FINAL RESEARCH REPORT
NOVA's Polar Extremes

Enhancing Experiential Digital Learning

Exploring the Impact of Interactive & Narrative-Driven Media on Informal STEM Learning in Kids & Young Adults

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EXECUTIVE SUMMARY

With a wide array of digital platforms and formats available to informal STEM media producers, it can be challenging to decide which approach to use to reach different audiences. This is particularly important in the context of distant, remote, or challenging concepts, such as polar science, which the average viewer might not have much experience with or exposure to.

This study therefore explores how two groups of younger audiences (ages 11-14 and 18-25) engage with polar science delivered through two media formats. One is a documentary film with a strong narrative and host guiding the viewer (NOVA's Polar Extremes), while the other is an interactive digital game that challenges the user to explore with the help of a guide (NOVA's Polar Lab). **Knowing how each audience engages with the format and what they learned can help media producers create more targeted and effective materials.** To help contextualize these findings, this study also explores the validity of a "strand" approach to understanding learning outcomes (our measures).

Finally, this study explores how early STEM socialization and exposure to science may make young adults (18-25) more or less open to exploring science topics or pursuing science as a career. **Knowing what keeps young people from more deeply engaging with science can help producers meet viewers where they are, and potentially help them find ways to make STEM concepts relevant to them.** Specifically, the goal of this study are to:

- **Goal 1: Design to Achieve Learning Outcomes:** Understand the learning outcomes associated with two popular styles of science engagement: narrative-driven approaches (Polar Extremes film) and immersive, exploratory approaches (NOVA Polar Lab)
- **Goal 2: Measure Polar Science Learning**: Develop a learning outcome metric appropriate for polar science and aligned with the "strand" framework
- **Goal 3: Understand Science Identity Development:** Understand whether and how young people experience science as a process or skill set, as opposed to a culture or group they identify with, or a potential career path

Data collection included surveys of 18-25 year olds on MTurk and Turk Prime and surveys and focus group discussions with 11-14 year olds in Santa Barbara CA and online.

Topline Findings

- Both the film and lab successfully supported learning outcomes across the six Strands of Informal STEM Learning.
- Learning outcomes varied between age groups, with younger audiences displaying more Strand 1 (interest & engagement) and older audiences exhibiting more instances of Strand 4 (metacognition, reflecting on science).

- The film was slightly better at promoting Strand 1 and Strand 4, while the lab more strongly supported Strand 3 (active inquiry), Strand 5 (collaboration and communication), and Strand 6 (identification with science).
- Two primary learning outcomes were observed within the viewers (18-25), despite designing a survey questionnaire to cover all six strands. This means that learning tended to fall within the broad categories of *polar science impressions* & *recognizing scientific inquiry***.**
- Respondents recalled knowledge only moderately well after the film and lab (Strand 2, understanding). While both audiences could reiterate what they saw, they didn't tend to explore 'why' or engage in deeper reflections, unless prompted by a focus group moderator.
- Results indicate that discussing science with others is more of an influence on learning outcomes than whether someone has a friend or family member in a science-related career.
- Young women (18-25) were far more likely than men to have abandoned science as a potential career because they felt "it wasn't for them." They recall times when they were 'bad' at science or math, or when they did not feel welcome in male-dominated STEM fields. Men, however, did not report feeling they lacked inherent abilities in STEM or that they felt unwelcome, if they decided not to pursue a STEM career.

Primary Recommendations

- ***Design materials with learning outcomes in mind:*** Strands that were explicitly reinforced by the resource saw greater boosts (e.g. Strand 5, collaboration in the lab).
- ***Be careful to not leave viewers with a sense of disempowerment:*** Younger audiences (ages 11-14) exhibited feelings of dread around climate change after having engaged with the materials, whereas older audiences were more 'inspired' by climate science.
- ***Provide positive examples of everyday solutions:*** Science media creators might consider 'everyday heroes' or give viewers transformative ideas of how they can help in their daily lives to reduce climate change impacts.
- ***Reinforce that women are good at STEM:*** Young women were far more likely to report that they didn't belong in STEM, that they were inherently bad at it, or that they felt unwelcome. Continuing to provide positive examples like host Caitlin in the Polar Lab can potentially help reverse these internalized negative stereotypes.

INTRODUCTION

Goal 1: Design to Achieve Learning Outcomes

Science media and education producers have a myriad of options for presenting science content to audiences. Most choices are made with either the producer's skills or preferences in mind— or the likelihood that a particular format will generate more online engagement or views. Yet an equally important consideration for selecting media format is the **learning outcome desired for a given audience.**

For instance, might it be useful to excite young people to pursue science careers and engage older crowds with science news, or help audiences of all ages develop critical thinking skills? By exploring whether there are different learning outcomes associated with other media platforms (and whether this differs across age groups), STEM content producers can better understand how to use media to achieve engagement and learning outcomes. Polar science in particular, can seem quite distant from the everyday experience of audiences; are there ways to engage informal learners differently, using different media formats?

Content on a Spectrum of 'Narrative & Interactivity'

A major consideration in creating science media and informal STEM educational material is the level of narrative structure versus open exploration available to learners. Both approaches have been shown to be effective at engaging audiences and promoting learning outcomes:

- ***Interactive, experiential learning*** gives players the opportunity to learn through experience— for instance, by taking on a different role and learning skills associated with that role, exploring a new location, or being given a novel task to complete (Kolb, 2015). Experiential learning has the potential to generate powerful and enduring learning (Kolb, Boyatzis, & Mainemelis, 2000), and seems likely to foster deeper cognition (de Freitas & Neuman, 2009), attitude change (Mazzocco, Green, Sasota, & Jones, 2010), and can promote flow, leading to increased learning and perceived behavioral control (Killi, 2005).
- ***Narrative storytelling***—whether delivered through books, oration, or video, a well-crafted story with a compelling protagonist and narrative tension —can transport readers to a different time and place (Green & Brock, 2000). In fact, psychologists have argued that storytelling is fundamental to how individuals remember and make sense of the world and themselves (Bower & Morrow, 1990; McAdams & McLean, 2013).

Given that both approaches are effective at engaging viewers, are there any differences in learning outcomes associated with each approach in the context of STEM content—particularly polar science? We assessed this question using both quantitative and qualitative approaches.

<u>RQ 1:</u> Uncover the unique learning outcomes associated with two science media formats: a hosted film and an interactive online game

We assessed two different informal STEM media formats (focused on polar science) that vary with respect to narrative guidance provided for the learner: a traditional, hosted 1-hour film with a strong narrative (NOVA Polar Extremes film), and 2) an interactive online game with exploratory and interactive elements (NOVA Polar lab). We used the Strands of Informal Science Learning as our guiding framework.

The game is higher in interactivity, while the film is higher in narrative guidance, provided by a host or guide. In the film, host Kirk Johnson leads the viewer through a clear storyline enabling the viewer to find and integrate various clues about the history of the polar landscape and what it means for the changing climate of Earth. In the interactive lab, with Caitlin as the guide directs the player from one activity to the next, but with relatively less 'narrative guidance,' as the film. In the lab, the player was more actively involved in exploratory play in-between the narrative direction from the host.

We examined learning outcomes exhibited by participants after they engaged with the lab or film. We conducted A/B testing to determine whether participants expressed different learning outcomes across the platforms (quantitative approach). We supplemented this by conducting focus groups and observing whether their verbal responses were consistent with what was observed in the survey data.

Goal 2: Understand the Strands of Informal Science Learning

The Strands of Informal STEM Learning (NRC, 2009) are a helpful framework to understand learning outcomes. They can be used to guide the *design* of learning materials—helping developers aim toward distinct learning outcomes, such as excitement or learning the scientific method— but they can also be used for *effective evaluation*, as was the case in this study.

We used the Strands framework to guide the development of our measures: surveys, open-ended reflection questions, and focus group prompts. However, just because we included items to measure each Strand, it doesn't mean the Strands necessarily reflect distinct learning outcomes. It's possible that our measures do not capture six distinct strands; rather they may capture a simpler (or more complex) underlying learning outcome structure. We, therefore, explored what broader learning outcomes were reflected in the participants' responses.

***RQ2:** To determine whether our learners truly experienced six distinct 'strand' learning outcomes, or whether their responses reflect broader categories of learning.*

We answered this question through exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). These modes of analysis indicated whether our responses cluster around six distinct learning outcomes or not. This can be helpful in understanding which learning outcomes are most appropriate to pursue in polar science materials design and evaluation.

Goal 3: Science Identification & Socialization

Scientific thinking and skill can be a helpful tool for any young person, regardless of if they decide to pursue a science-related career. Critical thinking and weighing of evidence are not only helpful in any job, but also in navigating an increasingly complex media and political environment. The importance of this skill is reflected in *Strand 6: Identifying with the Scientific Enterprise: someone who thinks about themselves as a science learner and develops an identity as someone who knows about, uses, and sometimes contributes to science* (NRC, 2009).

When exploring Strand 6, however, the concepts of scientific skill, confidence, and identification with science/scientists/science careers can sometimes be conflated. For instance, sometimes it is primarily seen as viewing oneself as a scientist (NRC, 2009), other times as having an identity where one contributes to science (Loveland, M., Buckley, B. C., & Quellmalz, E. S., 2015), or knowing about, using, and sometimes contributing to science (Shouse et al., 2010). This hints at some underlying complexity in science identity, skill, and confidence.

One way to explore the complexity embedded in Strand 6 is to consider early STEM socialization and experiences; which is likely to have an impact on skill, confidence, and identification with science. Men are more likely to be interested in STEM than women overall, and the predictors of STEM interest vary greatly between them (Robnett & Leaper, 2012; Knezek, 2015; Holmes et al., 2018; Wang et al., 2015). Possessing high 'cultural capital' (i.e. privilege), being male, having a parent in a STEM occupation and high prior achievement in reading and numeracy are also high predictors of STEM interest (Holmes et al., 2018). Even at the middle school level, predictors of STEM career interest are different for boys and girls (Knezek, 2015). For boys, the strongest predictors of STEM career interest are creative tendencies, and positive attitudes towards science and math. But for girls, the predictors are attitudes toward science, then creative tendencies and attitudes toward math. Therefore, for middle school boys, it seems that being creative is enough to want to go into a STEM career, but girls seem to need the prerequisite of feeling like they are *good* *at science*. Girls' STEM interest was also observed as particularly low when their friendship group was primarily female and not perceived as having a supportive STEM climate (Robnett & Leaper, 2012).

It's therefore likely that **confidence or skill in science is independent from identification with science and a desire for STEM-related careers and experiences**. Perhaps some people have an interest in it, but don't feel that it's for them— or perhaps they are socialized to feel it's not for them. We therefore want to explore the relationship between perceptions of science, identification with science, and whether individuals feel they could 'do science' as a career.

***RQ3:* Explore whether confidence/skill in science functions independently from identification with science and STEM-careers; explore why and whether early socialization with STEM had an impact.**

To explore these relationships, we use a survey to explore peoples' perceptions of science, whether they identify with it, whether they have STEM skills (or have gone into a STEM career). We then probe whether they had been *dissuaded* from pursuing a science-based career or from contributing to science (see Appendix B for full survey instrument). **By understanding what may be holding people back from participating in STEM or identifying with science/scientific thinking, media producers and educators may be better able to create inclusive materials.**

RESEARCH DESIGN

Approach

We used mixed methods to achieve the goals outlined in Goals 1-3. Mixed methods is an integrative approach, which equally utilizes quantitative and qualitative data collection and analysis techniques. The mixed methods approach is not intended to replace qualitative or quantitative approaches but draws on positive aspects of both methodological techniques while diminishing their respective weaknesses. Integrating methods allowed us to generate “meta-inferences” (Gutterman et al., 2019) about science learning processes, which we could not have achieved using one approach alone.

We used a combination of in-person surveys and focus groups, and online surveys with open-ended and guided reflection questions to capture informal STEM learning. Specifically, we worked with two groups of informal learners: a younger group aged 11-13, and an older group aged 18-25; these were selected to reflect the primary audience ages for the NOVA Polar Lab.

We relied on the Strands of Informal Science Learning to develop survey questionnaires as well as focus group guides.

Measures: Learning Outcomes & the Strands Framework

The Strands of Informal STEM Learning framework (NRC, 2009) provide an excellent starting point to generate a list of learning outcomes tailored specifically to polar science informal learning. A rigorous review of existing literature found very few validated survey measures for strand learning, as each category of learning is rather broad and needs to be interpreted in the context of a given topic and format. For our purposes, we developed survey questions that followed the intent of each Strand, which we adjusted for polar science:

- **Strand 1:** Enjoyment, inspired to learn more, the importance of polar science
- **Strand 2:** Self-reported knowledge & tests of knowledge of polar science
- **Strand 3:** Understanding & observing the scientific method (formulating a question, formulating a hypothesis, making a prediction, testing & experimentation, making observations)
- **Strand 4:** Understanding polar science in broader social context/metacognition
- **Strand 5:** Understanding science/polar science norms
- **Strand 6:** Confidence with science skills and personal identification with science

We also included a series of open-ended questions and prompts to explore free associations of our participants; see Appendix B for full survey questionnaires and focus group guides.

Study Data

Phase 1 (Goals 1 & 2)

11-13 year olds, in-person & online[1]

- In-Person Surveys & Focus Groups (MOXI N=23; MESA Day N=28): Working at MOXI, The Wolf Museum of Exploration + Innovation in Santa Barbara, CA, and at Science & Technology MESA Day at UC Santa Barbara, we surveyed and talked with middle-school kids between the ages of 11-13. Participants would play the Polar Lab Module 2 or watch a segment of the NOVA Polar Extremes film (20 min each); they would fill out a short pre-survey (5 min) and post-survey (10 min), and then engage in a focus group with about 5-8 other kids (20-30 min). *(Note: the limited sample size is due to COVID-19; further in-person data collection was not possible.)*

- Online Surveys (N=73): We transitioned our work online after COVID-19, and used the same survey instrument and open-ended questions, providing students with links to view the film or play the lab. We circulated the survey widely to teacher and parent networks to capture students home from school (surveys lasted about ~45 min, including viewing the film or playing the lab).

Phase 2 (Goals 1, 2, & 3)

18-25 year olds, online through nationally representative survey panel[2]

- Online Surveys (N=243). Using Turk Prime and Mechanical Turk, we used a slightly adjusted survey instrument targeted at 18-25 year olds. Participants were provided a link to the Polar Lab or Polar Extremes film segment, which they watched/played before returning to complete the survey.
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- Online Open-Ended Reflections (N=41). We found it important to collect "rich data" to help understand *why* a learning format had a particular impact. Therefore, we recruited participants to Polar Lab or watch the Polar Extremes film segment and provide written feedback to several open-ended questions.

- Online Survey + Open-Ended Reflections (N=108). To explore the nuances of science identity, confidence, and socialization, we developed a third survey/open-ended response instrument. This did not require watching or playing

[1] See Appendix C for demographic information
[2] See Appendix C for demographic information

any NOVA materials, just reacting to sample science content, and answering a series of general and personal questions about science and science perceptions.

Data Analysis

Quantitative Analysis (closed-ended survey data)

Both interactive, experiential learning and narrative storytelling have been utilized by science educators to engage audiences and promote learning outcomes. The present analysis investigated whether there are any differences in learning outcomes associated with each approach in the contexts of STEM content and polar science. Independent samples t-tests and logistic regressions were conducted to examine whether respondents who watched a 20 minute film clip from the Polar Extremes film or played the interactive Polar Lab for 20 minutes would exhibit differences in their educational outcomes. Demographic variables such as gender and race/ethnicity as well as pre-treatment covariates (pre-existing interest in science and socialization in science) were included in these analyses as controls.

The question of how socialization affects scientific learning outcomes, confidence in understanding science content, and desire to pursue a science-related career was also explored using t-tests and logistic regressions. Demographic variables, media intervention type, and pre-treatment covariates were included in these analyses as controls. Namely, we examined socialization using three variables as proxies: how often one discusses science topics with others, whether one has a family member in science, and whether one has friends in science. Participants were categorized as either “low” or “high” on these three variables, and then differences in means on a variety of scientific learning outcomes were examined.

Qualitative Analysis (focus group data)

The focus groups were semi-structured spaces that enabled us to explore how, when, and in what context the Strands emerged. Although the focus group interviews were semi-structure, we utilized a loose interview guide (i.e., a set of questions) to investigate how the Strands and climate science learning occurred among focus group participants. The focus group itself, however, dictated the sequence we asked the questions, and when a Strand appeared in an unexpected place, we intentionally followed the direction the focus group took itself in (Rubin and Rubin 1995; Lofland 2006).

Once the focus group data was completed and transcribed, we analyzed the transcripts utilizing content analysis and systematic textual observation. It entailed coding for the emergence of Strands in group conversation about the Polar Extremes lab and film clip, respectively. The methodological bedrock behind our content analysis processes was grounded theory, which is a “systematic, inductive, and comparative approach for conducting inquiry” (Bryant and Charmaz 2011, p. 2). While the primary purpose of the qualitative analysis was to locate for the emergence of Strands, we did not limit our inquiry scope and recorded attitudes toward climate and polar science and change. This methodological approach, combined with findings garnered from quantitative analysis, enabled us to discover phenomena outside the original research questions' scope. Following Charmaz’s “Coding in Grounded Theory Practice” (2006), we coded each of the focus groups' transcripts twice. The first phase was intensive and entailed a line by line reading and analysis of each transcript, and was primarily intended to locate the emergence of the Strands. The second coding phase was more expansive and focused on the most frequent patterns and themes around climate change and polar science observed across focus groups. We then sorted and organized the Strands, which enabled us to observe their frequency and general location of emergence.

Qualitative Analysis (open-ended survey data)

As mentioned previously, the scope of our in-person interviews were limited because of the COVID-19 pandemic, requiring us to adjust our methods. To achieve reliability and validity, we followed the exact qualitative research steps and methodology described above in the analysis of online surveys.

Factor Analysis

Assessing the validity of a measure learning is not a perfect science, though the measure developed for the purpose of this research is valid. Researchers first reviewed all prior studies on the Strands of Informal Science Learning. From this, they identified any measures that were used to assess their applicability to this study. Many of these were already tested to be valid.[3]

A number of additional questions were added to the measure, based on areas where there was little to no prior question development. In addition, questions were reworded to fit the specific context of polar science. Researchers were subsequently left with multiple questions corresponding to each of the six dimensions. From this, questions were further refined and selected for the measure included in Phase 1 of the research. The results of Phase 1 allowed us to further adjust questions for clarity and specificity. In sum, researchers followed a reasonable and accepted approach when designing their measure.

Nonetheless, this process does not ensure that the structure found in the Strands Framework is similarly constructed in the minds of young people. Thus, the measure was further assessed through factor analysis, which helps to identify the underlying structure of a measure and how well responses fit that measure.

[3] See the survey matrix in Appendix A

We hypothesized that the instrument would contain a six-factor structure (Strand 1: Interest and Enjoyment; Strand 2: Understanding Science Knowledge; Strand 3: Engaging in Scientific Reasoning; Strand 4: Metacognition/Reflecting on Science; Strand 5: Engaging in Scientific Practice; and Strand 6: Identifying with the Scientific Enterprise). This analysis aims to provide psychometric support for the internal factor structure of the questionnaire and to discuss future implications for its usage.

- **Exploratory Factor Analysis (EFA) Statistical Methodology:** Prior to conducting EFA and CFA, we randomly selected cases using a 50%-50% split of the subset sample. Splitting the sample allows us to test for the emergent factor structure using EFA on a “calibrate” sample, and to confirm this factor structure using CFA on the “validate” sample. We performed an EFA on the “calibrate” sample to determine the initial factor structure of the selected twenty-five items[1] corresponding to the learning strands literature. The EFA was performed using the maximum likelihood estimation with robust standard errors (ML) method, to fit the model by freely estimating the parameters of the common factor model. We applied oblique Promax rotation using MPlus software version 5.2 (Muthén & Muthén, 1998-2016) to allow factors the possibility to correlate.

- **Confirmatory Factor Analysis (CFA) Statistical Methodology:** The CFA was performed on the “validate” sample using MLR estimation methods. The CFA tested the factor structure recommended by the EFA results. Loadings specified for each factor were freely estimated, except for the item that was chosen as the reference variable for each factor (set to 1.0). To set the scale for CFA, Unit Loading Identification (ULI) was used, where the item with the highest loading variable for each factor was set to 1.0 and chosen as the reference variable for the other freely estimated parameters.

FINDINGS

Goal 1: Design to Achieve Learning Outcomes

What are the unique learning outcomes associated with two science media formats: a hosted film and an interactive online game? (RQ 1)

Overall, the hosted Polar Extremes film and the guided, interactive Polar Lab successfully encouraged learning outcomes in audiences, yet which varied slightly by age group. A detailed review of the findings is presented below for each age group: young adults (ages 18-25, older Gen-Z and younger millennials) and adolescents (ages 11-14, younger Gen-Z).

Young Adult Audiences (ages 18-25)

Both learning approaches—narrative storytelling and experiential learning—engaged viewers and fostered positive learning outcomes. Not surprisingly, learning about polar science through film was effective at fostering an understanding of science concepts and how polar science connects to the broader scientific context. In contrast, interactive learning in a lab-style format can be utilized to boost confidence and teach audiences that science is a collaborative, multi-step process.

Summary Findings (quantitative/survey): Participants who watched the film (a stronger narrative structure) were more likely to recognize the importance of polar science (Strand 1) and understand polar science in a broader social context (Strand 4), as predicted. In contrast, participants who played the lab were more likely to recognize the collaborative aspects of science (Strand 3), and reported that they felt more like part of a team (Strand 5). Consistent with our theorizing, those who played the lab were more likely to understand and recognize several aspects of the scientific method (Strand 3). Finally, participants who played the lab were significantly more likely to report feeling confident that they could understand other science content that they come across and that they could go into a science-related career (Strand 6), as compared to those who watched the film. All other learning outcomes were observed about equally between the two groups.[4]

These findings are summarized in chart form and presented in graphs below. They represent findings from a logistic regression that modelled the effect of treatment (film/lab) on each learning outcome, controlling for race / ethnicity, gender, age, pre-existing interest in science, and socialization in science.

[4] For additional detail on the quantitative findings see Appendix D.

SUMMARY OF QUANTITATIVE FINDINGS: Comparison of Lab & Film Learning
Ages 18-25, findings represent statistically significant differences between Lab & Film
For a full description of findings with graphs, please see Appendix D

FILM STRENGTHS | Learning Outcomes Achieved More Effectively in Film

STRAND 1 - Interest & Engagement
• **Importance of polar science** Participants who watched the film were significantly more likely to report that the information they learned is so important that others should be aware of it as well, compared to those in the lab ($p = .002$)
STRAND 4 - Metacognition / Reflecting on Science
• **Polar science helps us see humans as a 'force of nature'**? Participants who watched the film were significantly more likely to report that polar science helps us to appreciate how humans are a 'force of nature', compared to those in the lab ($p = .002$)

LAB STRENGTHS | Learning Outcomes Achieved More Effectively in Lab

STRAND 3 - Scientific Method
• **Testing/experimentation** *Participants who played the lab were significantly more likely to recognize "testing/experimentation," compared to those in the film ($p = .0017$)* • **Making observations** *Participants who played the lab were significantly more likely to recognize "making observations", compared to those in the film ($p = .046$)*
STRAND 5 - Engaging in Scientific Practice / Science Norms
• **Feeling like a part of the team** *Participants who played the lab were significantly more likely to report feeling like part of a team, compared to those in the film ($p = .042$)*
STRAND 6 - Identification with & Confidence in Science
• **Confidence to understand other science content** *Participants who played the lab were significantly more likely to report feeling confident that they could understand other science content that they come across, compared to those in the film ($p = .035$)* • **Confidence to pursue a science-related career** *Participants who played the lab were significantly more likely to report feeling confident that they could go into a science-related career (whether or not they decide to), compared to those in the film ($p = .00018$)*

Summary Findings (qualitative, open-ended responses): In their open-ended reflections, 18-25 year olds shared inspiration after watching the film or playing the lab. They overwhelmingly expressed joy around learning about climate change and science, especially among those who watched the film. Polar Extremes inspired them to learn more about climate change and to think immediately about how they can do things in their own lives to lessen their carbon footprint.

Despite being inspired by the science of Polar Extremes, they also expressed fear of climate change. Since fearful— yet hopeful and inspired—reactions to Polar Extremes were so consistent (especially among film viewers), we termed this reaction an **"inspired dread."** The concept of inspired dread is two-fold: the first aspect is that the participant is afraid and aware of climate change's existential scope. The second part of inspired dread is that participants are motivated by Polar Extremes to be a part of the solution, and expressed that they were immediately inspired to transform their lifestyle to mitigate their impact on the climate.

SUMMARY OF QUALITATIVE REFLECTIONS: Differences in the Lab & Film
Ages 18-25, findings from open-ended survey responses

FILM STRENGTHS | Learning outcomes experienced after viewing film
INSPIRATION (strand 1) Nearly every participant exuberantly expressed how inspired they were by the film itself and grateful for the work that the scientists were doing for the planet. ○ *Participants strongly indicated that watching Polar Extremes greatly inspired them to learn more about climate change and take steps within their own lives to mitigate their carbon footprint.* **REFLECTING ON SCIENCE** (strand 4) Nearly all of the respondents who watched Polar Extremes expressed how the film helped them learn about how humans are a "force of nature" and how the scientific method can help us understand climate change and how it can help curtail climate change. **COLLABORATION & COMMUNICATION** (strand 5) Almost all participants remarked that the scientists and host articulated how their research helped to illuminate the urgency of climate change, which included describing how scientists interacted with one another. This shows that the film effectively conveyed collaboration and communication. ○ *Participants tended to remark how they enjoyed seeing scientists from all around the world working together to learn and solve problems* ○ *Almost every participant had extremely positive things to say not only about Kirk Johnson. They* also expressed enjoyment in seeing Kirk interact with other scientists (especially Julie).

LAB STRENGTHS | Learning outcomes experienced after viewing lab
ENJOYMENT (strand 1) Participants expressed enjoyment playing the lab, but did not necessarily demonstrate inspiration in the same way as film participants. Participants demonstrated active inquiry more clearly, suggesting that the lab acts like a de-facto guide or facilitator. **ACTIVE INQUIRY (strand 3)** Participants who engaged the game tended to remark on the uniqueness of the game. These participants were also very enthusiastic about playing and learning from the game. They gave rich

descriptions of how they played the game, which indicates not only enjoyment but also that the Polar Lab is beneficial for people of all ages.

Adolescent Adult Audiences (ages 11-14)

Evidence for learning was seen across both the lab and the film for adolescent audiences, summarized in the table below. Strikingly, younger participants also tended to see themselves overall as part of a broader, global community that is responsible for listening to scientists so that they can “be a part of the solution.” However, younger audiences did not discuss actionable measures that they could take to palliate the consequences of climate change. And like the older group, while younger participants shared positive emotions towards learning, they tended to express existential dread about climate change: there were elements of the film that kids described as ‘scary.’ So they, too, experienced “inspired dread.”

Our adolescent survey participants provided feedback in the form of open-ended responses to survey questions, as well as a few in-person focus groups. Note that summary findings for written responses and focus groups are presented separately, as different trends emerged between the two contexts.[5]

SUMMARY OF QUALITATIVE FINDINGS: Comparison of Lab & Film Learning

Ages 11-14, findings represent open-ended reflections from surveys (focus groups not included)

FILM STRENGTHS | Learning Outcomes Achieved More Effectively in Film
STRAND 2 - Knowledge & Understanding. Film participants tended to display a higher degree of knowledge and understanding than those in the lab. ● *They didn't just describe scenes but gave in-depth descriptions of understanding.* ● *For example, film participants frequently discussed carbon dioxide and an understanding of the impact that humans have had on CO2 outputs.* **STRAND 3 - Scientific Method.** Those who watched the film clearly connected scientific methods observed and why they are important to conducting science. ● *Younger participants who watched the film described how they observed the scientific process, such as collaboration, hypothesis formation, repeated observation, and experimentation, and connected this to how people work together to gather information and come to a conclusion.* **STRAND 5 - Engaging in Scientific Practice / Science Norms.** Young participants who watched the film did an excellent job describing the importance of collaboration and communication in scientific endeavors.

[5] *Note that some participants viewed the film or played the game at home and completed an online survey, while a smaller subsample completed these in-person at a science museum in Santa Barbara, CA.*

- *Many gave lengthy and astute descriptions of how communication enhances scientific inquiry, insofar as scientists trying to solve a problem through collaboration come to more robust conclusions if they have different backgrounds.*
- *Those in the lab described why collaboration is vital to the scientific process but did not necessarily link it to what they saw and experienced directly.*

LAB STRENGTHS | Learning Outcomes Achieved More Effectively in Lab
STRAND 1 - Interest & Engagement. Kids expressed positive motivation and explained how they liked seeing all the different parts of the lab and that they enjoyed the interactivity it provides. They were motivated to learn about the scientific process and stated enjoyment of science learning. **STRAND 3 - Active inquiry.** Kids gave very nuanced descriptions of how they played the game. Additionally, kids detailed the processes of analysis they partook in as players, and described the way that they came to scientific conclusions in the game.

BOTH EFFECTIVE | But in Different Ways
STRAND 6 - Identification with Science. Both the film and the lab appeared to make scientific identity salient for the participant. It is clear that the resources are highlighting and reinforcing an underlying collective identity more than helping to create a new identity. ● *FILM* - Kids who watched the film talked about how "we" can work together to solve problems and find solutions to climate change, or how when "we" work together, scientific discovery is expedient. It is possible that these language patterns in particular are indicators of kids imagining themselves as part of a team, thus identifying a connection to scientific culture. ● *LAB* - Some kids who played the game were so jubilant about precisely explaining how they played the game that it indicates that they identify with scientific culture. Similarly, they expressed satisfaction with playing the games, as well as the act of playing while learning, which indicates science identity among kids who played the game. ○ *There were instances where kids used the rhetorical "you" to describe why collaboration is important, which possibly indicates that they imagine themselves as scientists and identifying with science culture.*

Summary Findings: Film

Open-ended reflections (written): Adolescents frequently discussed how people work together to gather information and come to a conclusion. They also described how they observed the scientific process, such as collaboration, hypothesis formation, repeated observation, and experimentation. These discussions tended to surround climate science and how collaboration and diversity of understanding and expertise are key to scientific discovery. There were also some instances of metacognition that far exceed the boundaries of the film. Though these responses seem to be outliers; our semi-random subsample of kids whose parents brought them to a science learning museum on the weekend may explain the instances of nuanced and sophisticated expressions of metacognition and scientific understanding.

Although instances of metacognition were uneven, those who watched the film and participated in the focus group and survey gave vibrant descriptions of how scientists (in the film) came together to find out how and why the climate has changed. Moreover, kids discussed how discovery scientists achieve discovery by engaging in collaboration and experimentation. There were instances where kids explained how collaboration speeds up the scientific process and helps scientists answer questions more quickly. These participants also described how sharing and testing ideas and looking at different components of the earth (e.g., air, sediment, and ice) helped scientists come to conclusions about climate change.

<u>Focus Groups (verbal group share):</u> Across all focus groups there was immediate evidence of Strand 1 (motivation). Young participants discussed excitedly how scientists can predict temperature. Almost simultaneously, Strand 3 (active inquiry) emerged. Young participants were interested in seeing the multiple methods that scientists use to discover the dramatic rise in CO_2 emissions in the past fifty years. Although young participants tended to possess a relatively sophisticated understanding (Strand 2) about climate change, they did not tend to connect what they saw in the film. Strand 5 (communication & collaboration) was the last to appear and only emerged when focus group facilitators prompted it. Despite this, we believe they were the most salient responses. Young focus groups participants who watched the film expressed being inspired by seeing how different scientists, working in locations worldwide, can all contribute through communication to understand climate science. Despite these positive takeaways, younger participants tended to express being overwhelmed and experiencing existential dread thinking and learning about climate change. Yet, across all focus groups of film viewers, they were consistently inspired by the collaboration they saw among scientists and perceived themselves as part of a larger scientific body politic, committed to being guided by scientists to work within their communities to fight climate change.

Summary Findings: Lab

<u>Open-ended reflections (written):</u> The adolescents who engaged with the lab gave detailed descriptions of how they played the game, which indicates the strong presence of active inquiry. Reports of the pollen game and the sediment game, and videos of drilling were especially prevalent. Younger survey participants who took part in the focus groups and survey illustrated how the lab helped them understand the scientific process, especially in collecting data and calculating ratios. The younger participants who played the game also emphasized the importance of collaboration and communication, and that collaboration is vital to science because people have different perspectives, which helps solve problems. In more precise reference to how scientists collaborated, they overwhelmingly discussed seeing the drilling. By watching the scientist drill and then individually participating with the sediment activities, younger participants indicated understanding and how drilling helped scientists learn about climate and how the climate has changed. Throughout the survey,

there is a strong indication that seeing the video and then playing the game was instrumental in understanding and enhancing the players' experience.

Focus Groups (verbal group share): Among focus group participants who engaged with the lab, motivation (Strand 1) tended to be individualistic, and young participants conveyed motivation by describing an aspect of the game they liked. This observation indicates that motivation is different in the lab than the film, which tended to evoke motivation by seeing science in action. As with those who watched the film, Strand 3 (active inquiry) quickly emerged with focus group participants who played the game. The focus groups who played the game perceived active inquiry very differently from those who watched the film and the concept of active inquiry was abstract and individualistic. However, there are indications that young participants who played the game frequently conceptualized the scientific process and discussed the repetition entailed in finding an answer. Strand 2 (understanding) did not emerge for young participants who played the game until relatively late into the focus groups and appeared much less frequently than the focus groups who watched the film. When understanding did occur, it was in the context of them enjoying the game, and focus group participants did not relate their engagement with broader scientific patterns, as with the film. It was only after the interviewer probed kids about what they learned from the game that they connected the game to more general scientific themes, such as that layers of sediment operate like a climate time capsule. Strand 5 (communication and collaboration) appeared less frequently and the focus group facilitators had to prompt these focus groups to discuss science as a collaborative process. When kids discussed collaboration, they did not refer to their own experiences or feeling like they were part of the team. Instead, kids reported that collaboration is vital because people have independent knowledge, and collaborating can speed up scientific processes

Goal 2: Understanding the Strands of Informal Science Learning

Do our learners truly experience six distinct 'strand' learning outcomes, or whether their responses reflect broader categories of learning.

Working with young adult audiences (ages 18-25), our results did not find evidence for six distinct learning strands within the outcomes measured. Rather, the findings suggest a "two-factor model" consisting of 11 polar science items—this means we observed two primary learning outcomes. These appear to represent ideas related to '**polar science impressions**' and '**recognizing scientific inquiry**.' This should be considered when developing future surveys related to the Strands Framework. (Though this doesn't necessarily warrant exclusion of any particular item or Strand, as they are still likely to provide important additional insights or context to researchers.) The findings from the EFA and CFA are provided in more detail below:

- **Exploratory Factor Analysis:** Exploratory Factor Analysis points to a 2-factor solution of nineteen items based on the observed data. The results of the parallel analysis and factor loadings are in Appendix E. Based on the loadings, the two factors most closely represent: (1) Impressions of Polar Science and (2) Recognizing Scientific Inquiry. [6]

- **Confirmatory Factor Analysis:** A CFA investigating the 2-factor model solution derived from the EFA was performed. Based on the recommendations of Costello and Osborne (2005), only items with 0.32 or greater loading were included; thus, 7 items were removed. Figure 1 illustrates the path diagram tested with CFA. Based on the goodness-of-fit statistics guidelines, the results of this CFA did not yield good model fit.

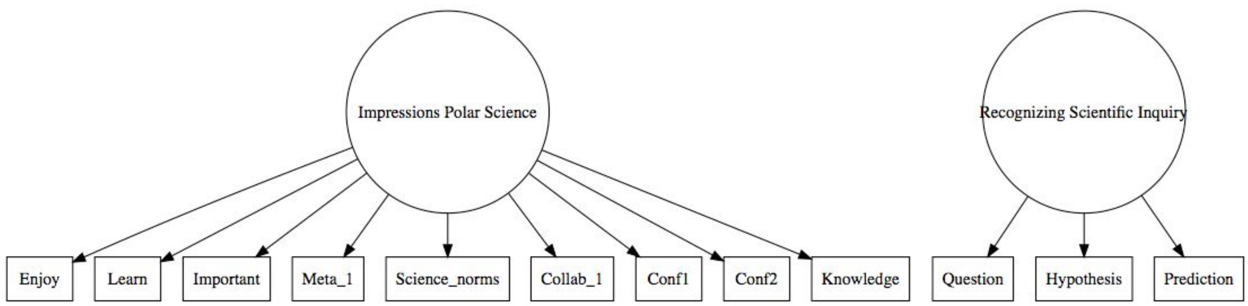

Figure 1. Two Primary Learning Outcomes (Path Diagram)

To improve model fit, we next reviewed modification indices for with statements based on expected parameter change (EPC) values. Two item pairs (i.e., Items 2 and 1, with 29.82; Items 5 and 2, with 16.00) were identified as measuring similar constructs and loading onto the same factor. In the re-specified model, residual variances of the two pairs of items were permitted to correlate: Item 2 (inspired to learn more) with Item 1 (had fun learning about polar science), and Item 5 (I understand what polar scientists do) with Item 2 (inspired to learn more), and the re-specified model was analyzed with the same sample. The CFI is closer to .95 in the modified model than in the unmodified model.

Goal 3: Science Identification & Socialization

Does confidence/skill in science function independently from identification with science and STEM-careers? Does early socialization with STEM impact this, and why?

Socialization in science is likely to be a pre-determinant of how individuals engage with the polar science media. To investigate this relationship, we first asked 18-25 year olds about whether they talk about science with others, have family members in science-related careers, or have friends in science-related careers. We then explored whether people abandoned dreams of STEM-related careers, and why.

[6] Based on Costello and Osborne (2005), only items with loadings of .32 or greater were retained.

Discussing Science Promotes Interest: Results indicate that discussing science with others is important— more important than whether someone has a friend or family member in a science-related career. Specifically, those who *talk about science* more:

- Are more interested and engaged with polar science (Strand 1)
- Have a greater perceived understanding of polar science (Strand 2)
- Likely to recognize several aspects of the scientific method (Strand 3)
- Agree that polar science helps them understand how the climate works (Strand 4)
- Understand what polar scientists do (Strand 5)
- More confident and express interest in pursuing a science-related career (Strand 6)

We also found that young adults who talked about science topics more often scored higher on most Strands, expressing a greater enjoyment, knowledge, and understanding of science, being more likely to recognize several aspects of the scientific method, being able to connect polar science to the broader scientific context, being more likely to understand what polar scientists do, and feeling more like part of a team.

Friends & Family in Science: Having family and/or friends in science appears to only be related to Strand 6 (confidence and identity). Those with a family member in science are more to be pursuing a science-related career and are more sure they would like to pursue a science-related career. Those with friends in science are also more likely to pursue a science-related career.

Having a family member or friend in science did not seem to make a difference on the learning outcomes experienced by the participant. However, as expected and consistent with the prior literature, respondents with friends and family in science were significantly more likely to be confident about pursuing a science-related career or already be pursuing a science-related career.

The Influence of Science Socialization on the Strands

Strand	*Learning Outcome*	*Talk about Science*	*Family in Science*	*Friend in Science*
1	Enjoyment	×		
	Learn more	×		
	Importance			
2	Self-reported knowledge	×		
	Correct responses to 3 knowledge tests			
3	Formulating a question	×		
	Formulating a hypothesis	×		

	Making a prediction			
	Testing/experimentation			
	Making observations	×		
4	Understand how the climate works	×		
	How humans are a force of nature			
5	What polar scientists do	×		
	Feeling like part of a team			
6	Confidence in other science material	×		
	Confidence in science-related career	×		
	Already pursuing a science-related career	×	×	×
	Want to be a polar scientist			
	Want to pursue a science-related career			
	Interest in finding out more about science-related careers			
	Interest in finding out more about polar science careers	×		
	Not very interested in a science-related career (reverse coded)	×		
	Not sure about going into science-related career (reverse coded)		×	

***Shading indicates a positive effect of the variable on the strand. The above is based on logistic regression with 95% confidence and includes gender, age, race / ethnicity, pre-existing interest in science, and treatment condition as controls.*

Personal Definitions of Science/Scientists: While this provides insights into the influence that being socialized in science has on people's interactions with the media, it does not help to explain why socialization is important. We therefore asked participants to share how they define science and scientists and what prevented them from pursuing a science career. Our analysis points to three categories of respondents:

1. those who wanted to and did end up going into STEM
2. those who never wanted to go into STEM and didn't
3. those who initially wanted to go into STEM as kids, but were thwarted later on.

The following focuses on those who ended up not pursuing STEM to see what accounts for their disinterest early or later in life. Importantly, ***there do not appear to be clear***

differences based on race or gender between those who chose to pursue a science-related career and degree versus those who did not.

Science is "Not For Me." For respondents who didn't want to go into STEM (types 2 and 3), when asked why they did not choose to go into science, ***over 40% respond 'I didn't feel like it was for me'*** (see Figure 2). The second most common response was 'I wasn't interested in it' (34%) and 25% say 'I felt it was too difficult.' However, for those who never wanted to pursue STEM (type 2) ***type 2 individuals specifically, we can see that 59% agree that 'I didn't feel like it was for me,'*** as compared to only 23% of type 3 individuals.

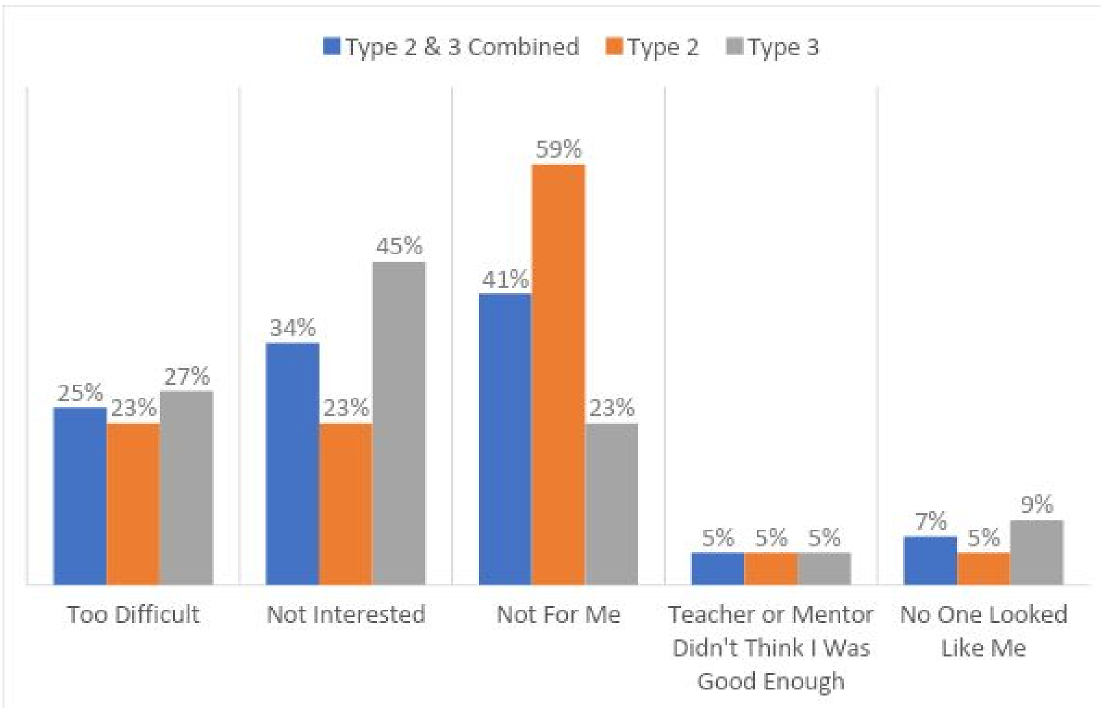

Figure 2. Reasons for Not Pursuing Science. The bars represent the percent of respondents that marked that as a reason they did not go into science, either originally, or later on. Type 2 individuals are those who were originally interested, but later cooled. Type 3 individuals were never interested in pursuing a science career or degree.

Women Don't Feel Welcome or "Good Enough." When we explore responses of those who responded 'I didn't feel like it was for me' further, women are far more likely than men to agree with this statement. ***In fact, 56% of women in this group respond with the affirmative, compared to only 21% of men.*** There is no major difference between people of color and white people. This suggests that for women in particular, not feeling like science was for them is a major determinant of not pursuing STEM.

Within these results, we looked at the qualitative responses of two groups: women and men who never aspired to a STEM career, and women and men who had once aspired to a career in STEM but abandoned this career path. There was no significant difference in the responses between women and men who never aspired to have a career in STEM. ***However, when we examined differences between those who dreamed of becoming a scientist but abandoned these ambitions, the responses between women and men had stark differences.*** For example, ***women reported a precise moment when they discovered they were "bad" at math or science. Some women also gave nuanced descriptions of feelings that women are not welcome in male-dominated fields.*** Among men who abandoned STEM career paths, there was no point where they described belief in an inherent inability or fear of discrimination. Men gave simple explanations that elucidated that they chose different career paths simply because their interests changed.

Regardless, nearly all participants, regardless of gender, stated that they thought science media is not only enjoyable but important. These findings underscore the point that there is a severe deficit among women's self-perceptions of their ability, confidence, and belonging in scientific communities despite interest. Please see the quotes from open-ended survey participants below.

Why men chose to leave STEM career paths

- "I just ended up not wanting to because I didn't like rocks."
- "Because I want to make big bucks, and felt that science wasn't going to give me that."
- "Science class was very boring and nothing in science stood out to me."
- "I just wasn't interested."

Why women chose to leave STEM career paths

- "As a girl in a lower class home, the expenses to go into doctoring, researching, and engineering didn't fit. Also there is a lack of female STEM jobs and it feels like the market is towards men."
- "Parts of it were difficult like the math that goes with science I'm really bad at math."
- "Things got complicated in Chemistry and Physics. Made me realize how hard science is."
- "I think that math is a huge obstacle to those who want to go into science— at least it was for me. Most majors require so many math courses which makes it feel impossible for those who struggle in math."

CONCLUSIONS

Results from the mixed-methods analytics suggest that both the film and the lab support the Strands of Informal Science Learning. Overall, the film seemed to be slightly more effective at promoting interest and engagement (strand 1) and identifying elements of the scientific method or displaying active inquiry (strand 3). However, the lab made kids and young adults feel a bit more a part of the team than the film (strand 5). While our survey and focus groups didn't explicitly ask 'why' this might be, we have a few potential explanations. We hypothesize that the narrative approach of the film may better 'explain' what kids see and put it in context or translate it into main ideas a bit more clearly. The focus groups additionally suggest that students who played the lab were first taken with the gameplay and the microprocesses of the game elements, and didn't reflect on broader concepts or 'learning strands' until they were prompted to do so by the focus group facilitators. This suggests that younger audiences may need the assistance of teachers or facilitators to put their learning in context, while the film narration already has that as a 'built-in' element.

Importantly, neither media strongly supported knowledge and understanding (strand 2) as we defined it. While kids and young adults could regurgitate what they saw, they rarely connected this to deeper reflections, unless prompted. This strand would therefore benefit from intentional cultivation through either written or verbal reflections.

Interestingly, kids tended to react to the material presented with feelings of dread and even hopelessness, whereas this was not the case with the young adults, who were more inspired by what they saw. It's difficult to say where this difference stems from, it could be due to ongoing curricula that the older audience members have potentially already been exposed to that highlights solutions and 'everyday heroes.' Regardless, it seems imperative to explore approaches that may help these young viewers feel more inspired.

Young adults who talked about science with their peers were more likely to have more robust learning outcomes across all strands, and be generally more engaged and interested in STEM topics. Interestingly, whether someone had a family member or friend in a science-related field was not as influential, by comparison. And many women who opted not to pursue a STEM-career could identify a time when they felt not good enough, or unwelcome in a male-dominated field (controlling for ethnicity/race). This makes it even more important that science media producers continue to normalize the presence of women in STEM, and work to "mainstream" STEM content and conversations in audiences.

RECOMMENDATIONS

What can STEM Media Producers Learn From This Study?

1. Facilitation is instrumental to learning

While older audiences can often make connections between what they see and what it means more broadly, younger audiences benefit greatly from facilitations that connect observations to learning outcomes and deeper understanding. Thus, producers should consider continuing to support teacher guides, include more opportunities for choice and autonomy (while the lab acts as a de-facto facilitator, the opportunity for learners to make their own choices about other media should be embedded into the program as well), and embed opportunities throughout materials for audiences to reflect.

2. Design media with clear learning goals

The quantitative results provide initial evidence to suggest that the lab is effective at making participants feel like they are part of a team. However, the focus group data shows that participants consistently viewed the lab as an individual experience. One approach that to consider in future interactive games is to make the labs a multiplayer experience. This will help audiences recognize that science is a collaborative endeavor. By engaging with other uses live and online, players can gain firsthand experience of the scientific process being a necessary outcome of team efforts.

3. Highlighting 'everyday' solutions may counteract feelings of dread

Data from the focus groups suggests that the film tends to evoke existential dread about climate change among younger audiences. While older audiences did not tend to exhibit this pattern, they still expressed a desire of how they can be a "part of the solution." Thus future programming might feature scientific endeavors to alleviate current problems caused by climate change. It would also be helpful, for older audiences in particular, to show "everyday people" who have taken steps to reduce their carbon footprint or make a difference. This can inspire and show viewers practical ways that they can contribute to efforts to help with problems caused by climate change. Such programming can show kids that interdisciplinary professionals are problem-solving to find ways to live on a planet damaged by human activity.

4. Discussing science with others enhances the experiences

Findings from quantitative analysis shows that young adults who discuss science topics with others more frequently tend to display greater learning outcomes in science on all of the strands. This is a simple change that people can make in their daily lives to reinforce scientific concepts. STEM media producers can encourage viewers to go out and share what they learned with friends and family members, or provide forums to do so.

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APPENDIX A - Survey Matrix

See attached Excel document for a summary of potential survey items for each strand, including response categories and sources.

APPENDIX B - Instruments

MOXI/MESA DAY PRE-SURVEY QUESTIONNAIRE

Participants will arrive with their parent or guardian, complete a check-in and receive a ticket to MOXI, provide their verbal consent, and fill out the following pre-survey on an iPad.

ID

1. Please enter your name:
    1. First
    2. Last

Science Background

1. In general, I find science:
    1. Very boring
    2. A little boring
    3. A little interesting
    4. Very interesting
2. I see a challenge as a way to grow and learn.
    1. Never
    2. Not that often
    3. Sometimes
    4. All the time
3. I try and learn as much as I can in new situations.
    1. Never
    2. Not that often
    3. Sometimes
    4. All the time
4. I can see lots of ways that science makes a positive difference in our everyday lives.
    1. Never
    2. Not that often
    3. Sometimes
    4. All the time
5. Do you have family members that work in science?
    1. Yes
    2. No
    3. Unsure
6. Do you talk about science with your family members?
    1. Yes
    2. No
    3. Unsure

Demographic Information

7. What grade are you in?
    1. 5th
    2. 6th

    3. 7th
    4. 8th
    5. 9th
    6. Other[HH1]

8. My gender is
    1. Girl
    2. Boy
    3. Nonbinary
    4. Gender non-conforming
    5. Prefer not to say
    6. Other [text box]

9. My race is [check all that apply]
    1. African-American/Black
    2. Chicanx
    3. Latinx
    4. Native American
    5. Asian
    6. East Indian
    7. Filipino[x?]
    8. Native Hawaiian/Pacific Islander
    9. White/Caucasian
    10. Other [text entry]
    11. I would prefer not to say

MOXI/MESA DAY POST-SURVEY QUESTIONNAIRE

ID

1. Please enter your name
    1. First
    2. Last
2. Which of the following groups were you in?
    1. I played the NOVA Lab
    2. I watched the NOVA documentary

Strand 1

1. I had fun learning about polar science in [the documentary / the Lab].
    1. Strongly disagree
    2. Disagree
    3. Agree
    4. Strongly agree
2. This inspired me to learn more
    1. Strongly disagree
    2. Disagree
    3. Agree
    4. Strongly agree
3. This information is so important, I feel others should be aware of it as well
    1. Strongly disagree
    2. Disagree

3. Agree
4. Strongly agree

Strand 2

4. I have a greater understanding of [polar science] because of [this documentary / the Lab]
    1. Strongly disagree
    2. Disagree
    3. Agree
    4. Strongly agree
5. How has Earth's climate changed over its long history? *[multiple choice]*
    1. Yearly average temperatures have not changed much over time
    2. Earth has alternated between very warm and very cold periods
    3. Earth has always had ice year round at the poles
6. Why do scientists study the poles to learn about Earth's climate? *[multiple choice]*
    1. Climate in the polar regions is more stable than other areas on Earth
    2. There are no seasons at the poles
    3. Differences between hot and cold climates are obvious at the poles
    4. Both a & b
7. What is the connection between carbon dioxide levels in the atmosphere and Earth's climate? *[multiple choice]*
    1. Carbon dioxide levels have stayed about the same, even as Earth's climate changes
    2. Carbon dioxide levels have stayed about the same, and so has Earth's climate
    3. Carbon dioxide levels cycle between highs and lows, and these changes correspond to change in Earth's climate
    4. Carbon dioxide levels cycle between highs and lows, but Earth's climate doesn't change

Strand 3

8. How much were the following research practices emphasized in the [Lab/Doc]? *[3 point scale: Not at all - A little - A great deal]*
    1. Formulating a question
    2. Formulating a hypothesis
    3. Making a prediction
    4. Testing / Experimentation
    5. Observations
9. (LAB) Which activity did you enjoy the most? Describe your approach! / (DOC) Can you remember a time when the scientists were trying to solve a problem? Can you describe how they approached it?
    1. Open-ended (text box)

Strand 4

10. Knowing polar science helps me understand how the earth's climate works:
    1. Strongly disagree
    2. Disagree
    3. Agree
    4. Strongly agree
11. Do you think polar science helps us to appreciate how humans are a 'force of nature'?

1. No
2. Maybe
3. Yes

Strand 5

12. I understand what polar scientists do:
    1. Strongly disagree
    2. Disagree
    3. Agree
    4. Strongly agree
13. Did the [Lab/Documentary] make you feel a part of the team?
    1. Strongly disagree
    2. Disagree
    3. Agree
    4. Strongly agree
14. Did you see any scientists collaborating, or working together, in the [Lab/Doc]? If so, please explain / describe:
    1. Open-ended (text box)
15. Based on these observations, why would you say collaboration in science is important?
    1. Open-ended (text box)

Strand 6

16. This [NOVA experience] made me feel more comfortable studying science (+)
    1. Strongly disagree
    2. Disagree
    3. Agree
    4. Strongly agree
17. This [NOVA experience] helps me feel I have the ability to become a scientist, whether or not I decide to be (+)
    1. Strongly disagree
    2. Disagree
    3. Agree
    4. Strongly agree
18. The science presented in the [Lab/documentary] was intimidating.
    1. Strongly disagree
    2. Disagree
    3. Agree
    4. Strongly agree
19. After [watching/playing]: *[check all that apply]*
    1. I want to be a [polar] scientist
    2. I want to pursue a career in science
    3. I am interested in finding out more about careers in [polar science]
    4. I am not very interested in a science career

Focus Group Questions

STRAND 1 (MOTIVATION) - Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world.

- [Both]: What did you like from the [lab/documentary]?
- Anything you didn't like or think was interesting?

STRAND 2 (UNDERSTANDING) - Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science.

- [Both]: Thinking back on what you just did / saw, what really stands out to you?
- What would you say you learned, if anything?

STRAND 3 (ACTIVE INQUIRY) - Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world.

- [Lab]: When you [insert activity here, either tree rings, fossil dig, pollen or carbon], can you tell us a little bit about how you solved this puzzle? (walk us through your steps)
- [Documentary]: In the documentary you saw scientists [aging tree rings, participating in a fossil dig, identifying pollen, dating carbon], can you tell us a little bit about how they solved this puzzle?
- [Both]: On your survey we asked you about [X], for those of you who answered [X], can you tell us why you answered that way?

STRAND 4 (METACOGNITION) - Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on students' own process of learning about phenomena.

- Raise your hand if you think knowing polar science, like that presented in the [lab/film], is important? How so?

STRAND 5 (COLLABORATION & COMMUNICATION) - Participate in scientific activities and learning practices with others, using scientific language and tools.

- [Lab]: Were there any moments while you played that you really felt like part of the NOVA science team?
- [Documentary]: Why do you think it's helpful for scientists to work together?

STRAND 6 (IDENTITY) - Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science.

- Raise your hand if you think you might want to be a scientist. What about a polar scientist?
- What about the [lab/documentary] makes you want to be a polar scientist?
- *You know, you don't have to want to be a scientists to be good at science. Taking a scientific approach can help you in lots of different areas of interest.*
- Would you say that [the lab / documentary] makes you feel more confident in your ability to understand and do science? How so? Why not?
- Does the science happening on the poles intimidate you or scare you a little? How so?

Phase 2, Survey Questions

The survey questionnaire used for MOXI was the same as used in the online survey

Phase 2, Open-Ended Questions

1. When you think back to what you just completed, what really stood out to you or left an impression and why? For instance, what did you like, dislike, learn, find to be interesting or exciting, or consider boring?

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2. Please tell us what you think of the following (for instance, what you liked/disliked, or general thoughts, feelings, or other reflections):
    1. Storyline of [Lab/Doc]
    2. Host personality / host interactions with scientists (ex. Kirk in the video clip or Caitlin in the Lab)
    3. Featured scientists
    4. Ideal / Target Audience (ex. Who you think would enjoy this)
    5. Goal of Lab mission / Main message of video clip (ex. What is the goal or main message, and do you think it's valuable or not?)

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3. How might the [doc/lab] help kids understand how the world works?

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4. Did you see any collaboration happening between scientists? Do you think that collaboration is important?

< PAGE BREAK >

5. Did this experience inspire you in any way?

< PAGE BREAK >

6. Did the [doc/lab] demonstrate diversity and that anyone can do science? Please explain.

Demographics

7. What is your age? (text box)
8. What is your current gender? (Check all that apply)
    1. Woman
    2. Man
    3. Non-binary / non-conforming
    4. Gender not listed here: _____________

    5. Prefer not to say
9. What is your racial, ethnic, or tribal identity (check all that apply)?
    1. African American / Black
    2. Chicanx, Latinx, or Hispanic
    3. American Indian / Indigenous or Native American / Alaska Native
    4. Asian American
    5. Filipina/o/x
    6. East Indian
    7. Pacific Islander / Native Hawaiian
    8. White
    9. Identity not listed here:______
    10. Prefer not to say

Phase 2, Identity/Culture/Socialization Questions

Key: Open-ended BOLD Survey REGULAR

1. **When you think of 'science,' what comes to mind first? For instance, what is science or how do you feel about science? Share your general thoughts and impressions-- anything is ok!**

Enjoy science (interesting/enjoyable/curious)

2. Would you say that you enjoy reading, watching, or otherwise learning about scientific topics? (5-point sale of agreement)

Confidence / Competency in science understanding

3. When you come across science-related content or information online, how confident are you that you understand it? (5-point sale of confidence)

Is NOVA "science?"

4. [show images/headlines from NOVA science] Take a look at the following images. Do you think these reflect what you think of when you think of 'science?'' *(images: a) 2-3 NOVA + Nat Geo, b) wired or popular science, c) some "fake science" pages, e.g. vaccines)*
5. **Please explain your choice.**

Identification with science/scientists

6. **How would you describe a scientist?**
7. **What would you say scientists do?**
8. To what extent do you see or not see yourself as a scientist? (5-point sale of describes-does not describe)
9. Are you pursuing a science-related career? (yes, maybe, no)
10. **Can you tell us why or why not?**
11. **What do you think determines whether someone wants to pursue a science-related career or not?**

Socialization / Science Belongingness

12. When you were growing up, did you have a dream to work in a science-related job? For instance, astronaut, marine biologist, vet, doctor, engineer, or work in technology or research? (yes, no)
13. [IF YES] What did you want to be “when you grew up?”
14. [IF YES] As you got older and progressed through school, did you still want to work in science? (yes, no)
15. **[IF YES] What inspired you to work in science?**
16. [IF NO from 14 or NO/Unsure from 12] Why did you not choose to go into science? (select all that apply)
    - I felt it was too difficult
    - I wasn’t interested in it
    - I didn’t feel like it was ‘for me’
    - My teacher or other mentor didn’t think I was good enough to be successful in it
    - I didn’t see scientists who looked like me
    - Other reasons: (text box)
17. **Do you have a memory or anecdote to share about your choice? For instance, what made you feel that science wasn’t ‘for you?’ Why did you feel it was too difficult?**
18. [IF SELECT b-f, if DIDN’T SELECT a] Do you think you have the skills (or could develop the skills) to do a job in science, even though right now you’re not planning to? (yes, no, unsure)

Final Reflection

19. Can you share some final thoughts on science or science media in general? You are also welcome to expand on anything else that may have come up.

Demographics

20. What is your age? (text box)
21. What is your current gender? (Check all that apply)
    - Woman
    - Man
    - Non-binary / non-conforming
    - Gender not listed here: _____________
    - Prefer not to say
22. What is your racial, ethnic, or tribal identity (check all that apply)?
    - African American / Black
    - Chicanx, Latinx, or Hispanic
    - American Indian / Indigenous or Native American / Alaska Native
    - Asian American
    - Filipina/o/x
    - East Indian
    - Pacific Islander / Native Hawaiian
    - White
    - Identity not listed here:______
    - Prefer not to say

APPENDIX C - Participant demographics

Table 1: Descriptive statistics for MOXI & MESA Day focus group participants

	MOXI		MESA Day
Variable	Lab	Film	Lab
Age	M = 12.6, *SD* =0.74	M = 12.09, *SD* = 0.94	M = 11.5, *SD* = 0.58
Gender	45% Female, 55% Male, <1% did not say	20% Female, 80% Male, <1% did not say	36% Female, 61% Male, 3% gender non-conforming
Person of color	60% (primarily hispanic/latinx)	73% (primarily hispanic/latinx)	64% hispanic/latinx, 14% African American/black, 7% Native American
White/Caucasian	40%	27%	11%
Prefer not to say	<1%	<1%	<1%
N	10	11	28

Table 2: Descriptive statistics for youth online participants

Variable	Lab	Film
Age	M = 12.22, *SD* = 0.83	M = 11.87, *SD* = 0.95
Gender	53% Female, 44% Male, 3% prefer not to say	46% Female, 46% Male, 2.5% transgender, non-binary, non-conforming, 2.5% prefer not to say
African-American/Black	0	1
Chicano/Chicana or Hispanic or Latina/Latino	3	4
Native American	1	3
Asian	0	0

East Indian	1	0
Philipinx	0	0
Native Hawaiian/Pacific Islander	0	0
White/Caucasian	20	20
Other	2	13
Prefer not to say	4	4
N	34	39

Table 3: Descriptive statistics for close-ended MTurk participants

Variable	Lab	Film
Age	M = 21.83, *SD* = 2.05	M = 21.82, *SD* = 1.76
Gender	65% Female, 32% Male, 3% transgender, non-binary, non-conforming	53% Female, 42% Male, 5% transgender, non-binary, non-conforming
African-American/Black	13%	6%
Chicano/Chicana or Hispanic or Latina/Latino	12	13
Native American	4	2
Asian	16	25
East Indian	2	2
Philipinx	2	1
Native Hawaiian/Pacific Islander	0	0
White/Caucasian	58	57
Other	3	0
Prefer not to say	1	2

N	118	125

Table 4: Descriptive statistics for open-ended MTurk participants

Variable	
Age	M = 21.95, *SD* = 1.61
Gender	40% Female, 59% Male, 1% transgender, non-binary, non-conforming
African-American/Black	12%
Chicano/Chicana or Hispanic or Latina/Latino	10
Native American	0
Asian-American, Fillipina/o/x	24
White/Caucasian	51
N	41

Table 5: Descriptive statistics for identity and confidence Turk Prime participants

Variable	
Age	M = 20.83, *SD* = 3.52
Gender	56% Female, 41% Male, 2% transgender, non-binary, non-conforming
African-American/Black	22%
Chicano/Chicana or Hispanic or Latina/Latino	23
Native American	3
Asian	16
East Indian	2
Philipinx	0
Native Hawaiian/Pacific Islander	0

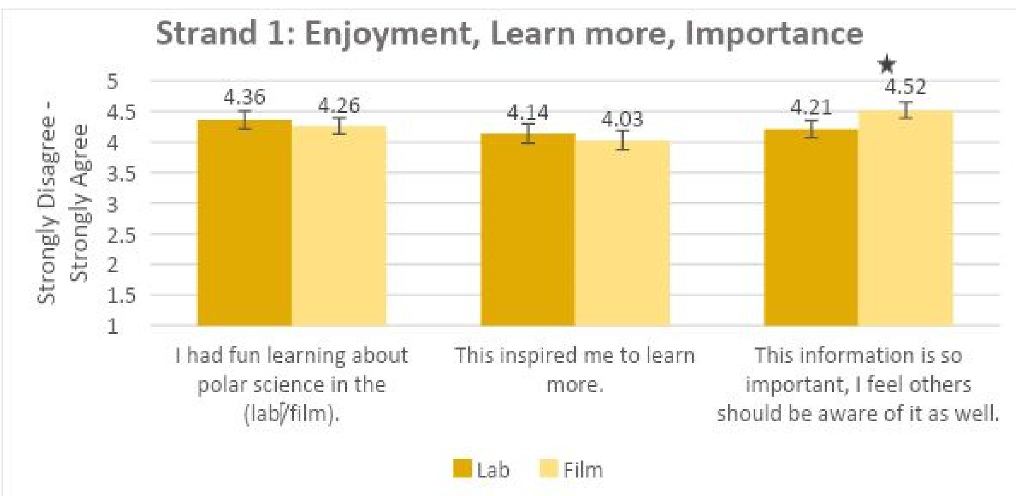
White/Caucasian	52
Other	2
Prefer not to say	2
N	108

APPENDIX D - Quantitative Comparisons Across Strands

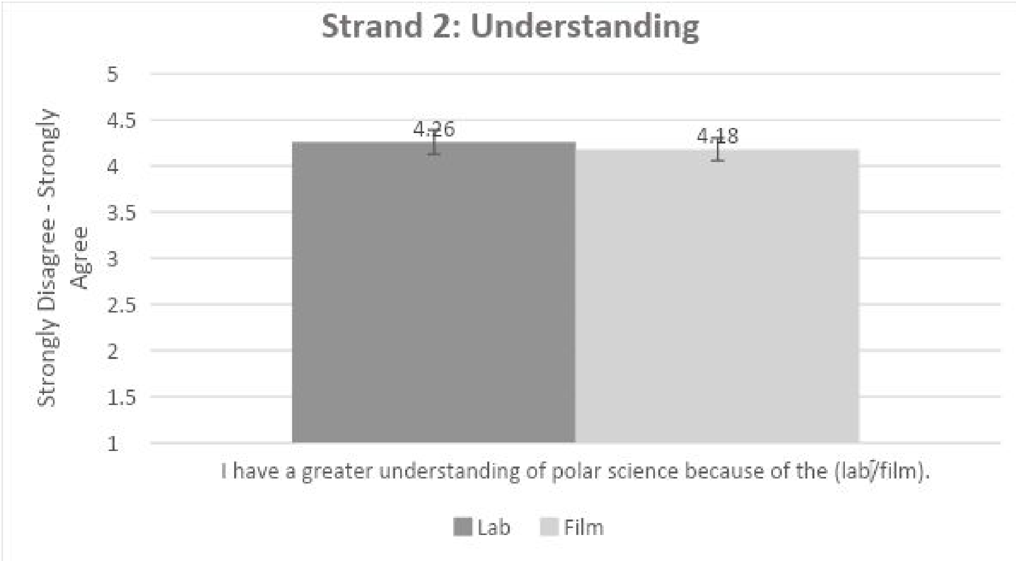
Comparing Learning Outcomes by Format

While the lab and film formats exhibited different strengths in certain learning outcomes, they still were both effective at reaching most all of the strand learning outcomes. The following section provides a more comprehensive review of findings. Analytic methods included**:** t-tests to explore differences in mean responses between film and lab participants, 95% confidence intervals, and logistic regression (controlling for other covariates).

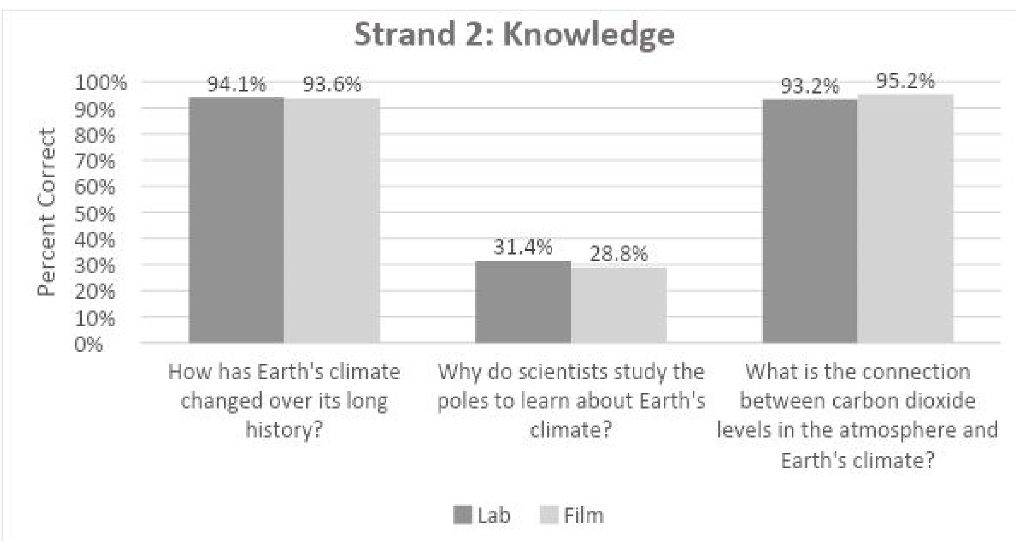
Strand 1. Interest & Engagement. ***All participants responded positively across the dimensions of Strand 1.*** On average, they had fun learning about polar science, were inspired to learn more, and found the information to be important. There are no statistical differences between media format, with the exception of "importance." Those who watched the film were even more likely to say, "The information is so important, I feel others should be aware of it as well." The difference remains statistically significant at 95% confidence, even when controlling for covariates.



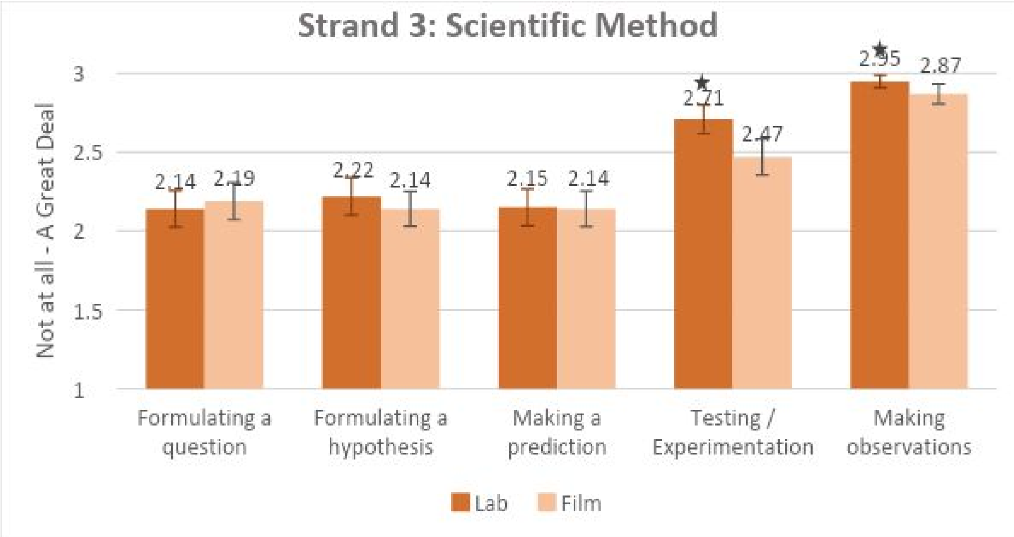
Strand 2. Knowledge & Understanding. Most participants agreed that both ***the film/lab provided a greater understanding of polar science,*** supporting the goals of Strand 2. Differences between film and lab participants in the case of polar knowledge were not statistically significant.



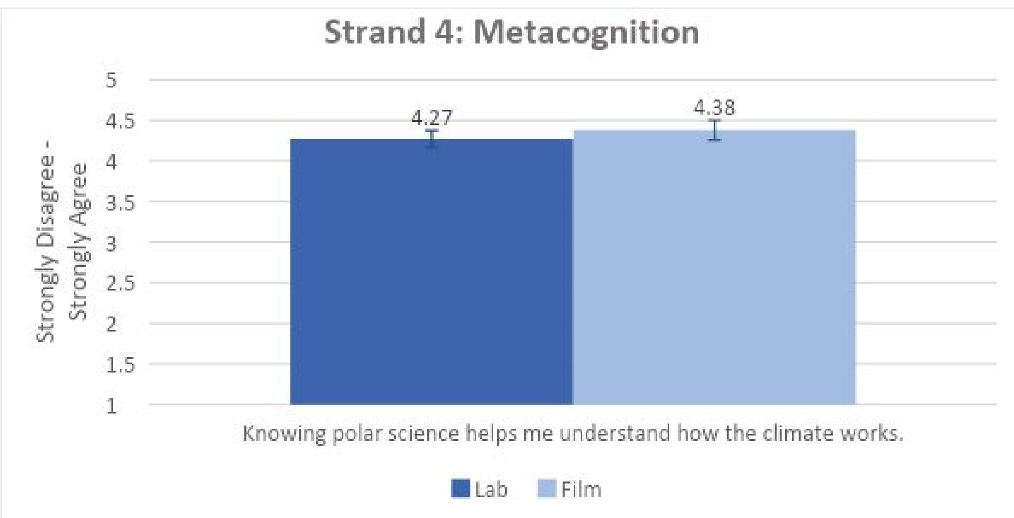
Participants were asked three knowledge-based questions. As shown below, most were able to answer the first question correctly– that the earth's climate has fluctuated between periods of warm and cold. However, far fewer participants correctly identified that scientists study the poles because the differences are more obvious at these locations. Fortunately, most selected the correct answer regarding the connection between carbon dioxide levels in the atmosphere and Earth's climate.

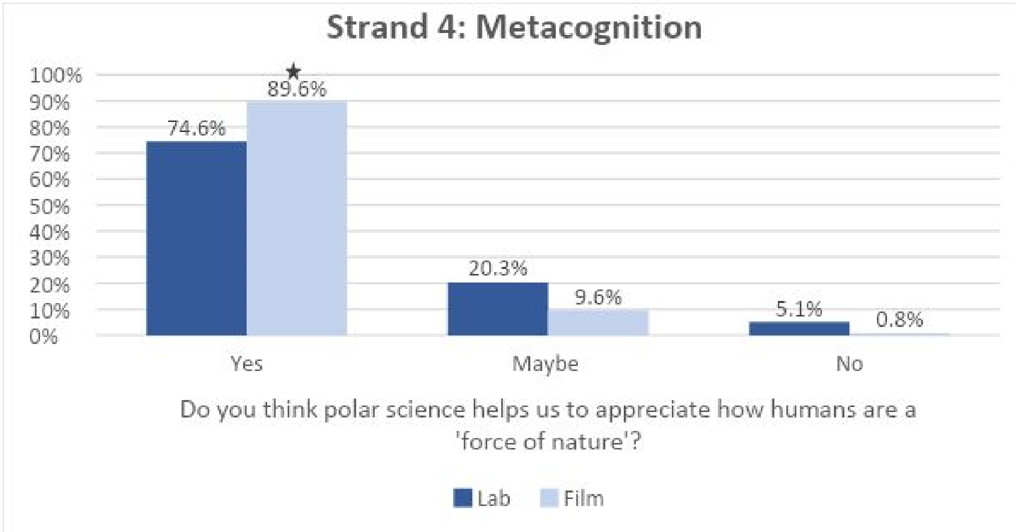


Strand 3. Metacognition / Reflecting on Science. Participants were asked about the extent to which the film/lab showed the various stages of the scientific method. Results indicate some evidence of formulating a question, formulating a hypothesis, and making a prediction. But, in the case of testing/experimentation and making observations, participants found the resources to promote these more than the other methods. When controlling for covariates, the lab was more effective at promoting testing/experimentation and making observations.



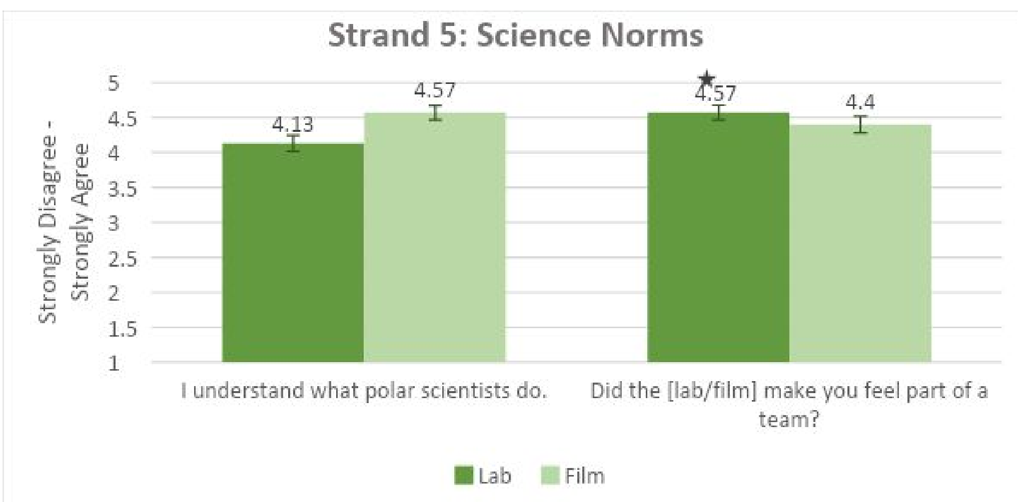
Strand 4: Metacognition / Reflecting on Science. Participants in both groups agreed that knowing polar science helps them understand how the climate works.





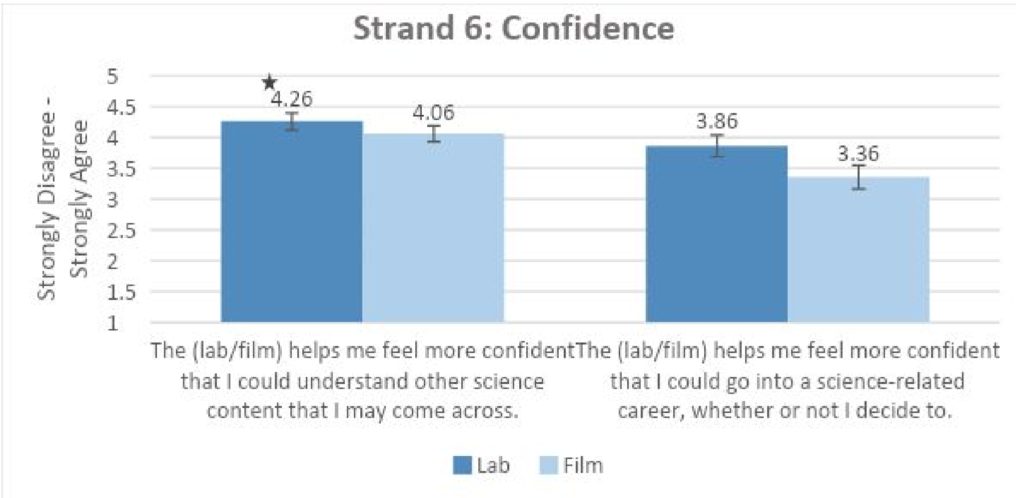
In addition, most agreed that polar science helps us to appreciate how humans are a "force of nature." Those who watched the film were even more likely to agree with this statement (statistically significant when controlling for covariates, alpha = 0.05).

Strand 5. Engaging in Scientific Practice / Science Norms. All participants found that the film/lab supported Strand 5. As shown, participants agreed that they understand what polar scientists do. In addition, while both the lab and film helped viewers feel a part of the team, the lab was even more effective than the film at reinforcing collaboration (controlling for covariates, alpha = 0.05).

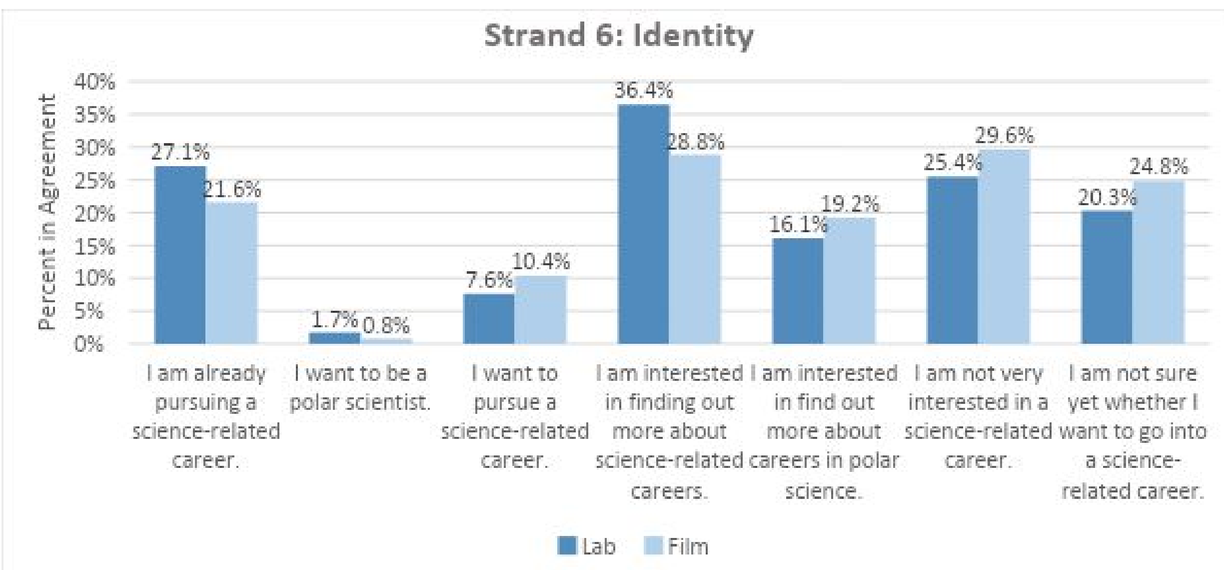


Strand 6. Identification with & Confidence in Science. Participants agreed that the lab/film would help them to feel more confident when encountering other science in the future and/or going into a science career if they so choose. Those who played the lab were statistically more likely to report feeling confident. The difference regarding coming across

science in the future remains statistically significant even when controlling for covariates. However, the difference is not statistically significant in the case of confidence in pursuing a science-related career, once controls are included.



About a third of participants state that they are interested in finding out more about science-related careers, but are far less likely to say that they are interested in finding out more about polar science careers specifically. There are no statistically significant differences between lab/film participants across the science-identity measures.



APPENDIX E – Factor Analysis

Factor Loadings for Exploratory Factor Analysis with Geomin Rotation

Item Description	F1: Impressions of Polar Science	F2: Recognizing Scientific Inquiry
1. Had fun learning about polar science in the lab/film	**0.78***	-0.08
2. Inspired to learn more	**0.74***	-0.09
3. Information is important and others should be aware of it	**0.66***	-0.06
4. Knowing polar science helps me understand how the climate works	**0.58***	0.01
5. I understand what polar scientists do	**0.62***	0.25
6. Polar science is a collaborative process	**0.52***	0.06
7. Confident: understand new science content	**0.49***	0.16
8. Confident: pursue science career	**0.45***	0.08
9. Have a greater understanding of polar science	**0.59***	0.14
10. Formulating a question	-0.09	**0.50***
11. Formulating a hypothesis	0.02	**0.71***
12. Making a prediction	-0.01	**0.69***
13. Testing/experimentation	0.07	0.16
14. Already pursuing a science-related career	0.06	0.04
15. Interested in finding out more about science careers	0.28*	0.11
16. Interested in finding out more about polar science career	0.23*	0.06
17. Not very interested in science career (**R**)	0.20	0.16
18. Not yet sure: pursue science career (**R**)	0.09	-0.04
19. Why do scientists study the poles?	0.21*	-0.14

Note. Factor loadings >.32 are in boldface. **R =** Reverse-coded item. *$p < .05$.