "chat" feature);
- when youth were able to interact in smaller break-out rooms;
- when youth were directly invited to engage (e.g., "Alex, what do you think?");
- when youth had an opportunity to interact with program materials sent to them via mail before the virtual sessions;
- when youth were given specific roles to play during sessions; and
- when a sense of "community" began to form as the program progressed.

During the end-of-event survey, youth shared statements about the kit. We independently highlighted in their statements the facets we hoped would stand out in the kits. For example:

"I liked the animals and the information about animals."

"I liked having a guest speaker because we got to learn more things about polar research!"

"Having Dr. Gardner here was a lot of fun. I found

Table 5. Average post-surveys for engagement by day for two user-testing events (on a four-point scale ranging from 1 "NO!" to 4 YES!).

	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
Fall 2020	3.53 (n=7)	3.62 (n=6)	3.46 (n=7)	3.51 (n=8)			
Spring 2021	3.36 (n=15)	3.35 (n=15)	3.53 (n=14)	3.30 (n=14)	3.44 (n=13)	3.36 (n=13)	3.52 (n=11)

his work very interesting and learned a lot more about the Arctic."

"Talking to a scientist was really cool!!"

"I liked the setting of the arctic for the mystery and the way everything tied in with the environment."

"I liked how the clues were real data."

In addition to the above statements about the Mystery Kit, some youth from the Fall 2020 pilot made additional statements in a newspaper article (The Review, 2020), including:

"I've learned how to think like a scientist, I love being a part of the program"

"... this work is really fun and the cases are very interesting"

"... I would recommend this to others who like investigations and detective work"

DISCUSSION

Interpretations. Both escape rooms and mystery-themed entertainment are popular but are primarily catering to an adult audience. In conjunction with the COVID-19 pandemic, this entertainment has gained traction at the university/professional level but is less popularized for a younger audience or an informal education audience.

Data and information buried in a mystery-themed story was shown to work. The clue-driven nature of the activities encouraged participants to determine causal chains, by generating predictions about what happened at key moments in Perm's story and then reevaluating those predictions based on additional pieces of evidence. The kit gradually introduced research topics and built upon the previous week's materials, allowing participants to rethink their hypotheses. These practices build on methods articulated by Hillocks (2011) for helping youth in grades six to 12 learn the nuance of developing claims from evidence and warrants, called argument writing in English language arts (ELA) education. While argument writing is often taught in ELA education at the high school level, it is a practice widely used in science and history that could be nurtured at a much younger age and in more education settings. As articulated in Rauch (2021), failure of society to appreciate, nurture, and participate in transparent dialogues, based on observable evidence, to ar-

rive at a truth-based reality could undermine the order we have come to depend on for our daily activities. The social dialogue of supporting or refuting claims, based on observable evidence and warrants, needs more opportunities to be practiced by everyone, including youth.

Literary theorists have discussed the reading process of mystery and detective fiction, how it involves both the uncovering of a main story (i.e., whodunnit) and the self-conscious following of the detective's investigation (Hühn, 1987). The Arctic Mystery produces a similar response in a more interactive environment; because participants were put directly into the role of the detective, they were encouraged both to discover what happened to Perm and to think critically about their own thought processes as investigators. Youth were offered several opportunities to rethink and discuss their own predictions, including in the "Explain" and "Elaborate" sections of each session and in the post-session digital updates.

The mystery aspects of the kit may have also contributed to youth engagement in these self-conscious processes by transferring attention to a "safe," low-risk fictional environment. This encouraged participants to posit new predictions and get more comfortable with adjusting or abandoning predictions based on new information, without fear of repercussions for wrong answers. This suggests that fictionalized mysteries can train students in inductive reasoning as effectively or even more effectively than laboratory exercises. At the same time, the kit introduced students to tools and ecological concepts that apply outside of the fictional environment, potentially sparking interest in the real-world effects of climate change and field research.

Youth each pursued different lines of reasoning and gravitated toward different content in their solutions. Thus, there were a lot of opportunities for free choice. While this is a hallmark of successful informal learning, it does make measuring specific learning gains on content knowledge and skills more difficult to measure.

Limitations. The onset and prevalence of COVID-19 posed multiple challenges for user testing. Informal education shifted to a virtual setting or closed entirely during the pandemic, limiting the team's ability to reach the target audience. Unreliable internet access or lack of a computer, iPad, or smartphone each barred youth in rural or low-income areas from participating in the Arctic Mystery. These barriers made it difficult to reach the target audience and find a representative sample size.

There is a lot of information that facilitators gather while observing students working as a team to solve a challenge. The dialogue, written/created products, and presentations are extremely valuable. Gathering this anecdotal, yet valuable, information over Zoom without all the cues available in person or the ability to quickly have a side conversation

with youths made the project team temper our claims of student understanding of all the materials in the kits.

Overall, the Arctic Mystery has undergone two phases of user testing, both of which were done in a virtual setting using Zoom. Each trial was a little different because of partner needs. During the synchronous virtual testing, youth expressed excitement for an online program with mailed materials. This excitement waned in spring and summer of 2021. This is consistent with reports from other programs (Koneru and Nnanna, 2021). While the team is confident that materials can be adapted to in-person delivery, continued uncertainty and wariness about unvaccinated youth has interfered with scheduling in-person programs and there have not been opportunities to user-test this format yet.

Implications. The Arctic Mystery gives youth an opportunity to explore the Arctic without physically visiting, including Arctic biology and ecology, cultural norms, and the effects of climate change. Youth can also enjoy gathering data, weighing evidence, synthesizing solutions, and communicating findings like "detectives", while thinking like a scientist to solve the mystery. The nature of the pre-packaged kit incentivizes youths to interact with new information at their own pace without much facilitation, alleviating the need for informal facilitators to have extensive background knowledge. This format was particularly well-suited to the COVID-19 pandemic and a middle school-aged audience. With minor adaptations, the Arctic Mystery could also be used with upper elementary and high school-aged audiences.

Informal science learning venues could develop similar materials for different topics and delivery formats. Unlike traditional escape rooms, the materials for the mystery are low-cost, easy to curate, occupy little space, and do not require intricate locks or codes. In addition, the authors believe that the Arctic Mystery could work with all three formats – individually with a support website, remotely/virtually with mailed materials and a remote facilitator, and in-person with print materials in more traditional setting– with only slightly different variation of materials needed in each. Therefore, time invested in development yields multiple routes to delivery.

Next Steps. The team is working to find partners to safely user test in-person in the coming months. Due to the pandemic and ages of the target audience, additional steps must be taken to safely host an in-person program. Additionally, the team is working to find families to user test the kit asynchronously with a support website. The website will allow youth to request hints, submit their evidence and claims to receive automated responses confirming or refuting their arguments, and if needed, contact the project team for assistance. The website will also have an option to have the intro letter and session answers to be read aloud. Lastly, the team intends to

train facilitators to use and facilitate the Arctic Mystery independently and receive feedback on the Facilitator's Guide. Videos will accompany the Facilitator's Guide to demonstrate how to assemble the kits, facilitate the activity, and an example of successful small group discussion. Successful asynchronous use and facilitation of the Arctic Mystery kit could demonstrate the kit's adaptability for a variety of educational settings, including independently at-home, in small groups, and during formal and informal education.

While the kits are complex to assemble, the project team and key organizations are collaborating to simplify, optimize production, and make the kits available at a reasonable cost with intention to make the kits accessible for organizations to use.

The project team is also developing Polar Puzzles, another mystery kit that features early career polar researchers and uses puzzles and a cryptogram to advance between modules. Unlike the Arctic Mystery, the Polar Mystery is modular, includes both the Arctic and Antarctic regions, and features polar research data from scientists. The kit is divided into 5 sessions, each session lasts one to one and a half hours. Moderate facilitation is necessary. Presently, Polar Puzzles is suitable for a middle to high school audience and the team is working to find partners to safely user test both online and in-person.

ASSOCIATED CONTENT

Supplemental material mentioned in this manuscript can be found uploaded to the same webpage as this the manuscript.

AUTHOR INFORMATION

Corresponding Author

Karina Peggau. Byrd Polar and Climate Research Center, The Ohio State University. Scott Hall, 1090 Carmack Road, Columbus, OH 43210. E-mail: peggau.1@osu.edu

Author Contributions

The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript.

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ABBREVIATIONS

ELA: English Language Arts; IPCC: Intergovernmental Panel on Climate Change; PLP: Polar Literacy Project; SPIN: Special Interest

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