SloverLinett at NORC

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Executive Summary

EXECUTIVE SUMMARY

In this study, we explore how community-centered streaming can help bring engineering to life for audiences through the example of *Building Stuff with NOVA's* Twitch and YouTube streams. *Building Stuff with NOVA* is a strong case of community-centered streaming, which we define as an ongoing series of interactive live streams that incorporate intentional host engagement, intentional moderation of the stream and its chat, and an active chat environment. The streams included a diverse range of content formats—interviews, gaming sessions, field trips, pre-recorded segments, model building, and an interactively designed multi-day escape room.

As online gaming and streaming trends continue, questions for science media producers who want to leverage these community-centered online environments to generate lasting STEM interest and learning are: What motivates people to engage in these online environments? Can we design them to be safe and inclusive? What new opportunities do these platforms offer, and what learning outcomes can they achieve?

Methods

We took a mixed methods approach to these questions that was both exploratory and directed. We looked for evidence of specific learning outcomes, while also taking an open-ended approach to understanding the culture of interaction, collaboration, and informal learning on streaming platforms like Twitch and YouTube.

We conducted three phases of research to fully address project goals and questions. In **Phase 1** work we laid the groundwork for our goals and questions through a kickoff workshop, a literature review, and interviews with Twitch streamers specializing in STEM content. Based on this preliminary work, we structured our learning objectives around three core inquiry areas, including 'Reaching Audiences,' 'Building Community,' and 'Deepening Learning.' We benefited greatly during this phase from the support of a core group of advisors and subject matter experts. For **Phase 2**, we began our investigation into engagement with the Building Stuff with NOVA Twitch and YouTube live streams through a mixed methods approach that included observations of the stream, 16 interviews with organic viewers, 16 interviews with recruited participants (with a majority interviewed twice, before and after they watched multiple streams), a survey of organic viewers (59 complete and 17 partial responses), and an analysis of the Twitch chat stream. In this phase of work, in addition to our three core inquiry areas, we also aimed to generally understand viewer's perceptions of value and purpose for engaging with the stream. In **Phase 3**, we extended our research to explore how audiences engage with NOVA's documentary film content as a comparison to community-centered streaming, relying on

10 interviews with organic viewers recruited directly from NOVA channels and 10 interview with recruited participants who were asked to watch the film prior to their interview.

Our study design evolved over the project based on feedback from advisors and in response to a smaller audience size than expected within the Twitch stream.

Key Findings

For **Inquiry Area 1: Reaching Audiences**, we examined the question of: To what extent can informal science communicators leverage community-centered streaming to reach a broader or different audience than traditional science media? Our key findings in this area include the following.

Streaming platforms like Twitch and YouTube are places of high opportunity to reach broader audiences. Trends in this research suggest that the *Building Stuff with NOVA* stream is reaching a more demographically diverse audience than the *Building Stuff* documentary.

Reaching less STEM-affiliated audiences takes time through live streaming platforms if the stream is not able to leverage platform algorithms to increase visibility. Even with a more demographically diverse audience than the *Building Stuff* film series, the *Building Stuff with NOVA* stream is largely reaching people with strong interest in STEM, rather than introducing STEM and science in new ways to those who are less affiliated.

Based on these findings, we recommend the following to science media producers who want to leverage community-centered online environments to reach audiences:

1. Take time to design "on-ramps," particularly for reaching folks for whom STEM content is not an immediate draw. On-ramps are avenues for drawing in viewers. In a saturated media landscape, that means showing viewers how the content might be relevant to them.

2. For each on-ramp path, consider a "stay-ramp." The things first-time viewers need are not the things repeat viewers need, especially for viewers who are less connected to STEM. Therefore, streams need to include elements that get people to return.

3. Consider how you schedule streams; it makes a big difference in who you can reach. Understanding your streaming model matters when tailoring your approach to a specific audience and platform.

4. Consider ways to re-use and adapt content in various ways to reach diverse audiences and platforms. When designing STEM learning experiences, think of content as versatile components that can be disassembled and reassembled.

For **Inquiry Area 2: Building Community**, we examined the questions of: To what are best practices for connecting with people through community-centered streaming? What are things that this type of engagement does well? What could be improved to best leverage this environment? Our key findings in this area include the following.

Streaming platforms may all deliver live video, but people use different platforms differently; this makes it difficult to engage multiple streaming audiences simultaneously. Audiences have different expectations around content, degree of polish, length of engagement, social norms, and more.

Community-centered streaming naturally aligns with participatory learning and collective problem-solving. Streams operate as communities of practice, where participants at different levels of expertise can make meaningful contributions.

Successful community-centered streaming involves intentional modeling of community norms by hosts, chat moderators, and guest collaborators. We heard consistent feedback that Dr. Nee maintained an upbeat presence while being genuine by sharing natural reactions with unscripted moments and showing vulnerability. Streams with Twitch guest collaborators modeled a kind of informal dialogue that reinforced Dr. Nee's general vibe and encouraged viewers to want to participate. And NOVA-affiliated chat contributions also appear to have been pivotal to community engagement as they helped model chat norms and invite engagement.

Creating positive chat environments takes work, but this can pay off in creating perceived feelings of community. In general, *Building Stuff with NOVA* created a strong perceived sense of community and highly positive chat engagement by projecting signals of both authenticity and informality.

Just as in any social environment, online chats are spaces where viewers pay close attention to vocabulary and other language cues to get a sense of who the audience is and whether they fit in. We saw indications of a self-reinforcement loop for how viewers perceived the *Building Stuff* stream audience, with many interviewees reading signals within chat participation that this was a close-knit community for those already interested in science.

Documentary screenings and asynchronous streaming cannot leverage community-centered mechanisms to the same extent, but they can incorporate elements. The *Building Stuff* documentary film series was less able to create a sense of informality, but some long-form

documentaries can include real-time dialogue and question-asking when disseminated as a community-format event (e.g., within YouTube). And asynchronous streaming can still foster community through hosts reference commentators in follow-up videos.

Based on these findings, we recommend the following to science media producers who want to leverage community-centered online environments to build community:

1. Building knowledge of platform norms and community expectations is work, and it needs to be someone's job. To engage viewers, we need to meet them on the platforms where they already are, and to understand their expectations for that platform (e.g., concentrated viewing/multi-tasking, watching from home/watching on-the-go, content expectations).

2. Consistently model and enforce stream-specific norms that foster a positive, informal space that also allows for vulnerable moments. Moderators and community leaders are key in building and maintaining successful communities, as they demonstrate critical norms for everyone.

3. Create roles in community-centered streams for both science experts and for experts in human dynamics. Getting people to engage in communities of practice isn't just about transferring knowledge. It's also about being *in community* together. People who facilitate connectedness between community members – especially novices, lurkers, and other peripheral participants – are playing an important role.

For **Inquiry Area 3: Deepening Learning**, we examined the question of: What lessons around learning and engagement are there for informal science communicators regarding community-centered streaming, with focus on qualities that are most conducive toward learning, both related to pre-defined objectives and emergent areas? Our key findings in this area include the following.

Both community-centered streaming and documentary formats can be effective in deepening STEM affinities and encouraging scientific thinking. Both the *Building Stuff* stream and the documentary series helped viewers see a diverse range of people participating in STEM and engineering activities. Within both formats, we also found that STEM affinities increased when viewers could connect contexts in the stream to something relevant to their lives.

Community-centered live streaming aptly reinforces the collaborative nature of science and engineering. Both the *Building Stuff* stream and the documentary series were effective in encouraging scientific thinking, although they did this to different levels of depth. The *Building Stuff* stream went further than the film series, allowing for viewers to directly participate in collaborative scientific processes to build on each others' ideas and problem-solve as a group, similar to the functioning of an actual engineering team.

Community-centered streaming is an ideal environment for highlighting "everyday" STEM, but there is still more work to be done to help people recognize and validate science within their own lives. Because people have expectations that streaming content will be highly variable, they are more open to apparent digressions from things that are considered normative. We do find it important to note that both stream and film viewers struggled to make links to STEM in their own lives without prompting from the research team.

Stream "lurkers" also benefit from the modeling of science behaviors. We spoke with some less affiliated viewers of the stream who were hesitant to participate, but we heard from many of these individuals that just seeing other people go through a trial-and-error process was also valuable, even if they themselves took a backseat.

Based on these findings, we recommend the following to science media producers who want to leverage community-centered online environments to deepen learning and STEM connection:

1. Encourage provocative reflection to recognize "everyday" STEM to support transfer (i.e., the ability to use prior learning to creatively solve new problems). This should be considered an important component for deepening STEM affinities and seeing science as not just something that people in lab coats do, but as something every person already engages with.

2. Play with components of curiosity, failure, and iteration to break through barriers to STEM affinity and facilitate learning. Community-centered streaming is an ideal format for showing the importance of failure in learning.

3. Allow viewers to engage to the level they feel comfortable, making space for both "lurkers" and "participators." Mandating participation harms both motivation and learning, even if the activity itself is pleasurable– and in practice, would likely cause the lurkers to depart. Fortunately, streams can still serve these audience members, as it provides a context for them to watch hosts enact science behaviors.

4. Use community-centered environments as feedback opportunities for other initiatives. These spaces can be used to pilot learning strategies, test content, and recruit people for future engagement.

Background

BACKGROUND

Project Summary

This research project complements a larger endeavor that includes the *Building Stuff* documentary film series and *Building Stuff with NOVA* Twitch and YouTube channels, produced by GBH Boston and funded by the National Science Foundation. NOVA *Building Stuff* live streams aired every weekday, starting on June 3rd, 2024, and concluding with four finale episodes on October 27th, 28th, 30th and 31st. The show included a diverse range of content formats—interviews, gaming sessions, field trips, pre-recorded segments, model building, and interactively designing an escape room. The finale episodes comprised of guests playing in the escape room designed throughout the season. All episodes were aired through Twitch, offering an opportunity for real-time interaction between producers of live-streamed content and viewers. A selection of streams was also aired live on NOVA's YouTube channel. To align with the informal and community-informed mentality of Twitch, the NOVA team took an iterative and adaptive approach to the stream, which meant that content, formats, and timing evolved over the course of the stream. The accompanying film series, which also was developed as an experimental format, presented loosely connected segments, each focusing on a different story, including unconventional approaches to engineering.

In this study, we explore how community-centered streaming can help bring engineering to life for audiences through the example of *Building Stuff with NOVA*. We further investigate how the iterative and problem-solving elements of these platforms impact learning—particularly in remote settings—and how they compare to other formats, like film. As online gaming and streaming trends continue, questions for science media producers who want to leverage these environments to generate lasting STEM interest and learning are: What motivates people to engage in these online environments? Can we design them

DEFINITIONS

Streaming – the transmission of continuously delivered audio and/or video content that does not require the viewer to download the content

Live streaming – the transmission of live video and audio content through the internet in real-time with no delay

Asynchronous streaming – the transmission of pre-recorded video and audio content through the internet in real-time with no delay

Twitch – is a live-streaming platform, often used by gamers, where streamers share their activities via their screen with people who can watch them live (most common) or via videos on demand later

Chat – a real-time method of text-based communication (popular on Twitch)

YouTube – a video sharing platform that allows users to watch and upload videos, while there are opportunities for live-streaming, most users engage with pre-recorded content

Community-centered streaming – is a streaming strategy guided by an ongoing series of interactive live streams that incorporate intentional host engagement, intentional moderation of the stream and its chat, and an active chat environment

to be safe and inclusive? What learning outcomes do they achieve?

To answer these questions, this project considers what informal learners are experiencing cognitively, socially, and emotionally while viewing or participating in a *Building Stuff with NOVA* live stream, or while viewing content from the *Building Stuff* film series. We took a mixed methods approach that was both exploratory and directed. We looked for evidence of specific learning outcomes, while also taking an open-ended approach to understanding the culture of interaction, collaboration, and informal learning on streaming platforms like Twitch. This report integrates a variety of data sources and analytical techniques to provide robust insights into how streaming and documentary formats can be leveraged to promote STEM learning and community engagement. Furthermore, it's important to note how newer informal learning formats may be similar to or different than traditional platforms, such as documentary media.

Building Stuff with NOVA Stream Mechanics

The live stream *Building Stuff with NOVA* evolved over time. Initially, streams were scheduled at 1pm Eastern Time, but as the series progressed, there were adjustments to include additional later afternoon and evening slots, such as 2pm, 4pm, 6:30pm, 9pm and 10pm ET. All streams were aired on the Twitch platform. A selection of streams also aired on NOVA's YouTube channel from late July through the end of October. Streams were loosely designed around the following formats, with later streams often combining multiple formats:

Interviews: Featured experts who discussed engineering topics and provided deeper insights.

Gaming Sessions: Included titles like Poly Bridge and Kerbal Space Program, which introduced engineering concepts through interactive play.

Field Trips: Took viewers to engineering labs, makerspaces, and landmarks like the Golden Gate Bridge for on-location experiences.

Pre-Recorded Segments: Added depth to live content with explorations of specific topics, including clips from the NOVA documentary Why Bridges Collapse for expert commentary on bridge engineering.

Building IRL: Showcased real-time construction projects, where viewers could learn about engineering principles through hands-on activities.

Escape Room Design: Invited audience participation to brainstorm puzzles and challenges for the finale. All streams of this format were aired both on Twitch and YouTube.

Finale Episodes: Culminated in an escape room game featuring those crowd-designed puzzles, letting viewers watch the rooms in action and help solve the challenges.

In addition to attending the livestreams, people could access stream recordings retroactively on both Twitch and YouTube. Each stream was tagged with one of the following categories to help viewers quickly orient to the content: "IRL," "Science & Technology," and "Just Chatting."

Building Stuff with NOVA Example Images

Study Goals & Research Questions

To guide this study, we developed a series of goals and corresponding research questions to make sure that our research approach, analytical process, and reporting address the most critical questions. In addition to these inquiry areas, we also separately report on viewers' general perceptions of value and purpose in engaging with the *Building Stuff with NOVA* stream.

➔ Inquiry Area 1: Reaching Audiences

To what extent can informal science communicators leverage community-centered streaming to reach a broader or different audience than traditional science media?

To what extent is the NOVA Twitch stream reaching people who might not be welcomed to STEM spaces otherwise?

How can we reduce barriers that may exist for reaching the widest possible audiences on Twitch and YouTube?

➔ Inquiry Area 2: Building Community

What are best practices for connecting with people through community-centered streaming? What are things that this type of engagement does well? What could be improved to best leverage these environments?

How are participants experiencing *Building Stuff with NOVA* on Twitch and YouTube? What is the digital culture that emerges (e.g., cognitive, emotional, social reactions)?

How do the different formats of streams impact engagement (e.g., game time, live commentary, interviews, building IRL, escape game)? What formats result in deeper or more impactful engagement?

How do hosts (style, background, etc.) impact engagement?

Do recruited participants have a different experience than those who would find and engage in the stream organically?

How can we effectively design and moderate for a welcoming, inclusive, safe space?

➔ Inquiry Area 3: Deepening Learning

What lessons around learning and engagement are there for informal science communicators regarding community-centered streaming, with focus on qualities that are most conducive toward learning, both related to pre-defined objectives and emergent areas?

Do we see evidence of learning on Twitch and YouTube through *Building Stuff with NOVA*? What type of learning is most prevalent?

How do different engagement styles (e.g. active, passive, light responder, contributing member, community leader, troll) impact engineering and science-related learning outcomes?

Methodology

We conducted three phases of research to fully address project goals and questions. In Phase 1 work we laid the groundwork for our goals and questions through a kickoff workshop, a literature review, and interviews with Twitch streamers specializing in STEM content. These early steps helped us refine our research questions, develop data collection instruments, and establish key metrics—all of which guided our later steps when implementing the research and analyzing data in Phase 2 and Phase 3. We structured our evaluation of STEM learning and engagement on dimensions of scientific practice as well as scientific affinity, developed from Burns & Lesseig, 2017, Doran & Swenson, 2022, and Zimmerman, 2007. For a full list of key metrics, please see the Appendix.

During Phase 1 we worked closely with many partners. We consulted throughout with our core subject-matter advisor, Dr. Jessica Hammer, Associate Professor of Learning Sciences and Director of the Center for Transformational Play at Carnegie Mellon University. Dr. Lisa Leombruni, GBH's expert consultant, led a review of 48 sources, organized into six thematic areas. Our interview guide and survey questionnaire were reviewed by our advisory group of additional subject matter experts, who further enriched our methodology with their specialized insights. Dr. Kishonna Gray is an Associate Professor in Writing, Rhetoric, & Digital Studies and Africana Studies at the University of Kentucky, Dr. Katie Salen Tekinbas is a game designer, animator, educator, and Professor at the University of California, Irvine, and Dr. TL Taylor is a Professor of Comparative Media Studies at MIT and Director of the MIT Game Lab. We'd also like to offer special thanks to our colleague Edward Chong who made essential contributions to this early phase thinking.

DEFINITIONS

Organic viewer – a stream viewer who made the decision to watch a stream because of their own desire/interest in the stream, regardless of if they end up participating in research connected to the stream

Recruited viewer – a stream viewer who watched a stream because they were paid by a third-party recruiting organization to participate in research on the stream, and who may not have otherwise watched the stream

For Phase 2, we began our investigation into engagement with the *Building Stuff with NOVA* Twitch and YouTube live streams through a mixed methods approach that included observations of the stream, 16 interviews with organic viewers, 16 interviews with recruited participants (with a majority interviewed twice, before and after they watched multiple streams), a survey of organic viewers (59 complete and 17 partial responses), and an analysis of the Twitch chat stream. For the chat stream analysis, qualitative chat messages were systematically coded using GPT-4,

with inter-coder reliability assessed via Gwet's AC1 coefficient (Gwet, 2008). We want to thank the Social Data Collaboratory with their help in this study, including Simon Page, Data Analyst, Alex Kresovich, Research Scientist and Hy Tran, Senior Data Scientist.

In Phase 3, we extended our research to explore how audiences engage with NOVA's documentary film content as a comparison to community-centered streaming. In this phase we relied on 10 interviews with organic participants recruited directly from NOVA channels and 10 interview with recruited participants, all of whom were asked to watch the film on YouTube before their interview. For more details on specific Phase 2 and Phase 3 activities, please see the Appendix.

Study Evolution

Our study design evolved over the project based on feedback from advisors and in response to a smaller audience size than expected with the Twitch stream. For example, early on, advisors emphasized that analyzing chat interactions in isolation was insufficient to capture the full dynamic between hosts and audiences. In response, we added observational methods to our protocol, enabling us to better assess the interplay between live-stream hosts and chat participants. Additionally, the Twitch algorithm changed during the stream run which removed prominent home screen positioning and limited the number of people exposed to the stream randomly within their feeds. Because of the smaller viewer pool, we shifted away from an initial evaluation plan of relatively equal qualitative and quantitative investigation. Instead, we allocated more resources to qualitative components such as more in-depth interviews and robust textual analyses of the Twitch chat—and we removed a direct quantitative survey comparison between the Twitch and documentary series audiences. These changes ensured that our research framework remained agile and responsive, which enhanced our ability to triangulate findings across observations, textual analysis, and interviews.

IRB & Ethical Considerations

Ethical considerations were central throughout our study. We used only public data and took careful steps to protect user privacy. For all qualitative interviews, quotations are displayed without attribution to ensure participant anonymity and to encourage open and candid dialogue. The entire research design—including all protocols for interviews, surveys, observations, and data analysis—was reviewed and approved by the NORC Institutional Review Board (IRB). Advarra, an independent IRB provider, also reviewed and approved the project research design and data collection tools. As the project evolved and changes were made to the research design, updated IRB submissions were provided to both boards.

Study Limitations

The current study faced some limitations throughout the data collection process. Twitch is a very quickly evolving social media platform, which did not align with the relatively slower pilot creation, grant application, research design, and research implementation processes. The popularity and use of this platform changed between the inception of this project and data collection. Also, some changes to how Twitch promoted the stream occurred early in the life of the stream, which could not have been anticipated by the research team and changed the number of people who were exposed to the stream. Consequently, the number of viewers dropped significantly after that change was made, and the sample size for chat participants, and survey respondents was lower than anticipated.

Moreover, the iterative nature of the stream was also a limitation. Although it was necessary for the stream to evolve to meet the changing environment, these changes made it difficult to do a comparative study with equal emphasis on quantitative and qualitative components. For example, there were fewer aired streams on YouTube than Twitch, with a different chat environment. We switched to a greater focus on qualitative data sources to adapt to these changes.

Lastly, both the Twitch/YouTube stream and the film series were stylistic departures from the typical NOVA documentary. Therefore, in some ways the research team was studying the impact of two different exploratory directions without the presence of a more traditional control group option.

Key Findings

KEY FINDINGS

Inquiry Area 1: Reaching Audiences

To what extent can informal science communicators leverage community-centered streaming to reach a ***broader or different audience*** *than traditional science media?*

Streaming platforms like Twitch and YouTube are places of high opportunity to reach broader audiences. This research suggests that the *Building Stuff with NOVA* stream is reaching a more diverse audience than the *Building Stuff* documentary. Although this study relied on a small sample size, viewers of the *Building Stuff with NOVA* stream represent a wider range of demographics than do documentary series viewers. The stream draws from Twitch and YouTube audiences, which other studies identify as a younger and more racially/ethnically diverse pool (Yao, 2022).

Reaching less STEM-affiliated audiences takes time through live streaming platforms if the stream is not able to leverage platform algorithms to increase visibility. Even with a more demographically diverse audience than the *Building Stuff* film series, the *Building Stuff with NOVA* stream is largely reaching people with strong interest in STEM, rather than introducing STEM and science in new ways to those who are less affiliated. During the first days after launch, the *Building Stuff with NOVA* stream had a communication advantage, as it was highlighted as promoted content on the Twitch home screen. But the Twitch algorithm changed during the stream run which removed that prominent home screen positioning and limited the number of people exposed to the stream randomly within their feeds. Without that extra promotion, it was more difficult for an audience with looser connections to STEM to develop. If you needed to independently seek out the stream, or be invited through existing digital communities, you were more likely to have some pre-existing openness to STEM. We heard from many stream viewers who either had a professional STEM-affiliation (e.g., engineer, science teacher) or who were self-professed science "geeks." A number of people also noted that they were NOVA fans who had discovered the stream through a NOVA communication channel.

Inquiry Area 2: Building Community

What are best practices for ***connecting with people*** *through community-centered streaming? What are things that this type of engagement does well? What could be improved to best leverage this environment?*

Streaming platforms may all deliver live video, but people use different platforms differently, which makes it difficult to engaging audiences of multiple streaming audiences simultaneously. Audiences have different expectations around content, degree of polish, length of engagement, social

norms, and more. While these may seem like surface features, audiences treat these features as guides for what to expect and how to behave. The *Building Stuff with NOVA* stream was broadcast simultaneously on Twitch and YouTube, across a variety of formats and episodes, and we see some evidence that viewers on each digital platform interpreted it slightly differently. For example, some features of informality and spontaneity that were optimized for Twitch created impressions of lower production value on YouTube (as well as among existing NOVA fans who are used to a documentary-style polish). In fact, many viewers of the stream on both platforms seemed to pay careful attention to production value as a way to understand intended audience.

Community-centered streaming naturally aligns with participatory learning and collective problem-solving. Streams operate as communities of practice, where participants at different levels of expertise can make meaningful contributions (Lave & Wegner, 2001). This provides opportunities for participants to learn "with" rather than "from" the streamer, as well as learning with one another. The streamer becomes a trusted co-pilot to help the entire community make sense of a complex world. Many viewers highlighted Dr. Nee's frequent verbal acknowledgment and engagement with comments (along with highlighted on-screen display of chat contributions), which created a feedback loop that made viewers feel the audience mattered within a genuine conversation.

Successful community-centered streaming involves intentional and consistent modeling of community norms by hosts, chat moderators, and guest collaborators. We heard consistent feedback that Dr. Nee maintained an upbeat presence while being genuine by sharing natural reactions with unscripted moments and showing vulnerability in the effort and iteration it takes to get good at something. He set a tone for how audiences could expect to engage with the channel's content. Streams with Twitch guest collaborators modeled a kind of informal dialogue that reinforced Dr. Nee's general vibe and encouraged viewers to want to participate. When guests shared their learning journeys or showed enthusiasm for specific topics, it resonated with interview participants even when the viewers had little experience with the topics themselves. And NOVA-affiliated chat contributions also appear to have been pivotal to community engagement as they helped model chat norms and invite engagement. NOVA affiliates, though comprising just 4.55% of the chatting accounts, drove nearly a quarter (23.36%) of chat activity.

Creating positive chat environments takes work, but this can pay off in creating perceived feelings of community. In general, *Building Stuff with NOVA* created a strong perceived sense of community and highly positive chat engagement by projecting signals of both authenticity and informality. We heard many appreciative comments from our interviewees about the unique and supportive community that developed within the *Building Stuff* stream. Many felt that this was not always a guarantee, especially in Twitch streams. Many survey respondents also explicitly recognized that the *Building Stuff* chat was a community. And an analysis of chat engagement shows that formats

with invited guests or other Twitch collaborators resulted in greater chat participation—in other words, a heightened community dialogue. *Building Stuff's* host, Dr. Nee, and other NOVA moderators were key to helping set these norms for a supportive community space.

Just as in any social environment, online chats are spaces where viewers pay close attention to vocabulary and other language cues to get a sense of who the audience is and whether they fit in. We saw indications of a self-reinforcement loop for how viewers perceived the *Building Stuff* stream audience, with many interviewees reading signals within chat participation that this was a close-knit community for those already interested in science. For individuals who we recruited to view the stream, if science wasn't their interest area, they were unlikely to re-engage with *Building Stuff* on their own. One exception involved the *Escape Room* episodes, which seemed to be read by viewers through a gaming lens and were perceived more novel, entertaining, and interactive than other types of streams. We did hear that this encouraged multiple viewings from less STEM-interested recruits.

Documentary screenings and asynchronous streaming cannot leverage community-centered mechanisms to the same extent, but they can incorporate elements. The *Building Stuff* documentary film series was less able to create a sense of informality (although it was perceived as authentic and high-quality), since watching doesn't allow for dialogue or opportunities to ask follow-up questions in real-time. However, some long-form documentaries can include real-time dialogue and question-asking when disseminated as a community-format event (e.g., within YouTube). And asynchronous streaming can still foster community through hosts reference commentators in follow-up videos.

Inquiry Area 3: Deepening Learning

*What lessons around **learning and engagement** are there for informal science communicators regarding community-centered streaming, with focus on qualities that are most conducive toward learning, both related to pre-defined objectives and emergent areas?*

Both community-centered streaming and documentary formats can be effective in deepening STEM affinities and encouraging scientific thinking. We structured our evaluation of STEM learning and engagement on dimensions of scientific practice as well as scientific affinity, developed from Burns, & Lesseig, 2017, Doran & Swenson, 2022, and Zimmerman, 2007. Both the *Building Stuff* stream and the documentary series helped viewers see a variety of people participating in STEM and engineering activities. Within both formats, we also found that STEM affinities increased when viewers could connect contexts in the stream to something relevant to their lives. These "aha" moments typically happened by recognizing past experiences as connected to STEM, either through popular culture (e.g., references in movies and TV) or within personal real-life experiences (e.g., "things that I interact with every day but never saw through this perspective before").

Community-centered live streaming aptly reinforces the collaborative nature of science and engineering. Both the *Building Stuff* stream and the documentary series were effective in encouraging scientific thinking, although they did this to different levels of depth. The documentary effectively highlighted the trial-and-error process of engineers through examples. The *Building Stuff* stream also demonstrated a real-time trial-and-error process through host and guest activities. And it went further than just demonstrating scientific thinking. It allowed for viewers to directly participate in collaborative scientific processes to build on each other's ideas and problem-solve as a group, similar to the functioning of an actual engineering team. A number of people we spoke with considered moments of collaborative problem-solving to be a highlight of their experiences with the stream.

Community-centered streaming is an ideal environment for highlighting "everyday" STEM, but there is still more work to be done to help people recognize and validate science within their own lives. Because people have expectations that streaming content will be highly variable, they are more open to apparent digressions from things that are considered normative. For STEM, streaming contexts can counter a sense of expected formality in STEM content (e.g. the science of Double Dutch). This openness provides opportunities for learners to connect STEM to their own lives, building on educational theories of connectivism (Duke, 2013) and for them to feel as if they belong in STEM conversations. This is in contrast to the documentary series, where viewers often expected more formal science content, which made it harder for them to take the leap to see STEM in informal contexts. We do find it important to note that both stream and film viewers struggled to make links to STEM in their own lives without prompting from the research team, which is consistent with prior literature on transfer (Sala et al., 2019). However, the literature also shows that prompts and examples can help people transfer knowledge across contexts. With space for additional reflection in our interviews, people often did acknowledge multiple everyday STEM connections (e.g., within cooking, lawn care, home projects).

Stream "lurkers" also benefit from the modeling of science behaviors. We spoke with some less affiliated viewers of the stream who were hesitant to participate, but we heard from many of these individuals that just seeing other people go through a trial-and-error process was also valuable, even if they themselves took a backseat. And a number of viewers were engaging with the *Building Stuff* stream while multi-tasking, and they appreciated the low-pressure environment. Empirical evidence from social networks suggests that lurkers make up the large majority of online audiences, compared to a smaller group of active participants (Kuindersma et al., 2016). Research on observational learning has shown that this is an effective method for teaching norms, values, and behaviors (Bandura, 1986).

Recommendations

RECOMMENDATIONS

(Co-written by Slover Linett at NORC and Dr. Jessica Hammer)

Inquiry Area 1: Reaching Audiences

1. **Take time to design "on-ramps," particularly for reaching people for whom STEM content is not an immediate draw.** On-ramps are avenues for drawing in viewers. In a saturated media landscape, this means showing viewers how the content might be relevant to them. On-ramps that emphasize STEM content will draw learners with prior interests in STEM. To access more diverse audiences, we can create on-ramps around content categories that are not STEM-specific (e.g. escape room fans), around other media affiliations (e.g. a specific streamer who visits the channel), or around relationships with community members (e.g. people inviting their friends to join). Also consider different formats for on-ramps, such as short-form videos as teasers for long-form content, or by recruiting at special events. More broadly, a diverse and complementary set of on-ramps are more likely to be successful than focusing team efforts on just one strategy.

2. **For each on-ramp path, consider a "stay-ramp."** The things first-time viewers need are not the things repeat viewers need, especially for viewers who are less connected to STEM. Therefore, streams need to include elements that get people to return. These elements may be different depending on how the person originally connected with the stream. For example, someone who joined because their favorite streamer was visiting the channel would likely be motivated by knowing that streamer is coming back, while that would be less effective for someone who joined because a friend invited them.

3. **Consider how you schedule streams; it makes a big difference in who you can reach**. Understanding your streaming model matters when tailoring your approach to a specific audience and platform. Are you working on a "must-see TV" model where people schedule around your event, or hosting a casual drop-in science party, or something else entirely? Either way, you need to take into account how much audiences value liveness. People want to be there when interesting things happen, and that means adjusting streaming hours to when people are most likely to be available (e.g. outside a traditional 9-5). To support this, staffing of this type of projects may need to be done differently than legacy media companies are used to.

4. **Consider ways to re-use and adapt content in various ways to reach diverse audiences and platforms.** When designing STEM learning experiences, think of content as versatile components that can be disassembled and reassembled. Content components can be combined in multiple sequences, pathways, or lengths, adapted for different age groups and skill levels, transformed across various platforms, and connected to diverse real-world applications. Community-centered streaming and traditional media formats is not an either-or equation – they can help amplify each other. For example, take advantage of confluences and overlaps, such as live reflection and commentary on documentaries. Stream hosts can also switch between modes, such as pausing to engage with the audience and then resuming the content.

Inquiry Area 2: Building Community

1. **Building knowledge of platform norms and community expectations is work, and it needs to be someone's job.** To engage viewers, we need to meet them on the platforms where they already are, and to understand their expectations for that platform (e.g., concentrated viewing/multi-tasking, watching from home/watching on-the-go, content expectations). These are nuanced differences that take time to understand, which means that this knowledge cannot be quickly acquired and translated to action. Make sure that someone on your team is working to outline audience expectations for the platforms of your choice. Intentionally decide where you might bend or break a norm to stand out from other streams on the platform.

2. **Consistently model and enforce stream-specific norms that foster a positive, informal space that also allows for vulnerable moments.** Moderators and community leaders are key in building and maintaining successful communities, as they demonstrate critical norms for everyone. Strategies for norm-setting can include proactive declarations of policies or values, as well as reactive elements such as muting problematic members. We also see in other research that when moderators and high-status users use these strategies, community members change their behavior in response (Seering, Kraut, & Dabbish, 2017).

3. **Create roles in community-centered streams for both science experts and for experts in human dynamics**. Getting people to engage in communities of practice isn't just about transferring knowledge. It's also about being *in community* together. People who facilitate connectedness between community members – especially novices, lurkers, and other peripheral participants – are playing an important role. Additionally, these "people experts" provide a path for less-STEM-engaged audience members to see themselves as leaders. In other words, you don't have to be a STEM expert to be part of a STEM community.

Inquiry Area 3: Deepening Learning

1. **Encourage provocative reflection to recognize "everyday" STEM to support transfer (i.e., the ability to use prior learning to creatively solve new problems).** Stream hosts can provide relevant prompts and examples. For example, in a session about fluid dynamics, the host might encourage viewers to think about fluids they encounter on a regular basis. Stream hosts can also show how they themselves build connections. This should also be considered an important component for deepening STEM affinities and seeing science as not just something that people in lab coats do, but as something every person already engages with.

2. **Play with components of curiosity, failure, and iteration to break through barriers to STEM affinity and facilitate learning.** Community-centered streaming is an ideal format for showing the importance of failure in learning. When people are afraid to fail, they become less effective learners (Elliot, 1999). On the other hand, failing unhelpfully can cause them to give up (Elliot, 1999). Stream hosts can model how to fail effectively within the learning and iterative design process, such that failures promote curiosity and positive engagement (To et al., 2018). The host can also model a culture where failure is destigmatized, and sometimes even desired as part of the iterative design process.

3. **Allow viewers to engage to the level they feel comfortable, making space for both "lurkers" and "participators."** Mandating participation harms both motivation and learning, even if the activity itself is pleasurable (Kuindersma et al., 2016) – and in practice, would likely cause the lurkers to depart. Fortunately, streams can still serve these audience members, as it provides a context for them to watch hosts enact science behaviors.

4. **Use community-centered environments as feedback opportunities for other initiatives.** These spaces can be used to pilot learning strategies, test content, and recruit people for future engagement. You can test content components for traditional media, engage educators in the stream, and provide them with clips and activities for classroom use, addressing challenges with documentaries being too long and not engaging for students.

Emergent Implications: Growing Audiences

1. **Consider the unique opportunities of small but engaged audiences; scaling up may not always need to be the goal.** Scaling up on community-centered streaming platforms requires new strategies. Although as streams become less intimate, they lose some of the unique opportunities for informal STEM learning engagement (and could result in reduced chat participation), this is also a design opportunity. When the community starts to scale, you may

have to build more activities that are explicitly aimed at connecting people. (Flores-Saviaga et al., 2019)

2. **Build relationships with key stakeholders at distribution platforms to help minimize risks within high-change streaming environments.** They can assist with audience onboarding strategies to grow viewership, such as by featuring the stream in platform-level advertising. They can also provide insights about upcoming platform changes, giving you critical time to adapt before shifts occur.

3. **Build back-end data analytics and feedback loops, as qualitative methods such as this study are likely too intensive and impractical at scale and over the longer-term.** Analytics might include features such as annotating the live video stream (Hammad, Harpstead & Hammer, 2023), tracking which content users clip and save, deploying automated surveys, identifying return viewers, and capturing data on lurkers as well as those who directly engage (Harpstead et al., 2019).

Detailed Findings

1. Building Stuff Audience

DETAILED FINDINGS: BUILDING STUFF AUDIENCE

In this section we share findings about the *Building Stuff* audience, including their demographic backgrounds, typical media consumption behaviors, and specific uses and perceptions of streaming platforms. This section informs Inquiry Area 1 and its related research questions.

➔ **Inquiry Area 1**: *To what extent can informal science communicators leverage community-centered streaming to reach a* ***broader or different audience*** *than traditional science media?*

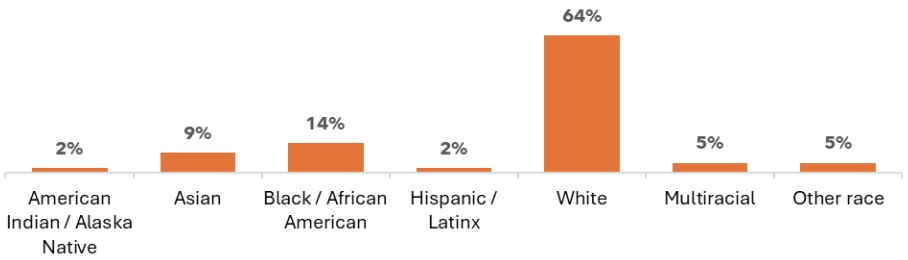
- To what extent is the NOVA Twitch stream reaching people who might not be welcomed to STEM spaces otherwise?
- How can we reduce barriers that may exist for reaching the widest possible audiences on Twitch and YouTube?

For relevant sources refer to the following thematic areas listed under Literature Review Sources in the Appendix: *User characteristics & motivation*.

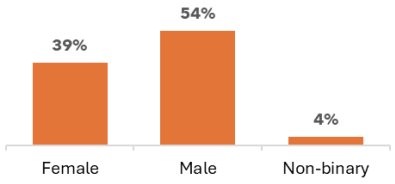
Twitch/YouTube Audience

NOVA's *Building Stuff* streams attract a diverse audience with younger, STEM-interested viewers. Organic viewers who we interviewed represented a variety of ages and races and ethnicities, and this is mostly consistent with the *Building Stuff* survey data. In the survey data women were slightly underrepresented among the organic *Building Stuff* Twitch viewers (39% female vs. 54% male), 23% reported having a disability, and 11% identified as LGBTQ+.

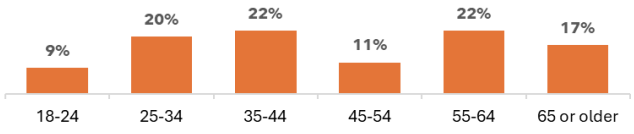
q18: Which of the following races / ethnicities do you identify as? Please select ALL that apply.
(Organic Viewers, n=44)



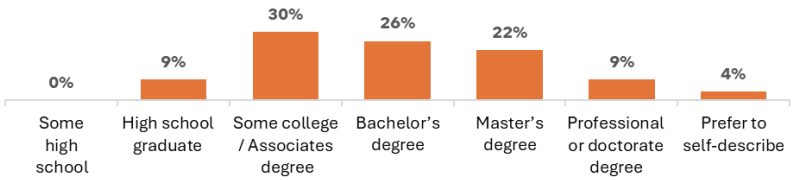
q19: What is your gender? Please select all that apply. (Organic Viewers, n=46)



q17: Please select your age category (Organic Viewers, n=46)



q20: What level of education have you completed? (Organic Viewers, n=46)



Many organic Twitch viewers had some background in a STEM-related field or strong interest in learning more about the world through science. For some, their interest began in childhood through exposure to NOVA and PBS. See section 5: *Deepening Affinities with Engineering* to explore science affiliations further.

> *"NOVA also helped as motivation. My family has watched on Wednesday nights for decades." – Twitch chat comment*
>
> *"Thank you to NOVA and PBS for providing me with a lifetime of high-quality educational programming. I still recall sitting as a child watching NOVA with my mom and dad in the late 70s." – YouTube chat comment*
>
> *"Part of the reason why I like the NOVA thing is because as a kid I used to watch NOVA a lot on TV, and then as I got older I watched less TV and more video games." – Interview quote: YouTube organic viewer*

The *Building Stuff* viewers we spoke with consume a wide range of media, from various digital platforms to TV, podcasts, books and radio. YouTube and TikTok typically serve passive viewing needs, while Twitch offers interactive engagement. Media choices vary by age, with older audiences favoring TV and reading, and younger ones giving a preference to digital platforms. Media choices are frequently driven by purpose. Many use YouTube in a manner similar to TV, playing it in the background while multitasking, but also turning to it if they want a deeper dive on a

particular topic. It is also a go-to platform for problem-solving through 'how-to' videos and tutorials. For many younger viewers TikTok serves not only as a source of quick entertainment but also as a platform for concise, straight-to-the-point informational and educational content. Although some report actively creating content and engaging on TikTok, both platforms seem to be frequently used for passive consumption rather than interactivity, reflecting the broader trend in digital media usage. On Twitch, typical active users enter the platform through gaming communities, driven by a strong interest in specific games. They often follow a few streamers some of whom they know in real life, often stream themselves, and seek a sense of community.

Age also plays a significant role in media consumption habits. Older audiences are more inclined to watch traditional TV or read, valuing long-form content and familiar formats. In contrast, younger generations gravitate toward digital platforms like TikTok, Twitch, and Instagram, which offer fast-paced, interactive, and visually engaging content tailored to their preferences and social habits.

> *"I'm on YouTube a lot. I like YouTube. It can go anywhere from financing to savings, to cooking and recipes, to travel or methods of travel – trains, airplanes, how cruises work. I have some military stuff on there, how they train people for the military. Cooking and recipes. Children's videos, dinosaurs. It's not one thing." – Interview quote: Twitch/YouTube organic viewer*

> *"[On Twitch] my friend streams every week, and I'll watch her play for at least an hour. On YouTube, it's hard to say because I'm on it sporadically, but it's more generally. I think every day I'll watch something on YouTube." – Interview quote: Twitch organic viewer*

Twitch and YouTube shape viewers' expectations for educational content, with Twitch perceived as offering real-time engagement and community learning, while YouTube is perceived as providing digestible science content frequently used by educators. Twitch and YouTube users have preexisting expectations about the educational content often shaped by the overall platform environment. They appreciate the accessible and digestible science content on these platforms often presented in a pop-culture format. They also like the bridge between technology/science and real life that these platforms offer. Educators use YouTube extensively as a valuable teaching tool to supplement their lessons.

In contrast to YouTube, Twitch adds informality and engagement to the educational content. Twitch users also value an opportunity to learn from streamers, and from the broader community, appreciating the ability to provide and get feedback instantly. They highlight the value of learning together with streamers who frequently break down complex processes in real time.

> *"I appreciate learning different media and learning new skills. That's some of the greatest benefits of Twitch, YouTube and Instagram, which are the three I most use. [Creators] describe the process and create simultaneously... Interacting on the chat, since hopefully it's live and*

they're giving feedback, makes you feel closer. Certain channels email me when they have a course coming up, either in fused glass or other glass mediums. I go to Twitch because that's where it's offered, but I like interacting in the chat, getting live feedback, seeing how other people are interacting and learning from them as well." – Interview quote: Twitch recruited viewer

"I engage in some of those engineering and science in more of a pop culture kind of way. It is easily accessible and digestible. I am part of this generation where our attention span isn't great. If it is fast and easy and brief I can identify with that." – Interview quote: Twitch organic viewer

"What draws me back to the same channels, they do a really good job at breaking things down and showing the progress they make. The channels I go back to have a good ratio of preparation, explanation, and also results." - Interview quote: YouTube recruited viewer

Stream viewers recalled a variety of popular science shows (such as Bill Nye, the Magic School Bus, MythBusters and others), highlighting both nostalgic favorites from their childhood and program they currently enjoy. These shows seem to serve as key influences in shaping their interest in science, with many recalling how early exposure sparked their curiosity.

Twitch users tend to prioritize host personality, valuing engagement, authenticity, and a relatable, informal style, while YouTube users focus more on content quality. This difference influences how content, like the *Building Stuff* stream, performs across platforms. Host personality seem to matter more for Twitch users, whereas content is more important for those using YouTube. And this has implications for sharing content created for Twitch on another platform like YouTube, as seen when simulcasting the *Building Stuff* stream across both platforms.

For Twitch audiences, the feeling of welcome is associated with a host who actively engages, connects, and acknowledges the viewers, showing genuine interest in them – making them feel like they are having a conversation. They also believe a good Twitch host is entertaining, upbeat, and charismatic, with an authentic, relatable, and personable presence. A host who feels like a "regular" human, who is able to make mistakes without being overly scripted, helps create a more genuine connection. Viewers appreciate seeing natural environments and glimpses of the host's personal space, making the experience feel more intimate and real.

"I enjoy people who when you come in they acknowledge your presence. If you do it, I'm 95% likely to return. Because I'll feel welcome in the space." – Interview quote: Twitch organic viewer

> *"I think a host that's engaging - you can get the information, but it can seem like they're just reading from a script, not passionate about it, just reading from a book. I wouldn't really subscribe to that. But if you're a person talking and giving stories in between, connecting to personal anecdotes/histories - people who are throwing personable things and making it relatable, I would subscribe more to that than someone who's just throwing information at me and not passionate about it." – Interview quote: Twitch/YouTube organic viewer*

> *"Do they make me laugh, are they saying something intriguing? Does it resonate with me, do I want to learn more about it? Host has to be entertaining as well, upbeat. Has to be an interesting person, or act like an interesting person." – Interview quote: Twitch recruited viewer*

There's an expectation that Twitch is an informal space, where content is unpolished and not overly produced or glossy. This probably stems from a feeling that gaming is about trial and error, experimenting, and having fun, with advice and support coming from peers in a relaxed, low-pressure environment.

A welcoming space on Twitch is one that centers on a respectful, inclusive, and safe community, where hosts and moderators actively shut down inappropriate behavior and ensure that everyone follows these principles. There is also an understanding that trolls may appear on any stream, but what matters is how the host handles these disruptions and maintains a positive environment.

> *"Streamers usually will tell us out loud: "guys it's a safe space", they welcome us with open arms. Sometimes they'll talk about mental health and stuff like that. I have mental issues myself, social anxiety, and depression. When they talk about things like that, at least there are people who understand it, who understand it's real." – Interview quote: Twitch recruited viewer*

> *"Greeting people when people show up. If anyone is acting up on chat, asking them to stop, makes me feel seen and even protected in a way. Those are all things I do on my own streams." – Interview quote: Twitch organic viewer*

Viewers highlighted several popular Twitch streamers as examples of creators who facilitate welcoming communities and excel as hosts, including those who collaborated with *Building Stuff* on Twitch: *EJ, Mohoodles, metadevgirl* and others.

Live chat participation is more common on Twitch than on YouTube, where passive viewing is common. Factors like community vibe, strong personal opinions, and the likelihood of receiving a response influence engagement.

People shared that watching live videos tends to lead them to interact more often compared to recorded content, as viewers feel a sense of real-time engagement and connection with the streamer and other audience members. Passive viewing or a "lurking" is common and acceptable on Twitch, and it appears to be the norm on YouTube, with not many turning to YouTube for interactive experience. While YouTube live chat can be highly active and engaging in certain other contexts, this study did not focus on live engagement patterns on this platform. Platform features facilitate interaction on Twitch, and chat participation is more common there – as users there are more likely to receive live reactions or responses to their comments than on YouTube.

The overall vibe of the stream and the community is an important factor influencing participation. Many are hesitant to engage in the chat if the vibe feels "off". Viewers are more likely to comment when they feel strongly about a certain aspect of the video or stream.

Highly active chats, such as those on large Twitch channels, can feel overwhelming, with comments getting lost or disappearing quickly in the fast-moving feed, which may discourage participation. In contrast, some people note that participation in smaller Twitch communities is more rewarding, as they are more likely to receive a response or reaction from other users or hosts.

> *"On Twitch, [I chat] If there is something I would like to specifically say to the person I'm watching or people in the chat. When it comes to YouTube, I'll leave a comment if I feel very strongly about what I just watched. Or if someone's comment speaks to me, then I'll reflect on how I feel about the comment." – Interview quote: Twitch/YouTube organic viewer*

> *"I like to read the comments and comment if there's something to comment on. I like to ask questions. If I'm on a stream vs. watching a video, I like to be engaged. It makes you feel like more of a community, like you're there for something more than the video." – Interview quote: Twitch recruited viewer*

Documentary Film Audience

In contrast with the Twitch/YouTube streams, the organic film audience that we engaged in interviews is typically older than 50. It is important to note, however, that our sample size was quite small and this trend may be influenced by self-selection bias among interview participants, who were often longtime passionate NOVA fans and avid documentary viewers. They have a strong curiosity about science and many have STEM-related backgrounds: meteorology, architecture, computer science, science teaching and others.

"Science, I think about science all the time. I have a curious mind and one of the things about the show was my interest in science and engineering and the confluence between the two." – Interview quote: Film organic viewer

"I am a college professor at a two-year school in Florida, and I teach biology. I am a very adamant supporter of interdisciplinary learning, so I frequently try to catch the NOVA series on TV." – Interview quote: Film organic viewer

The organic film audience members we spoke with primarily consume content through reading (with science fiction emerging as a favorite genre), watching traditional TV, but also engaging with digital platforms like YouTube and the PBS website. While they appreciate high-quality, in-depth storytelling, they are less likely to use interactive or short-form platforms like Twitch or TikTok. Their viewing habits reflect a preference for curated, high-quality content from a reliable source over the fast-paced, user-generated material that dominates newer digital spaces. In contrast, among the recruited film audience – who tend to be younger than the organic viewers – many report spending more time on social media and display a higher level of familiarity and comfort with platforms like TikTok, Facebook, Instagram and YouTube.

"I've been kind of a science fiction fan all my life. I enjoy Star Trek, the whole series. Movies, science fiction movies, I like those a lot. I certainly like public television, enjoy science shows on that. So that's why my attraction to NOVA, I've been watching it for many years. There are 3-4 PBS stations in the Bay Area, and I watch them. Television, books, magazines... There seems to be an interest in science when it's entertainment that way." – Interview quote: Film organic viewer

"I spend more time paying attention to the NOVA PBS content – all of it really. With the assumption that it's peer reviewed and that I can trust they're providing fair representation of stuff that is widely agreed upon by more serious academic communities. When I'm watching content from other sources, I find myself looking for cues and clues to decide for myself how much of what they're saying is stuff I'd consider legit if I were to delve in the published works and the peer reviews of them." – Interview quote: Film organic viewer

Organic film audiences tend to seek to learn about science in many different ways, including though films and science shows. For them, documentaries offer education in an entertaining way and are viewed as a more high-quality and trustworthy source than social media content. Film viewers also tend to believe that documentaries can be used extensively in classrooms.

> *"I do a lot of YouTube because when I'm teaching most of the media I show my students is on YouTube. Also my PBS account, I use a lot of National Geographic stuff. But it's much easier to find stuff on YouTube. I don't have to deal with login and password etc. I'm looking for things to better understand myself, but also to supplement what I teach to my students. Documentaries – there are things I learn that I can take to my students." – Interview quote: Film organic viewer*

Similar to the stream audience, film viewers also recalled a variety of popular science shows that influenced their ongoing interest in science.

> *"I used to watch the Bill Nye show between ages of 5-13. I liked how interactive it was, I enjoyed how he talked, very interactive." – Interview quote: Film recruited viewer*

Detailed Findings

2. Engagement with Building Stuff

DETAILED FINDINGS: ENGAGEMENT WITH BUILDING STUFF

This section explores how people's behaviors, such as how they found the *Building Stuff* stream, frequencies of engagement, and kinds of engagement. We also share findings on discovery of the *Building Stuff* film series. This section provides important background context for Inquiry Area 2 and its related research questions.

➔ **Inquiry Area 2**: *What are best practices for **connecting with people** through community-centered streaming? What are things that this type of engagement does well? What could be improved to best leverage these environments?*

- How are participants experiencing Building Stuff with NOVA on Twitch and YouTube? What is the digital culture that emerges (e.g., cognitive, emotional, social reactions)?
- How do the different formats of streams impact engagement (e.g., game time, live commentary, interviews, building IRL, escape game) What formats result in deeper or more impactful engagement?
- How do hosts (style, background, etc.) impact engagement?
- Do recruited participants have a different experience than those who would find and engage in the stream organically?
- How can we effectively design and moderate for a welcoming, inclusive, safe space?

For relevant sources refer to the following thematic areas listed under Literature Review Sources in the Appendix: *User characteristics & motivation, Inclusive Gaming, Learning through livestreaming*.

Engagement on Twitch/YouTube

Twitch viewers typically discovered the stream via their connection with the host, guest, Escape Room players, or through a pre-existing connection to NOVA. Many organic viewers on Twitch found their way to the stream through awareness of the show host, guest, or connection to one of the Escape Room participants. Organic viewers also reported being intrigued when they learned about NOVA putting out a Twitch stream or an Escape Room experience and curious to check it out. This suggests that *Building Stuff* primarily engaged those who were on the platform already and did not necessary attract new audiences to Twitch. Educators use NOVA resources in their classrooms and learned about the stream through educator emails, and some others through the NOVA newsletter.

> *"I thought NOVA was like boomers, I'm surprised they're getting into my generation's stuff. And the next time, he was playing [space game] and I was like oh I love that game, I want to*

watch him play. It's more educational than some of the other stuff I watch on YouTube, I thought it was pretty cool." – Interview quote: Twitch organic viewer

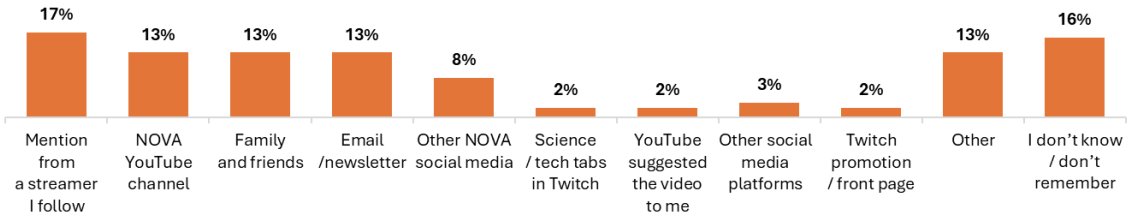
"My sister was on the show; she told me how to watch. When I joined, I wasn't sure what to expect." – Interview quote: Twitch organic viewer

"For me it was seeing that Escape Room-type stream that got me interested. Usually, I watch NOVA for the ocean-y stuff. So that's what got me to watch it originally, the Escape Room." – Interview quote: YouTube organic viewer

"I found you through EJ. I'm really curious to see your builds." – Twitch chat comment

In the survey, organic viewers reported that they found the stream through a variety of sources, with the top ones being a mention from another streamer (17%), NOVA YouTube channel (13%), family and friends (13%), and email/newsletter (13%).

q6: How did you first find out about Building Stuff with NOVA? (Organic Viewers, n=63)



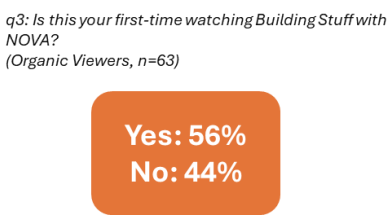
***Building Stuff* viewer behavior varied widely, with some keeping the stream on in the background, others watching regularly or selectively based on interest. Live viewing was important for some on Twitch, while YouTube audiences were more flexible, often opting for recordings.** People fit *Building Stuff* in their lives in a variety of ways, highlighting the flexibility offered by Twitch and YouTube. For some, the *Building Stuff* stream remained in the background while they were doing other things - just like with any other content on Twitch or YouTube. Some of the organic viewers watched the stream regularly, while others viewed some episodes. People mentioned watching episodes that appealed to them – and skipped those that they didn't find interesting.

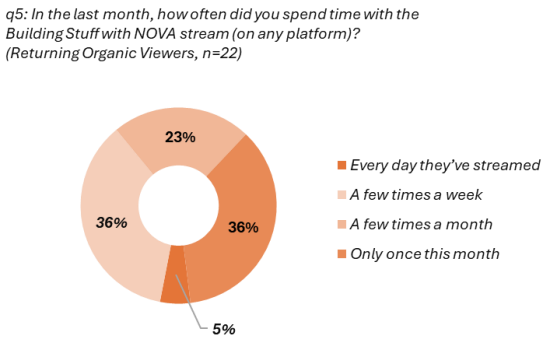
The ability to watch live or catch recordings allowed viewers to engage on their own terms. The live schedule didn't work for everyone, so some watched the recordings. Many YouTube viewers mentioned that live viewing wasn't as important on YouTube.

"I got an email from Dr Nee. I thought 'on Twitch, so cool'. I went right in. Typically, I'm in the lab, but the days when I'm working from home I have it on."- Interview quote: Twitch organic viewer

"I watch 3-4 x per week. Varies depending on what the stream is about. It's like with any stream – if someone playing a game I don't care about, if I'm not super interested in, I tend to not tune in. With NOVA, each day is something different. Even if some overlap, there is enough variety and it's pretty engaging." – Interview quote: Twitch organic viewer

Survey responses may suggest that a high proportion of organic viewers return to the stream and half of the return viewers watched the stream multiple times per month.





A positive and welcoming atmosphere on the *Building Stuff* stream encouraged participation, though some preferred reading the chat over directly contributing to the chat. Participation varied by comfort with STEM, community fit, and technology access, with the finale episodes boosting involvement to assist players. *Building Stuff* viewers were encouraged to participate in the chat by an overall positive and welcoming chat environment, free from negativity or disruptive behavior such as trolling, often seen on other Twitch streams (see section 4: *Creating a Sense of Community* for more on this dynamic). While not everyone actively contributed, many reported regularly reading comments and following the discussion. Many mentioned that they found value in observing conversations and learning without directly engaging. Some hesitated to contribute due to uncertainty about their STEM knowledge or place in the group, a topic explored further in a later chapter.

"[Why they didn't participate in the chat] I think because I was new. Also, because I'm not particularly well versed in engineering or science. That's not the fault of the channel, but more about me and my relationship with STEM." – Interview quote: YouTube recruited viewer

During the finale episodes, many viewers felt motivated to participate in the chat to help the Escape Room players, contributing hints and solutions. Others found following the chat distracting, especially during the highly active finale episodes – and some felt they couldn't keep up with the fast-moving chat.

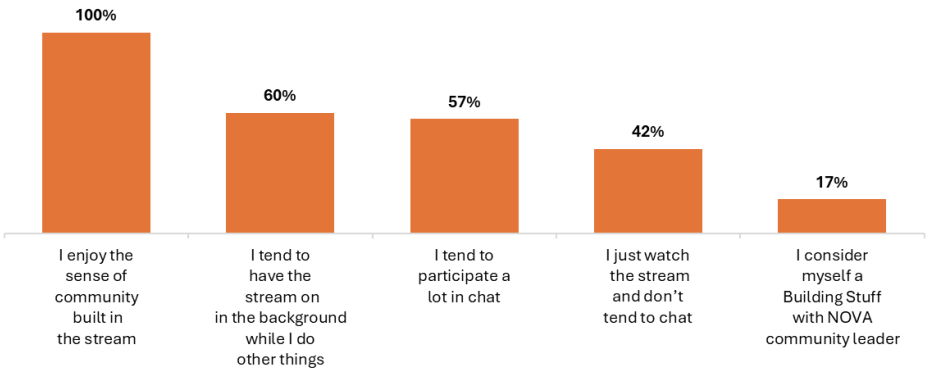
> *"Yeah, I was helping them [Escape Room players] crack the things they were working through. It was really neat because they gave us interactive materials, on Twitch at least… They gave us worksheets and puzzles to work on our own and help the players." – Interview quote: Twitch organic viewer*

The technology used to watch streams sometimes limited engagement: those watching on TVs or phones were less likely to participate in the chat. And some viewers reported difficulty seeing the puzzles fully and couldn't contribute for that reason.

> *"I did not participate in chat for this one. I don't think this had anything to do with the stream, it was just the format – I was watching on my phone vs. the computer. It was a lot harder to have the video playing and chat at the same time." – Interview quote: Twitch recruited viewer*

According to the survey data, 60% of organic viewers tended to have the stream in the background while they did other things. When it comes to chat engagement, 57% said they participated in chat a lot, while 42% said they tended not to chat.

q8: Please select whether the following statements are True or False based on your typical behavior on the Building Stuff with NOVA stream.
(Organic Twitch Viewers, n=29)



Chat data analysis suggests that format influences engagement. For example, *interview* and *field trip* formats boost viewership, while collaborations with other Twitch streamers drive chat activity. Due to the small sample size in this analysis, we highlight these as promising patterns rather than definitive conclusions. We conducted an exploratory analysis of the effects of

stream formats and types on viewership and chat activity that suggests several directions of interest in both drawing interest and creating deeper engagement. Collaborations with other Twitch streamers emerged as a particularly intriguing strategy, showing potential positive associations with both viewership and chat engagement.

Considering directions that draw viewership, *Interview* streams appeared to correspond with 12.4 times higher odds of above-median viewers compared to a control group of the stream's *Video Game* formats, while *Field Trip* formats appeared to correspond with 16.5 times higher odds of increased viewership compared to *Video Game* formats. Similarly, *Collaborations* with other streamers showed likely potential with 5.25 times higher odds of above-median viewers. These findings suggest that interactive stream formats like interviews, field trips, and collaborations with other streamers could be important levers for attracting viewers, with each format showing dramatic potential to boost audience numbers.

In terms of engagement, we found strongest effects when streams brought multiple Twitch personalities together. The chat analyses, again not controlling for other factors, suggest possible positive effects of cross-streamer collaborations, corresponding with 5.8 times higher chat engagement compared to the stream's video game formats. In contrast, these effects did not hold for the more general *Interview* format. In fact, both the *Interview* format and *Building IRL* format showed lower chat rates than *Video Game* streams, suggesting these formats may not lead as naturally to chat engagement, or may feature different engagement than that measured through chat contribution frequency.

Engagement with the Film Series

When it comes to the *Building Stuff* films, many documentary viewers found their way to the series through traditional cable TV, but some also accessed them online through links provided in NOVA emails. Those who watched it digitally typically accessed the episodes on PBS website or YouTube, and some mentioned Roku.

> *"Well, I get emails from NOVA, and whenever I find any new documentary from NOVA, I really look forward to watching it because I really enjoy them." – Interview quote: Film organic viewer*

There is less to explore in terms of engagement with the documentary film series because it involves more passive viewership, without a community component. Film viewers watched a varying number

of episodes, with some mentioning that they watched all three—among them were avid fans of NOVA who said that they never miss a NOVA episode.

> *"I found it on cable TV, probably one of the PBS stations. I think I saw the first show by just coming across it accidentally. There are at least three PBS stations that carry NOVA. So I came across it, enjoyed it. Then I learned there was a second one, so I watched the second one. When I know about a show, then I'll look for it. But I don't always know when NOVA shows are on." – Interview quote: Film organic viewer*

> *"I watch NOVA... I've been watching it for 30 years now. It is very very rare that I miss an episode. It's one of my favorite series for a long time." - Interview quote: Film organic viewer*

Detailed Findings

3. Perceptions of Value and Purpose

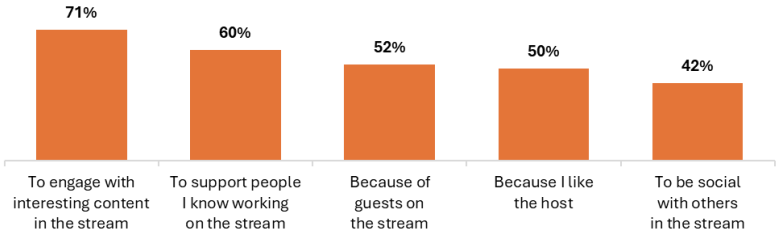
DETAILED FINDINGS: PERCEPTIONS OF VALUE AND PURPOSE

Because this study involves a robust qualitative component with open-ended interview discussions, we are also able to explore in an emergent manner some of the strongest perceptions that people had of *Building Stuff*. For both the Twitch/YouTube experience and the Film experience, we explore viewers' sense of value and purpose, reflected in their own words and framings. This section is not directly connected to the Inquiry Areas.

Twitch/YouTube Perceptions of Value

When asked what brought them to the *Building Stuff* stream, organic viewers are mostly motivated by interesting content (71%), and less by a host (50%), guests (52%) or a chance to socialize with others (42%).

q7: T2B - Please rate how accurate the following statements are about what brings you to the Building Stuff with NOVA stream.
(Organic Twitch Viewers, n=31)



Top 2 Box: those who selected "Like me"
(6 or 7 on a 7-point scale)

While this survey question provides a helpful starting point for our analysis, showing that multiple factors drive interest in *Building Stuff*, we wanted to explore these perceptions more deeply. In our interviews with Twitch/YouTube stream viewers, both organic and recruited, we asked people open-ended questions about their general impressions of the Twitch/YouTube stream (either positive or negative) as well as any highlights that stuck with them.

Using a thematic analysis of interviews, conducted through a combination of ongoing debrief discussions and thematic coding of interview quotes, we identified five ways where interviewees were most likely to express appreciation for the stream generally:

A	B	C	D
Figuring things out from different angles and learning styles	**Working together** with others in a collective journey	**Revelatory moments** about how the world works or could work better	**Getting to know** and connect to fascinating people

A. Figuring Things Out

Many interviewees highlighted how they appreciated the *Building Stuff* stream for how it focused on figuring stuff out rather than just presenting knowledge in more passive ways. A number of our interviewees appreciated the variety of content within the *Building Stuff* stream, both within an episode and across episodes. But within this variety, many saw a common thread in how *Building Stuff* approached its topics. Many appreciated seeing scenarios that explored problem-solving in ways that they would not have thought of themselves. Some liked seeing smart people dig and grapple with figure-it-out situations in ways that wouldn't be possible at home, while others appreciated mining the shows for ideas that they could do themselves or show others. Some noted that the pacing of different topics kept things feeling fresh and moving, and that it stood out from other Twitch streams that were often limited to one kind of repeated format.

> *"Sometimes on this kind of show about science people talk in acronyms, and assume that the audience knows what they are talking about, but here they took time to explain what that means for the audience. They did their best to be clear on why they did something, and what it means, breaking it down to the best of their abilities". - Interview quote: YouTube recruited viewer*

> *"In terms of educational content, it's nice to watch people who have resources and skills I don't, so I can watch them perform experiences that I couldn't at my home." – Interview quote: YouTube recruited viewer*

Quite a few also noted how interesting it was to see people figure things out in hands-on ways, and quite a few shared that highlight moments of the stream for them involved hands-on activities. Interviewees who had seen the finale week *Escape Room* streams were especially likely to appreciate the energy and excitement that could emerge when figuring things out had a timed component to it.

> *"I did watch all three episodes. The one where they were stuck in the crawl space was heart-pounding. I loved the one with the key." – Interview quote: Twitch organic viewer*

"The trebuchet was cool. The hands-on ones tend to be interesting, where he's building something. Also Poly Bridge. Most engineering I can say I know a bit about that, but civil engineering is a whole different world." – Interview quote: Twitch organic viewer

B. Working Together with Others

A number of interviewees appreciated the collective problem solving opportunity of figuring things out—being invited to do the work, instead of watching others do it was appealing. Quite a few people shared a highlight moment from their experience that involved a contribution that they had personally made within the chat to help the group come to a collective solution. Others noted that just seeing multiple people involved in an endeavor made the stream feel more "interactive," even if they hadn't personally contributed to the chat themselves. Although some viewers were hesitant to contribute to the chat if they did not feel like they had enough STEM-knowledge they often still expressed a desire to contribute, and reflected on the value of collective problem-solving, sometimes providing reflections about ways that the stream could have facilitated even more ways to involve viewers (see section 6: *Facilitating Scientific Thinking* for more details on these dynamics).

"I liked how they had to get into the Escape Room by crawling into a tunnel. I liked the set as well. It was really cool. I liked the water jug puzzle. Even though it wasn't as interactive as the last one, I liked the navigation puzzle, like where we had to click on the link to actually help out the players. Any time I get to interact I feel like I'm contributing something, and that's always a highlight for me." – Interview quote: YouTube recruited viewer

"I actually really liked this one. I appreciated it more than the other one. It was interactive, and I liked that there were more people involved. They were bringing in the audience more and it was a full-on experience. It was definitely more entertaining, for sure." – Interview quote: Twitch recruited viewer

C. Revelatory Moments

Many also valued how the *Building Stuff* format helped to reveal how things around us work or could work better, and they often identified revelatory moments where the stream provoked them to think about things from a new perspective. Sometimes these moments were about seeing everyday things afresh (like infrastructure) or about exploring the relevance of historical science to the present (hexadecimal programming). Other times it was about approaching a

scientific topic from a specific example that helped explore bigger principles (debugging with actual bugs, the highest land bridge).

> *"I don't recall a particular stream, but general topic of how infrastructure can be better. Because infrastructure is crumbling given the lack of upkeep. Regarding engineering, I'm mostly interested in what impacts our daily lives. Every time I go to a bridge, I'm like I hope it doesn't fall." – Interview quote: Twitch organic viewer*

> *"[It was fun to learn about] fulcrums, leverages, or the highest land bridge in Portland, Oregon." – Interview quote: YouTube, recruited viewer*

> *"The chat had to get involved to figure out old, hexadecimal programming to figure out the answers, and I thought that was so cool because that is such a big part of programming history. Having to solve something in binary, that was really cool. I think that was such a cool piece of history that I wanted to go into and research more. It reminded me that that even existed. It was something I knew of but totally forgot about. I would love to, next time someone was talking to me at a party, I could bring that out." – Interview quote: Twitch recruited viewer*

> *"I liked the part where they were debugging with the actual bugs." - Interview quote: Twitch recruited viewer*

At least a couple of interview participants connected the *Building Stuff* approach to interconnected revelatory moments within educational and science-related television programs they had experienced earlier in their lives, such as 321 Contact and Bill Nye the Science Guy. Many had fond memories of these programs. They understood NOVA's intent as bringing that kind of approach to science into a new forum through Twitch or YouTube—and they had very positive associations with this goal.

> *"I feel like this fills the niche of "312 Contact", the PBS show I used to watch as a kid after school, the after-school programs when you are still in a mindset, feeling like learning without needing a plotline to follow." – Interview quote: Twitch organic viewer*

> *"My overall impression was "this is fascinating". This is a government experiment of how to do science education on these new platforms." – Interview quote: Twitch organic viewer*

> *"When I joined, I wasn't sure what to expect. It was really great, but when I first tuned into the very first episode, it was nostalgic to me, as 90s baby, 2000s kid. I grew up on those gameshows that used to be on TV and it was giving those kind of vibes but for something that we do nowadays." – Interview quote: Twitch organic viewer*

D. Getting to Know People

A number highlighted their fascination with the people and personal stories highlighted by *Building Stuff*—especially journeys for how people came into scientific careers. Some were interested in Dr. Nee. Others focused on guests. Quite a few mentioned how they appreciated seeing how people from a wide range of backgrounds claimed their expertise in science and were honored as valued contributors to scientific fields. (see section 5: *Deepening Affinities for Engineering* for more details on these dynamics).

> *"For the first one, I just liked hearing her story. Her entire journey was inspiring to me. They made it go beyond – just getting to know her. Because then you're more inclined to look into things in the project because you're more connected to the person. I did [look into it afterwards], I was curious how accessible her stuff was." – Interview quote: Twitch recruited viewer*

> *"I liked him. It was also nice to see a Black man in engineering. It's very important to engage people. I came from a very culturally diverse community. A lot of the principals I came across were Black people (in schools). People tend to learn better from people of color than not. I can recognize somebody who looks like me." - Interview quote: Twitch organic viewer*

Viewers of Twitch streams specifically considered Building Stuff to feel educational and professional, especially compared to other Twitch streams. Quite a few also remarked that it felt like a more wholesome space than other Twitch streams.

> *"Very different than other streams. Gamers and others are more crazy, wild. This was more educational, professional. I wouldn't say it felt scripted, it was a random dialogue between two people." – Interview quote: Twitch recruited viewer*

> *"I would say this is slightly more structured. I've watched a lot of gaming streamers, who are very relaxed and there's not much structure. This was in between, it felt like you were hanging out, but also learning. It was interesting. I felt like I was able to keep up pretty well, all things considered. I thought they would go more over my head than they did. Throughout the week I was learning these concepts, and they were building up to the finale. It sounds interesting to actually see the full result of their efforts." – Interview quote: Twitch recruited viewer*

> *"It was more put together than I thought it was going to be. It made it seem like they were really there." – Interview quote: Twitch organic viewer*

However, when people compared *Building Stuff* to other kinds of content out in the world, like documentary films and YouTube, they often noted that it felt less polished. Since NOVA hosted the same stream on both Twitch and YouTube, this sometimes resulted in different perceptions for those watching through YouTube.

> *"Also learning from other channels, I think there could be a little bit more professionalism, or production quality. It's pretty good, but at least in every other stream the camera cuts out. Also there could be more visual aids, or visual demonstration of principles, even if it's an image or graph. I know it can be kind of tough because of the format of a livestream." – Interview quote: Twitch organic viewer*

Several people also noted that chat comments were highly polite and encouraging, different than they had seen in other streams on Twitch.

> *"Everyone wants to be helpful, you don't have people trying to give bad answers. The NOVA audience is much more refined, not sure how it would be in a different stream. It's a NOVA audience, no way someone would intentionally [troll] on a Sunday night trying to be that person." – Interview quote: YouTube recruited viewer*

Film Series Perceptions of Value

Similar to our interviews with Twitch/YouTube stream viewers, we also conducted interviews with *Building Stuff* film viewers, both organic and recruited. Interview participants answered open-ended questions about their general impressions of the film (either positive or negative) as well as any highlights that stuck with them. We conducted a thematic analysis of interviews, and we identified four kinds of value that interviewees felt that the film provided:

A	B	C	D
A variety of stories that reframe what counts as science	**Revelatory moments** about how the world works or could work in the future	**Cool things** that engineers are working on	**Seeing a wide range of people** participate in science

In some ways these areas of value have overlap with the Twitch/YouTube streams, but they are also inherently different because of this highly different format of engagement. From interviewees' words, it's clear that these modes are serving different purposes. For the film, perceptions are more focused on the value of the content that they *took in* from the film instead of the learnings that were *collectively built* as part of the Twitch/YouTube streams.

A. Variety of Stories

Many people said that they appreciated the way that the film series highlighted multiple stories that were loosely connected through science. They often saw that as a unique differentiation from a typical science-related documentary, and they felt that it provided more access points to get interested in the topic and helped keep viewers' attention. Even those who didn't find each topic segment equally interesting liked the principle of having different segments within the films. And a few noted that this format helped break through a pre-existing assumption they had that educational-content documentaries would be boring.

> *"I loved that there were multiple stories in that 1-hour period. I think that's a great format If you did the whole deep dive into the rocket in an hour, maybe you don't want to invest that much time in a rocket. You can go someplace else to get that. It's an introductory platform. It didn't give me the opportunity to get bored or worn out with a particular topic." – Interview quote: Film recruited viewer*

> *"So, it's PBS, and I was like, great, when I think PBS, I think "yawn, boring." I thought the intro was a little too much, it didn't really capture me, it was giving nothing. But as the documentary carried on, the part with the plane, that was actually super interesting to me. So that did a good job of capturing my attention. As it went on, I thought I was going to be learning about aircrafts, but then it quickly switched. So, we're learning about food now, not helicopters. And then it switched again. It was all over the place. There's nothing in common with any of them, I didn't think. But each segment was 10 minutes each, so I think that was pretty digestible, and able to keep viewers' attention. You quickly learn about these things that could change the world in some way." - Interview quote: Film recruited viewer*

> *"Certain things, if you haven't done them, you might have not as much interest. Like the Double Dutch jump rope, I never jump rope, so that wasn't too interesting. The dancing one was kind of interesting, but I didn't relate to it very much. I think it was important to have that kind of variety. That was the important part, the combination of all those things. The range of engineering, science and creativity." – Interview quote: Film organic viewer*

> *"It was good that it wasn't concentrated on just one thing. It was kind of easy that it was short stories, then another one, then another one. They were short topics, and I understand that I don't care about some things, but other people do. And I learned many things about it. There were plenty of things that I identify with. The one about the fire jackets, things about outdoors, camping and stuff, space, space flight. There were others that I didn't relate or understand. The thing about dancing and the interface for the public to feel how the dancers are feeling. But it was just five minutes." - Interview quote: Film organic viewer*

A number explicitly recognized these film content segments as relating to a broad definition of science and engineering. But some noted that not all segments felt as closely related to science, suggesting that they had not fully internalized a sense of science beyond its more narrow definition. Several noted that they had trouble understanding why segments more focused on every-day science were included (see section 5: *Deepening Affinities with Engineering* to explore these dynamics).

> *"I liked it. I felt that it was super engaging. You think of engineering as this super scary thing, done by super intelligent people, but didn't feel like that. I loved the Double Dutch video, because that is something that I've done before and that I enjoy." – Interview quote: Film recruited viewer*

> *"Some of the stories were more obviously significant in how they relate to the larger planet. Some seemed trivial – like the physics of Double Dutch. I didn't get the scientific point or implications. Dance – it was enjoyable, but I didn't follow the science aspect of it." – Interview quote: Film organic viewer*

We did hear some people being slightly taken aback by the unexpected format of the film. We heard this especially from avid science documentary watchers, who expected more of a cohesive and building narrative. They had to reorient themselves to a different format, and a few noted that they weren't sure how things all added up.

> *"While I thought it was an interesting series, I found it to be a little disjointed, so I wasn't sure who it was developed for. I have some science background, so it was very easy to understand. The individual-level stories were interesting, but pulling it together into one cohesive story, I found that hard to understand." – Interview quote: Film organic viewer*

> *"I watched about the skyscrapers. The part about the wind stood out. It was interesting, but kind of dragged a little bit. It bounced from clothing to outer space, to deep sea. It needed something spicy in the middle. It holds your attention too long. You can cut some of that stuff out. It dragged a little bit too long for certain topics. If it was someone I was interested in, then I'd go with it. I was interested in the firefighter." - Interview quote: Film recruited viewer*

B. Revelatory Moments

People were most likely to value content in the film that felt revelatory to them, either helping them think about the world in a new way, or exploring a new or future solution.

Because the film series didn't have a social or community component, interviewees spent a much longer time talking to us about how they took in the specific content of the documentaries. Many

appreciated learning about things that they felt have been ignored in their experiences with science education or media, or things that could provide new insight for the future.

> *"I thought dealing with themes in bursts as opposed to a whole episode was a good way to stimulate thinking, because it hit a range of interests and issues, and it dealt with issues I had never in my life thought about." – Interview quote: Film organic viewer*

> *"I didn't know that the Navajo don't have access to clean water. And I didn't know that the coral reefs were dying. So, I feel like those things were cool, that they were added to the documentary, because they shouldn't be ignored. That definitely stuck with me." – Interview quote: Film recruited viewer*

> *"I liked the blow-up buildings and outer space most. Because I'm thinking about the future, like wow can we live there? I think that's why they're doing it; they want it to be adaptable to us. I was thinking wow; would my grandchildren be living in outer space? How much would be the flight there?" – Interview quote: Film recruited viewer*

> *"I like how they talked about different topics. My favorite one was the one about wind and buildings, I had no idea it was that strong. Something very silly I never thought about, are we going to be able to buy submarines in the future? Just sizes of submarines. Are people going to buy a two-person submarine? Or a six-person submarine? So, I thought that was an interesting concept." - Interview quote: Film recruited viewer*

Some resonated with the solutions-focused perspective that some of the segments took. Others mentioned that solutions can be more complex and difficult than what the film showed.

> *"I recall they were trying this device that would be able to sniff any rotting with the food. I think that was great, because of the tremendous waste that we have with the food all over. I hope they manage to come up with some solution soon." – Interviewer quote: Film organic viewer*

> *"There are many consequences to many activities. There is always a solution [in the film], which I don't always feel happens in real life." – Interview quote: Film recruited viewer*

C. Things Engineers Work on

Viewers of the film were highly likely to recognize its focus around engineering, and they were excited to see what cool things engineers work on. Some who were science educators themselves felt that this was a value that they could bring directly to their classrooms by highlighting the NOVA film content. Other individuals explicitly noted how it was impactful to see all of the different kinds of things that engineers do in the world. With this perspective, we also spoke to a few

people who had strong feelings about how they felt engineers should make a positive impact in the world, and they sometimes critiqued the films when they weren't able to fully understand that impact.

> *"I liked electric helicopter/airplane. They did a good job describing the technology and how they worked on the blades to make it really quiet. We do things in my class with engineering design process. I thought it was a good example to talk to my students about. I'd bring it to my class, maybe show a part of it in my class to show what cool things engineers are working on. When students feel connected to what's going on outside the classroom it's important." – Interview quote: Film organic viewer*

> *"I think in general bringing to light things that people may not have thought about at all in engineering. Like what you can do in various fields, bringing sight to a blind person and dampening the sway of a building in Chicago. So, the breadth of the topics and the form of engineering." - Interview quote: Film organic viewer*

> *"What I really enjoyed is when inventions are trying to help people. The first one was very cool because they were trying to help someone to regain vision, or spasticity. The purifying water: I thought I was a great topic, but I couldn't understand what the collaboration with indigenous people was bringing to the scientists, besides the fact that they were using the clay. I couldn't understand the connection of why it was so important that they were working together". – Interview quote: Film organic viewer*

D. A Wide Range of People

Viewers of the film also appreciated seeing people from a range of backgrounds making contributions to scientific endeavors. Several older female interviewees with connections to STEM careers remarked how much harder it was to be a woman in their field in previous decades. (See section 5: *Deepening Affinities with Engineering* to explore these dynamics).

> *"It reminded me of going back up to labs where I used to work, where the people were so excited about research they were doing. I loved seeing women and minorities as science experts, covering building to launching rockets, showing people working in their labs." - Interview quote: Film organic viewer*

Detailed Findings

4. Creating a Sense of Community

DETAILED FINDINGS: CREATING A SENSE OF COMMUNITY

This section explores the complex and multi-factored elements that help build community and help create a perceived sense of community as part of the *Building Stuff* stream. It provides key details for Inquiry Area 2 and its related research questions.

➔ **Inquiry Area 2**: *What are best practices for **connecting with people** through community-centered streaming? What are things that this type of engagement does well? What could be improved to best leverage these environments?*

- How are participants experiencing *Building Stuff with NOVA* on Twitch and YouTube? What is the digital culture that emerges (e.g., cognitive, emotional, social reactions)?
- How do the different formats of streams impact engagement (e.g., game time, live commentary, interviews, building IRL, escape game) What formats result in deeper or more impactful engagement?
- How do hosts (style, background, etc.) impact engagement?
- Do recruited participants have a different experience than those who would find and engage in the stream organically?
- How can we effectively design and moderate for a welcoming, inclusive, safe space?

For relevant sources refer to the following thematic areas listed under Literature Review Sources in the Appendix: *Livestream theory & commentary, Inclusive gaming, Moderator tools, techniques, characteristics*

Twitch/YouTube Perceptions of Audience

Most people we spoke with in interviews felt that they had seen signals during their experience that *Building Stuff* was designed for a small and deeply passionate community, particularly people already interested in STEM. They read these clues through the vocabulary people used in the chat, the background experiences that people referenced, and one-to-one interactions between Dr. Nee and viewers that suggested they had been on the stream multiple times.

"People have common interests on chat. Everyone seems to have watched lots of PBS." – Interview quote: Twitch organic viewer

"I noticed less engagement In the Escape Room than I expected. There were not a lot of differences of options and instructions in the chat. People were mostly saying the same things. People there seemed to be knowledgeable, and maybe that's why the commentary felt so homogenous. It was difficult to participate if you didn't have the background." – Interview quote: YouTube recruited viewer

"Seemed pretty loyal. I remember Dr Nee shouting out a username that I remember watching. I think it's a loyal audience – a niche community almost. Into engineering, love the channel, have engineering minds. I say that because for the Escape Room they had an application open for viewers to join and participate and selected someone from their livestream viewers. Seems like a small deeply passionate community." - Interview quote: YouTube recruited viewer

We heard a range of comfort levels that people had with this perceived community of people who already love STEM. Some felt like it was a homecoming because they were around other people who were like them. Others felt a little out of place but appreciated interacting with smart, interesting people. Just a couple noted that the stream might not be the right place for "regular people."

"When I go in there, it's almost like a homecoming – it's like a collision of super nerdy, gaming side and scientific side. This is space where I feel 100%." – Interview quote: Twitch organic viewer

"Quite a bit stuck with me. The first half was getting viewers updated. The second half was engineers going into the Escape Room. They had all these different elements that they had to match up with colors to get the batteries charged. A lot of the engineering stuff was kind of over my head, but I appreciated that in the chat they'd drop the links to the clues. Somethings they had a hard time with – I didn't understand how they solved that. It would have been helpful to drop links for the solutions, for people like me." – Interview quote: Twitch recruited viewer

"Yes, and I felt like the community was for people who are maybe in the science field. I didn't feel like it was for regular people watching it." - Interview quote: Twitch recruited viewer

"I think I might be a little bit of an outlier, because I'm someone without a science or engineering background, so I'm not sure if I'm the target audience for this." - Interview quote: Twitch organic viewer

Although viewers we interviewed generally felt they understood the educational purpose of the stream, many were highly uncertain about what age the *Building Stuff* stream audience was intended for. Many noted that they came into the experience without a strong sense of the intended audience, and they either didn't see enough signals to indicate the audience or sensed conflicting signals about audience. Some people wondered whether the stream was geared toward a school-age audience or an adult audience. The lack of perceived signals meant that in our conversations they sometimes used their own intuition to make a judgement, or considered a person in their life who might enjoy it.

> *"I would say when I initially clicked on it I kind of thought it was more geared towards younger adults and more geared towards high school students but as I started watching I realized it is more geared towards whoever is interested in it." - Interview quote: YouTube recruited viewer*

> *"I would say that a middle school classroom seems like the ideal audience for the content that was produced. I would say a science class and laboratory, when you are measuring things... That kind of understanding and learning would go well with this." - Interview quote: Twitch organic viewer*

> *"It's good for engineers. I'd definitely say younger college students – 18- to 20-year-olds. It would be good to spread the word around college campuses, for people who are interested in engineering but don't know what they want to focus on." - Interview quote: Twitch organic viewer*

> *"My nephew would love this. He acts like he doesn't care about science stuff, 10 years old, he looks things up all the time, loves escape room type of games." - Interview quote: Twitch recruited viewer*

Others felt more certain that *Building Stuff* was likely geared toward school-age individuals, although they were often not clear whether towards middle school or high school. These individuals tended to use elements of design and production like color to make a judgement, but with no consistent conclusion.

> *"It was weird because I couldn't tell if the audience was high schoolers or kids, because high schoolers can engage better. I think under 18 is who I saw it for. Not to judge the hair style of the people, but bright colors make me feel "kids". But some of the problems I thought, this could definitely be a problem for older people, or for older kids. I engaged with that as a master's student." - Interview quote: YouTube organic viewer*

"The traditional NOVA films are wonderful, are polished, they are for adults. This is more like a science show. This seems like it's more educationally based, for younger people. It really looks something that's produced for middle school kids. And we do need more middle school kids thinking engineering." - Interview quote: YouTube organic viewer

After reflecting, quite a few people circled around to feel that *Building Stuff* would be good for any audience, including people who did and did not have STEM backgrounds. But it was interesting that this conclusion was not top of mind for most at the start of our conversations.

"I feel like it's best for anybody actually. I feel like it can get anybody interested in different aspects of science or math or engineering that they did not think about. I don't think I've ever thought about binary codes. It's how they had to come up with different things to solve puzzles that gets you thinking through problems you might not have thought of." – Interview quote: Twitch organic viewer

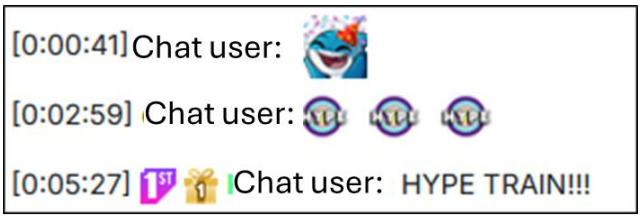
"I think that engineering students, and people who are interested in science and math, STEM... But I could see it reaching other audiences too who are interested in learning new things, and using their brains in a different way. Depends on the person... I found myself curious about what's to come, and I think other people without a STEM background could too, but it's probably more familiar to people who are entering that field or are already a part of it." – Interview quote: Twitch recruited viewer

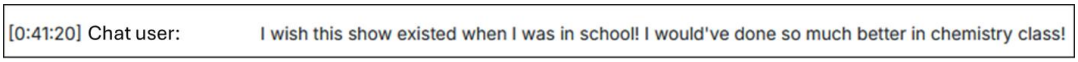
"It could be a niche audience for the game community, but also a younger audience or the science community. I don't want to be generic and say it's for everyone, but it kind of is. It's comparable to how interesting TikTok can be. But I think it can be for everyone if they want to have fun". – Interview quote: YouTube recruited viewer

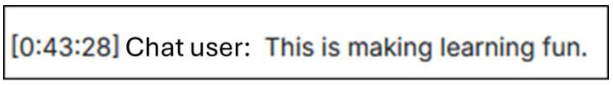
Twitch Chat Engagement and Dynamics

The NOVA *Building Stuff* channel demonstrates exceptional community positivity within chat, stemming from strategic host engagement chats, a positive community culture, and thoughtful use of digital communication tools. These elements created a rich, supportive online learning environment that balanced emotional connection with educational objectives. Within the NOVA *Building Stuff* channel chat, over a third (33%) of the messages expressed positive sentiment or emotional engagement, many expressing both (correlation of 0.73 between sentiment and

engagement), suggesting that when members express positive feelings, they also tend to be more emotionally invested in the discussion.





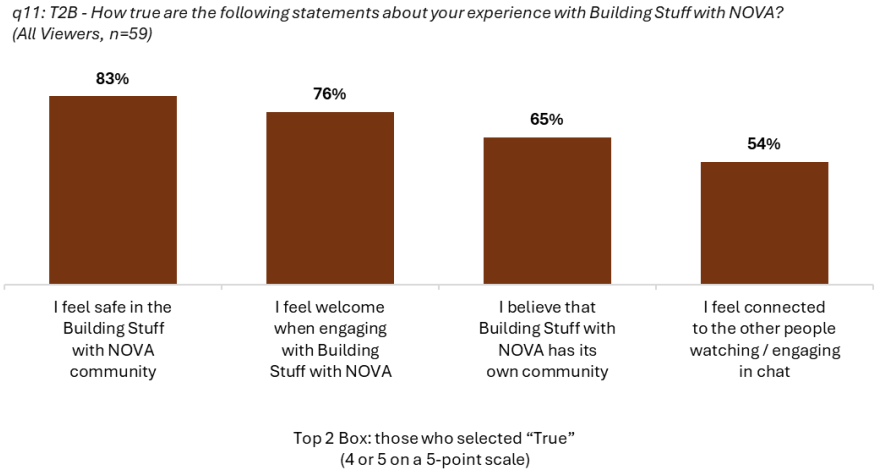


Statistical analyses revealed several key factors influencing viewer engagement in *NOVA Building Stuff* stream chats. For example, higher viewership streams tended to have more positive chat messages. Further, statistical testing revealed a different pattern for other forms of engagement – streams with below-average viewership showed higher levels of emotionally impactful messages and peer support in the chat. These findings reveal distinct patterns of chat engagement: while higher-viewership streams generated more positive messages, streams with fewer viewers fostered more emotionally rich discussions and peer support. This suggests that different types of viewer engagement may emerge depending on the size of the audience.

Viewers used different tools to engage with the streams. Emotes (special chat reactions) appeared in about one in six messages, often mixed with both emotional expressions and learning-related content. While critical or negative messages were uncommon - only about 3% of all messages - they regularly occurred during collaborative problem-solving. For instance, messages like 'the players don't know anything!' emerged when viewers felt Dr. Nee could better guide players through challenges. Our analysis indicated that these more critical moments frequently coincided with collaborative learning, suggesting that even seemingly negative messages often reflected viewers' investment in the stream's educational success. Rather than indicating a problematic environment, these moments showed how the platform's chat features enabled viewers to actively participate in shaping STEM learning experiences, using constructive criticism to enhance the educational value of the stream.

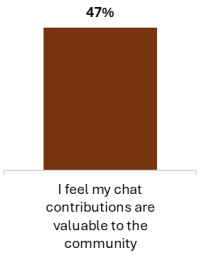
Twitch/YouTube Perceived Sense of Community

In addition to the Twitch chat analysis, we also asked people in the survey to share their own self-perceptions of the *Building Stuff community,* which were highly positive. A large majority of respondents felt safe within the NOVA Building Stuff community (83%), and they also felt welcome (75%). A slightly lower number, but still more than half of respondents agreed that Building Stuff has a unique community (65%) and that they felt personally connected to it (54%).



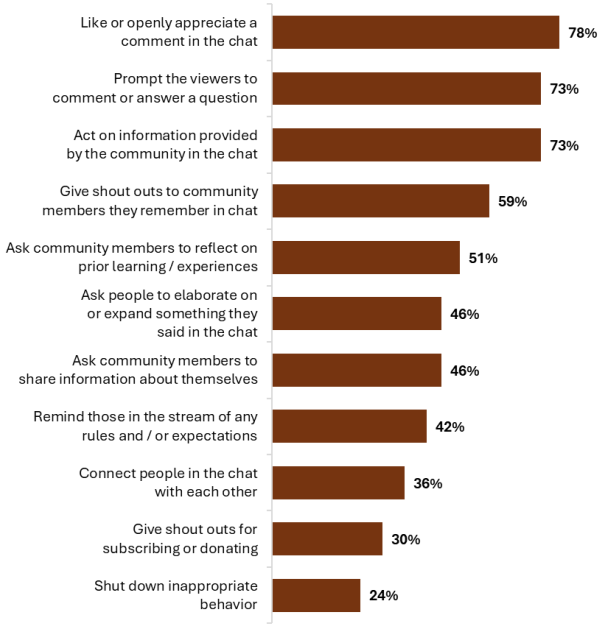
While 47% of survey respondents felt that their chat contributions were personally valuable to the *Building Stuff* community, there is still another half of viewers (53%) who feel hesitant about the value of their own contributions. Efforts by *Building Stuff* moderators and hosts to encourage comfort are highly desired by survey respondents. When we asked about specific techniques that hosts and moderators can do to encourage chat participation, respondents were most likely to appreciate when moderators provide positive feedback on contributions, create prompts to help guide contributions, and actually use contributions that are made by chat participants.

q9: T2B - Please rate how much you agree or disagree with the following statements about the Building Stuff with NOVA stream.
(All Twitch Viewers, n=37)



Top 2 Box: those who selected "Agree"
(6 or 7 on a 7-point scale)

q12: T2B - To what extent do you agree or disagree with the following statements about Building Stuff with NOVA: "I feel motivated to join in the chat and participate when the host or moderators do the following"
(All Twitch Viewers, n=37)



Top 2 Box: those who selected "Agree"
(6 or 7 on a 7-point scale)

When exploring perceptions of community in our analysis, we identified four mechanisms that most impact perceived sense of community:

A **Host tone and vibe**

B **Host interactivity with chat**

C **Guest interactions with Host**

D **NOVA team modeling of chat norms**

A. Host Tone and Vibe

Across interviews with both recruited and organic *Building Stuff* viewers, there was widespread sentiment that Dr. Nee maintained an engaging and approachable demeanor, and in doing so set a tone for how audiences could expect to engage with the channel's content and community. For many viewers, Dr. Nee's approach exemplifies the tone that Twitch viewers typically associate with successful hosts and a welcoming environment, such as by frequently

maintaining an upbeat presence while being genuinely oneself, sharing natural reactions with unscripted moments, and showing the effort and iteration it takes to get good at something.

> *"I thought that the host's energy was not way high and not overly boring and putting me to sleep, but also calm, welcoming, and friendly. It was inclusive." – Interview quote: Twitch recruited viewer*

> *"I try to find content from people I am already familiar with. When the NOVA thing came up, I was like 'No, I do not like escape rooms. Might as well be stuck in a space shuttle.' And I saw Dr. Nee, he was so friendly, personable and down-to-earth. I didn't want to stay initially, because I do not have time to invest in this thing, but he was so engaging with the audience." – Interview quote: Twitch organic viewer*

Many viewers appreciate how Dr. Nee balances his engineering expertise with accessible language, connecting through both his deep subject-matter knowledge and his willingness to learn in real time. This openness about being a novice resonated particularly well when he tackled new challenges on the stream, whether playing a game like Poly Bridge for the first time or attempting unfamiliar DIY builds.

> *"I think he did a good job, reminding us that he is a knowledgeable person in STEM but also put it in a more understandable way for people who don't have prior knowledge. He put it in simpler terms, and he has a very engaging voice." - Interview quote: YouTube recruited viewer*

> *"I was enraptured by the tone he took to bring these topics to a wide audience. It's really nice to see people who don't look so far above the topic that they can't relate to newer audiences. And I like the bona fide: I love that he has a PhD." – Interview quote: Twitch organic viewer*

> *"The host is great. I do like Dr. Nee quite a bit and he is very enthusiastic. I like people with a bit of an edge. It can be fun to watch someone with more authenticity as far as showing their frustration. That can be fun and relatable." – Interview quote: YouTube organic viewer*

Others noted how Dr. Nee's unscripted, informal hosting style was especially helpful in creating a welcoming atmosphere that bridged different worlds of science communication. While his approach embraced the natural learning process, including mistakes and real-time problem-solving, it also fell into an interesting middle ground: those familiar with Twitch found it somewhat more formal than typical streams, while viewers accustomed to NOVA programming or traditional educational settings saw it as notably casual.

> *"It feels more focused and educational [compared to other streams]. It's still fun. Fun in a different way though. It stimulates my mind in a different way. If someone's just playing a*

game, it's more casual, like I don't have to listen. The goals are different." – Interview quote: Twitch recruited viewer

"I thought it was pretty interesting. I had some perceptions going in: I thought it would feel like a NOVA episode, strict to a script. I was surprised in a good way that it's a lot more informal." - Interview quote: Twitch organic viewer

A very small number of viewers found Dr. Nee's presentation style overly enthusiastic and reminiscent of children's programming. While some felt this approach was misaligned with adult-oriented science content, others among this small group still reported an overall positive experience with the stream.

"The host wasn't my favorite. Maybe a female would have been better. He kept intervening and I wanted him to stop talking so I could hear what was happening and focus on what they were doing [referencing the Escape Room episodes]." – Interview quote: YouTube recruited viewer

"He's really good. I like how motivated he is about whatever he's working on that day. I like that he can open up and make things personable. Sometimes he seems a little too overly excited, but engineers, we're all special. I don't think there's been a single stream where I've thought 'Dr. Nee doesn't seem very into this.'" – Interview quote: Twitch organic viewer

B. Host Interactivity

Many viewers highlighted Dr. Nee's consistent engagement with chat and acknowledgment of chat contributions. They also appreciated the multi-layered interaction – from Dr. Nee's direct responses to moderators' engagement and the on-screen display of chat comments – which created a feedback loop that made viewers feel the audience mattered, whether or not they personally contributed to chat. This approach exemplified what Twitch viewers typically value in hosts: active engagement that makes viewers feel like they're part of a genuine conversation.

"He was really pulling the chat in, acknowledging the chat and people participating in the live stream. Not that some people forget, but it's easy to let the chat slip by and he didn't do that." – Interview quote: YouTube recruited viewer

"It's nice that if you ask a question, Dr. Nee will answer it. Even if he doesn't know the answer, it will come through on the back end [from the moderators], which is a really cool factor." – Interview quote: Twitch organic viewer

"They put people's comments on the screen, which goes into acknowledging people and making them feel like part of the show." – Interview quote: Twitch recruited viewer

Viewers noted distinct differences in Dr. Nee's chat interaction between regular episodes and Escape Room segments. During Escape Room episodes, he had to manage multiple conversation streams simultaneously – Twitch chat, YouTube Live chat, and interactions with the live cast. Most viewers felt he handled this complex dynamic well, but a few found that juggling these various channels of communication became confusing, making it unclear which audience or cast member he was responding to at any given moment.

"He was very good at both talking to the chat and also guiding the contestants through the challenges. He kept a good level with it, which is not an easy thing to do." – Interview quote: Twitch organic viewer

"I think the dynamics were pretty complicated to navigate, because the viewers were facilitating information to the host, and the host was facilitating information to the players. And the host had to pay attention to both Twitch and YouTube." – Interview quote: YouTube recruited viewer

"I will be watching more because I really liked the interactiveness of the Escape Room. I was in the chat, and the host said, 'The chat said this.' That was really cool. I'm not sure which chat [Twitch or YouTube] he was paying attention to the most. But I liked how excited he got." – Interview quote: Twitch organic viewer

A number of interviewees who we spoke with suggested additional opportunities they would have liked to see for more chat participation, particularly through lower-effort engagement options like polls, giveaways, and quick-response questions. These kinds of interaction methods were seen as potential ways to complement the more robust chat discussions by providing easy entry points for a broader audience, especially those more inclined to be "lurkers" than chat participants.

"I participated in some of the challenges. I realized I'm not the only weird one here. I would participate more if there was something we were supposed to do in the chat. Asking us a question, something to get the conversation going." – Interview quote: Twitch organic viewer

"I'd love if they had more audience moments, giveaways, rewards, incentives, something to make them come back for the next stream." - Interview quote: Twitch recruited viewer

"I think it would be nice if [the host] engaged more with the audience, asking questions that could be rhetorical, but that could also be answered. Doing polls, things like that." – Interview quote: Twitch recruited viewer

C. Guest Interactions

Throughout the run of *Building Stuff with NOVA*, guests brought fresh energy to the streams and often attracted their own followers. This created opportunities for two-way audience expansion – new audiences coming to NOVA and NOVA audiences finding new people to follow on other channels. The interview format, following Dr. Nee's presentation style as a host, also modeled a kind of informal dialogue that fit the tone of the stream and made people want to participate. When guests shared their learning journeys or showed enthusiasm for specific topics, it resonated with viewers and helped maintain engagement even when the viewers had little experience with the topics themselves. And as noted in section 1: *Building Stuff* Audience, streams with collaborations with other Twitch streamers showed potential positive associations with both viewership and chat engagement.

> *"It was nice to see a man of color leading the stream." - Interview quote: YouTube recruited viewer*
>
> *"I was excited to see the guest was Aisha Bowe. I know who she is. As a Black woman I was so excited to see hands on engineering with black people. She is a Black woman in it. That part was already really exciting to me because you don't see that as much as you should." – Interview quote: YouTube recruited viewer*

D. NOVA Team Modelling of Norms

NOVA affiliate messages also appear to have been pivotal to community engagement. NOVA affiliates, though comprising just 4.55% of the chatting accounts, drove nearly a quarter (23.36%) of chat activity. They posted proportionally more questions (10.6% vs 7.3%) and direct host interactions (4.7% vs 3.9%). These NOVA affiliate host interaction messages showed a strong 0.68 correlation with peer support and viewer inquiries, indicating their strategic role in sparking community discussion and in curating a supportive learning environment among viewers. Positive messages exhibited a 0.47 correlation with emotional impact and a 0.37 correlation with peer support, suggesting that emotionally resonant messages were more likely to foster a sense of community connection and mutual support.

[1:15:08] Chat user: Try opening the wall panels?

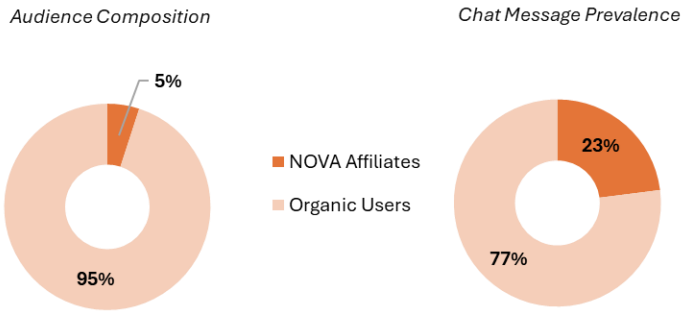
[1:15:11] Chat user: is there anything that can be done with the structure in the center?

[1:15:15] Chat user: what are the letters in the binders? if it's a cipher then chat can work on it

[1:16:18] Chat user: do the ladders move?

[1:18:12] Chat user: @novabuildingstuff could we have the survey link in chat please?

Meanwhile, organic users (95.45% of the chatting accounts, generating 76.64% of messages) focused on community building through shared experiences (10.1% vs 6.4%) and peer support (2.5% vs 1.3%), highlighting NOVA affiliates' strategic role as conversation catalysts and their subtle modeling of host interaction patterns, encouraging similar engagement behaviors among the broader audience.



Our controlled analyses of chat engagement showed streams with more peer support messages corresponded with 3.1 times higher odds of above-median chat activity. Similarly, streams with more collaborative learning moments aligned with triple the odds of high chat engagement. The friendly, non-toxic, and non-judgmental tone of chat interactions on *Building Stuff* was also explicitly recognized by our interviewees.

> *"Nobody was condescending. I loved that about it." – Interview quote: YouTube recruited viewer*
>
> *"Everybody seemed happy, and people seemed interested in what was going on, and were asking questions, and the questions were getting answered. Nobody was putting anybody down, everything was upbeat." – Interview quote: Twitch recruited viewer*
>
> *"It seems like a community I could be a part of. When chatting, I didn't feel any negative energy, or a bunch of negative chats or offensive chats. Nor did I see anything where people*

would go in on other people or called anybody out for getting the wrong answer. I felt very welcome in those who were chatting." – Interview quote: Twitch organic viewer

"I liked participating. Seeing my answers on the screens, and seeing others comments in the chat – I liked that. I felt it was really unique. I never participated in anything like this on YouTube. It would be amazing to get classes or schools participating in something like that. Like a national Olympiad." – Interview quote: YouTube organic viewer

Detailed Findings

5. Deepening Affinities with Engineering

DETAILED FINDINGS: DEEPENING AFFINITIES WITH ENGINEERING

This section explores learning strands related to deepening affinities with engineering for both the Twitch/YouTube stream and the film series. It directly relates to Inquiry Area 3 and its related research questions.

➔ **Inquiry Area 3**: *What lessons around **learning and engagement** are there for informal science communicators regarding community-centered streaming, with focus on qualities that are most conducive toward learning, both related to pre-defined objectives and emergent areas?*

- Do we see evidence of learning on Twitch and YouTube through Building Stuff with NOVA? What type of learning is most prevalent?
- How do different engagement styles (e.g. active, passive, light responder, contributing member, community leader, troll) impact engineering and science-related learning outcomes?

For relevant sources refer to the following thematic areas listed under Literature Review Sources in the Appendix: *General, Learning through livestreaming*.

Pre-Existing STEM Affinities

NOVA *Building Stuff* stream viewers tend to see science as a creative thought process intended to help people learn about the world. Science was seen as an iterative method of relating and engaging. Interviewees viewed science expansively as a process of asking questions about how things function. Yet many people still associated science with a more literally definition involving school classes and lab coats instead of a form of day-to-day engagement.

> *"[Science] Helps you broaden your horizons, outside the box. It's not set in stone, you can always change and do things, until things are proven beyond a reasonable way to not do it. And even then, there's always something new to learn." – Interview quote: Twitch organic viewer*

> *"Questions. How do we learn more. What do we do with what we learn. How does learning affect us. It's a process. Basically, there's no mistakes, right? So sometimes we learn things and then we find out later there's either a better way to do it or there was more information to be*

found. That's what science makes me think about – how things work." -Interview quote: Twitch organic viewer

"[Science is…] Research, discovery, inventing stuff. Science can be exciting, can be boring. I think what I do is a kind of science, because it's experience. You try different things, you have a hypothesis, you try to prove a statement. Though, when I think about science I think about people in lab coats, looking at test tubes."- Interview quote: Twitch recruited viewer

While stream viewers see engineering as the tangible practice of implementing science, they see it as the more concrete act of "building things" instead of a thought process or world view. In addition, people describe engineering as more directly related to a literal profession or degree that someone can earn. However, engineering was also seen as inextricably linked with science for many. Engineering could only exist in conjunction with the science that forms the basis of how people engage in engineering.

"Engineering is putting science into practice. Science is the uncovering of unknowns, and engineering is putting that understanding to use." - Interview quote: Twitch organic viewer

"I would consider engineering more of a profession. There are some small projects you can do but I feel like it's not the same level. For example, people on YouTube do these amazing things, but me myself, I couldn't do them." - Interview quote: YouTube organic viewer

"Engineering is application, I'd say. I do love pure science and stuff, but engineering is about applying the knowledge to make something useful." - Interview quote: Twitch organic viewer

"Building, structure, safety, are some of the words that come to mind. I don't know if I can separate the two (science and engineering), because you need the science to do the engineering, but engineering is more related to arts, in the sense that you have to consider all these materials, glass, stone, and consult specialists of all these areas to do a project." – Interview quote: Twitch recruited viewer

Much like how some saw science through the narrow lens of school, chemicals, and lab coats, many similarly saw engineering as restricted to a very specific academic pursuit. There was also some trepidation attached to the term engineering. Specifically, some (especially those who were recruited to participate in the stream) more often discussed engineering as hard, formal, or a topic that was too challenging for them to seriously consider.

"I think of invention, creating new products through science, a guy in a laboratory mixing chemicals and creating substances like, for instance, rubber. I think of somebody at a facility

who does scientific experiments in order to test the products. When you create a product you have to go through a bunch of tasks to make sure it works, that involves engineering." - Interview quote: Twitch organic viewer

"Engineering feels a little over my head, but a lot of people who knows me would say 'that's wrong, because all the things you craft may be beginner level but technically are engineering'."– Interview quote: Twitch recruited viewer

"I think of the word 'difficult'. My grandpa's a civil engineer, so I think about that, and like struggling in engineering school. That and maybe more stereotypical stuff about engineering." - Interview quote: YouTube recruited viewer

Whether or not an interviewee identified as a science person was very personal, and working in STEM or STEM adjacent fields was not automatically a precursor to this identity. How much people identified with the scientific enterprise and thought process discussed earlier often related to whether or not they considered themselves a science person. Stream viewers regularly viewed "science people" as those who approached the world through a scientific lens first. Similarly, some who did work in STEM did not see themselves as "science-y" enough and some who did not work in the field viewed their level of personal interest as enough for the identity outside of any career interests. Across the board, the degree to which a person thought about science or was interested in science at a deep level was the classifying factor.

"Not really, I guess... I do love to learn. I have actually been around actual "science people". People who are so intrigued about everything. But when I'm not studying science as a grad student, I'm thinking about something else." - Interview quote: Twitch organic viewer

"Yes, I definitely consider myself more of a science person. Even as a child, all through grade school, my highest thing was science, math. I would consider myself more scientific than mathematical – I lean on math because you need a foundation, but it's great to test things out, see what happens, back it up with the math. I feel like a science person is one who wants to try new things, test out different theories, and always question what is possible. The limits of our possibilities are only to our understanding of the world around us." – Interview quote: Twitch organic viewer

"I consider myself a science person, I approach problems through a logical approach first."- Interview quote: YouTube recruited viewer

"Yes and no. Yes, in terms of the field that I'm in, I think you have to be science-minded, we're expected to keep up to date on medical stuff that going on. But no in terms of, there are so

many things that are happening in science that I have no idea about. For me, I think of researchers, people who do scientific research. Not everyone can do research, there are so many of us who are clinical minded vs research minded. So in my mind, people who are more interested in the theoretical are more science-y." - Interview quote: Twitch recruited viewer

Moreover, we heard a recurring story of people having lost their connection to science. Many felt kinship with or interest in science as young people and appear to have lost this joy as they got older, or as they lost confidence in their ability to understand the material during their schooling. This disconnection was a common experience especially among those recruited to participate who were not actively engaging in engineering or science content in their spare time. The transition to high school and, later, into adulthood were turning points where many veered away from science as a pursuit because the spark of fun it used to bring had faded away. Additionally, for some those feelings of excitement were more specifically replaced with concerns about not being able to keep up with the content as it got more difficult. Science outside of the school arena was not really considered as an option anymore.

"Science used to be my favorite subject but that changed in high school." – Interview quote: Twitch recruited viewer

"I was a real science nerd when I was younger. Used to watch PBS. My favorite show was Zoom, I used to watch it every day after school. They had experiments you could try at home, mess up the kitchen. It got harder and harder as I got older. I got to high school, and it wasn't fun anymore." - Interview quote: Twitch recruited viewer

Mechanisms for Deepening Affinities

We developed learning metrics to explore *Building Stuff* impacts, and for deepening affinities with engineering we identified three mechanisms, or learning strands, that we have focused our attention on in this section:

A	B	C
Sparking interest & excitement (Strand 1)	**Identifying with Engineering Enterprise** (Strand 6)	**Reflecting on Engineering** (Strand 4)

To see more details on the specific components we identified for each learning strand and how we utilized them in our observations, please see the Appendix.

A. Sparking Interest & Excitement (Strand 1)

Enthusiasm during the stream and curiosity and interest in the content discussed in the interviews may be the strand that the *Building Stuff* with NOVA stream cultivated most easily. This format really fostered an environment of enthusiasm and interest in a range of engineering content. Both organic and recruited viewers of the stream noted topics and ideas that excited them. The Escape Room was a large point of interest for many viewers, as it shared a lot of interesting information in a novel and exciting format.

> *"It was fun. I felt like I was there. Especially with engineering, with math, and objects to calculate and stuff... It's a lot, but it's good, it teaches you. It's awesome, I have to go back and watch the other ones, I feel like I'm there." – Interview quote: Twitch recruited viewer*

We still noted that excitement was often tied to connections to youth, either positive science and engineering experiences from viewer's childhoods, or their desire to share the content with the young people in their lives. Plus, within the stream chat we saw these same themes along with a lot of thoughtful questions about the stream content, further demonstrating that curiosity and interest.

> *"The host spoke to this woman who's an educator and while they were talking, they were building chocolate buildings, and that was very interesting. Just building a structure out of chocolate definitely was unique. It reminded me of attending a science-based camp I went to as a kid, it brought back memories." - Interview quote: Twitch organic viewer*

> *"Joining late so might have missed this, but what's the maximum height a building could be using this tech?" – Twitch chat comment*

Moreover, people in the Twitch chat regularly brought up things they were interested in doing or seeing in the future that are related to the stream content. For example, some mentioned places they want to visit, activities they want to do, or people with whom they want to share the material. This implies that some are indeed intending to extend their interests beyond the stream itself, with *Building Stuff* as a catalyst.

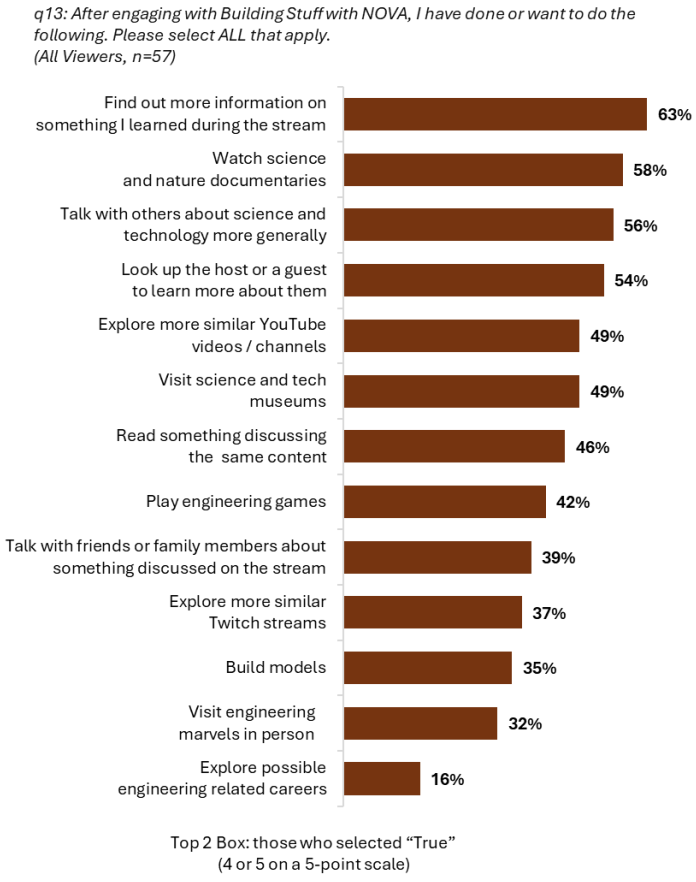
"Great reminder that I need to go to a maker space and connect with people!" – Twitch chat comment

"Would you or Mike from Trapology be willing to do a virtual classroom visit?" – Twitch chat comment

We also see a harmony with *Strand 4: Reflecting on engineering* as recognizing engineering in the day-to-day and applying it in different contexts, maybe from one's past, often served as a spark of interest and enthusiasm for people.

"This stuff is so cool, I love to see it - a long while back I worked with Douglas Trumbull in Western MA and got to see a bunch of their behind-the-scenes prop creation stuff, though my role was in computer graphics at that time!" – Twitch chat comment

The survey also showed the array of things that stream viewers had done or wanted to do following watching the stream—with 'find out more information on something learned during the stream' taking the top spot. On average, people chose 5.89 activities. 63% said find out more information on something learned during the stream, 58% watch science and nature documentaries,



56% talk with others about science and technology more generally, 54% look up the host or a guest to learn more about them, 49% explore more similar YouTube videos channels, 49% visit science and tech museums, 46% read something discussing the same content, 42% play engineering games, 39% talk with friends or family members about something discussed on the stream, 37% explore more similar twitch streams, 35% build models, 32% visit engineering marvels in person, 16% explore possible engineering related careers. While the stream really did inspire engineering related actions, it was least likely to inspire any person's career trajectory, which could also perhaps be most of the viewers were already set in their professions and not necessarily working on their schooling.

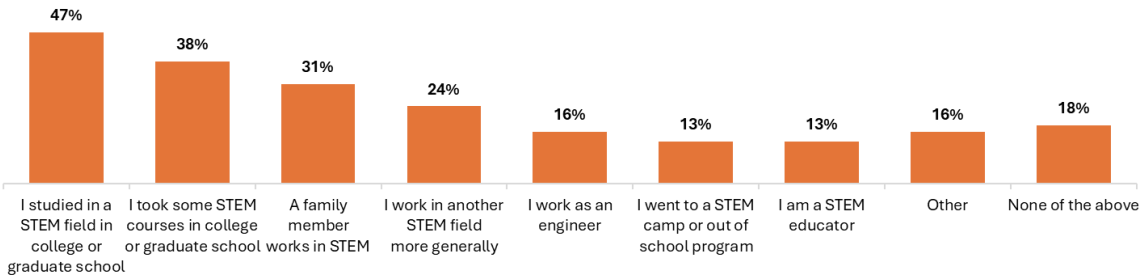
B. Identifying with Engineering Enterprise (Strand 6)

We see that a lot of those people who naturally engaged with the Building Stuff w/NOVA stream already had strong positive identifications with engineering, either as engineers themselves, as connected to STEM, or as strongly respecting and appreciating STEM content. Having these identities and interests helped them to gravitate toward this content in the first place, as it is inherently what they enjoy engaging with during their leisure time.

> *"I love math and science. Those are my interests when it comes to learning, I can never get tired of learning about interesting things." – Interview quote: Twitch organic viewer*
>
> *"I'm an aerospace engineer, and I also build model aircraft and model rockets. I also do scale-model railroading – it's a good hobby because it allows you to do so many different things." - Interview quote: Twitch organic viewer*
>
> *"I think a lot about things that are software-based now, because I have a lot of friends who are software engineers. But yeah, software engineering, mechanical engineering, chemical engineering. I am really into geology as well. So, when I talk about old books on my bookshelf, there is a lot about geology when it comes to science." - Interview quote: Twitch organic viewer*

Survey results support this interpretation of the organic viewers, as among those survey takers who naturally found their way to the stream on Twitch or YouTube 85% studied in a STEM field or took STEM courses that were not a major field. Broken down a bit 47% studied in a STEM field in college or grad school, 38% took some STEM courses even if it was not a major, 31% have a family member working in STEM, 24% work in a STEM field generally, 16% work as engineers themselves, 13% went to a STEM camp or out of school program, 13% are STEM educators.

q14: We would also like to hear about any science, technology, engineering, or math (STEM) related experiences you may have had. Please select ALL that apply.
(Organic Viewers, n=45)



We saw the building of additional enthusiasm for engineers among those engaging in the *Building Stuff* with NOVA stream because of hearing more about all that self-defined engineers know and do. There were statements reinforcing how interesting people thought both engineers and engineering were and their general positivity towards the field.

> *"Dr. B engineering is cool AF. Glad my daughter is watching right now." – Twitch chat comment*

Along those lines, we also heard and saw appreciation for the intelligence of those on the stream and for the displays of engineering knowledge. Those engaging with the stream were thankful for and excited about all the engineering knowledge from Dr. Nee, the many guests, and the knowledgeable community members in chat. These people were appreciated not only for their friendliness and community building but also explicitly for sharing what they know.

> *"People who would put the answers into the chat, I was like wow there are people out there who are really smart. It took me like a minute or two, but there were 10 people who had already said it. My mind isn't working as fast as people who I guess deal with science on a day to day basis. Yes, sometimes I got the answer wrong but it's okay, that's part of learning." - Interview quote: Twitch organic viewer*

> *"Yes, sensors are dope and that just fundamental science." – Twitch chat comment*

> *"Thanks, you two structural engineers" – Twitch chat comment*

Additionally, for a few viewers of the stream we heard that the accessibility of the content on *Building Stuff* with NOVA helped them to have confidence with the material. We discussed earlier how several viewers mentioned losing their love of science and their faith in their ability to understand the material in school. A couple of viewers elaborated on how the format of the stream removed some of the fear connected with not knowing or remembering.

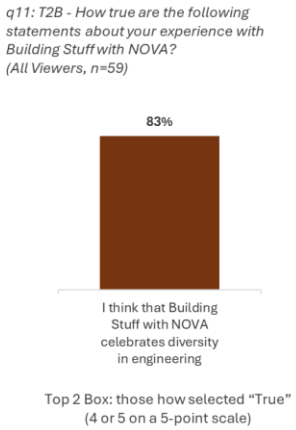
"NOVA feels like open-book learning. It's not trying to stump you, but figuring out "how do we get there?" - Interview quote: Twitch organic viewer

Many stated how seeing variety on the stream, which for some meant seeing people like themselves in the content, helped them to identify with the content and feel like engineering could be for them. Specifically, there was a lot of enthusiasm for the representation of Black people in science on the stream, with Dr. Nee highlighting the importance of Black people in engineering via his role as the host. Additionally, there was intersectional excitement in seeing Black women receive attention for their contributions to field.

"As a Black woman I see them by themselves at the spotlight. So as a Black woman, I really liked to see multiple Black women on the NOVA thing. It was really satisfying; I am like emotional." – Interview quote: Twitch organic viewer

"Right off the bat, I noticed the diversity and inclusivity on the screen immediately. Having 3 of the 4 members be POC and 2 of 4 be women – incredible representation of diversity in STEM. As someone who's worked in STEM, a lot of my colleagues have been white men, so I loved this diversity because we need to get more people involved." – Interview quote: Twitch recruited viewer

Survey results reinforce this message, as they demonstrate that the large majority of respondents believe that Building Stuff with NOVA celebrates diversity in engineering.



C. Reflecting on Engineering (Strand 4)

Even after specific engagement with *Building Stuff*, we saw that people often needed to be prompted to reflect on ways that they saw everyday science and engineering in their lives.

Even after engaging with the *Building Stuff* with NOVA stream and being exposed to its content which regularly demonstrated moments of "everyday engineering", it is still hard for people to make this connection for themselves. Most needed a bit of nudging to view their daily activities or interests in this light. When we asked directly about these connections between engineering and daily life, some had lots to say and others only thought of a few things or were reluctant to identify with this way of describing their activities.

> *"I don't think I consciously do things in my life that I consider science. In my job I do lots of research, usability research, which is science in a way, but I don't think of it consciously as science. Maybe cooking, transforming molecules, but I don't think 'what I am doing IS science'." - Interview quote: Twitch organic viewer*

> *"I build furniture a lot – we're renovating our house. I like to build things, but don't associate it with engineering." - Interview quote: Twitch recruited viewer*

> *"I don't know that I'm doing anything science in my daily life, but I like to watch cooking shows and they play around with molecular gastronomy and smoking techniques. I'm into photography - I guess the manual part is science, but I don't think of it as science, I'm still very stuck in an "engineering, biology" definition. More formal. As someone never really strong at it in school, I don't make a distinct connection to how science takes place in my everyday life." – Interview quote: YouTube recruited viewer*

Some were able to easily discuss this more "niche" way of looking at science and engineering quite easily. And many showed interest and even occasionally pride once they acknowledged the details of what they do in their lives that could be considered day-to-day engineering.

> *"I'm an auto technician, and I can relate to it because it's all about building and science and problem solving. It's all about thinking and figuring it out." - Interview quote: Twitch recruited viewer*

Some of the interesting ways in which people did see science and engineering as part of their daily lives were via building, creating, fixing, or tinkering with an array of practical and

leisure time items. These items or activities included: furniture, home renovations, Legos, Christmas lights, puzzles, woodworking, model building, model building, bicycles, cars, video games, computers, software, and programming, optimizing tools and tech (phones, new media, Amazon fire stick, appliances), cooking, plants/the environment/landscaping, photography, chess, glass making, the weather, and ceramics.

> *"My side hobby is chess, and if you think about chess in that kind of lens, every move you make, there is a calculation to it. There's dynamic programming, solving a problem backwards. Once you are back to your current position, you figure it out from there. Sitting at the board, calculating several moves ahead. Even more technical, I guess, is cooking - you never want to overcook your food. Making cottage pies, reduce the wine, making sure it's tasting and looking good." - Interview quote: YouTube recruited viewer*

> *"I do put together furniture, I help my little nephew build things with his little blocks. I have been known to take apart my own electronics and try to fix it myself. I've tried to start on my own starter replacement pieces for my computer. Key word is try." – Interview quote: Twitch organic viewer*

We also heard a few viewers discuss how they engaged with engineering and science on a daily basis via how they thought about the world and how it works and/or acknowledged all of the efforts of engineers around them (i.e., appreciated and considered what went into the bridge they take to work).

> *"Science is a part of my daily life because I find myself questioning how things are working and looking at plants and understand their growth habits and why they are growing in a certain area and what things in this environment are helping a plant act this way."- Interview quote: YouTube recruited viewer*

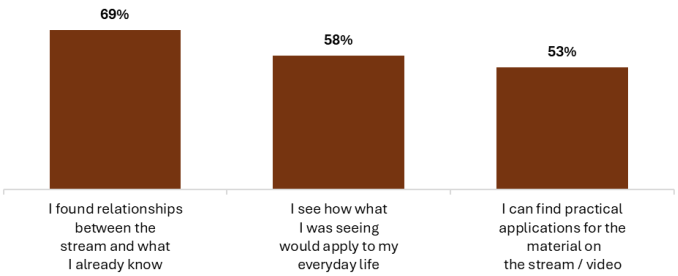
Though in chat we also viewed in real time people connect engineering to things they encounter in their everyday lives, including the infrastructure they use and popular culture references. People referenced more obviously engineered structures they see or engage with like familiar bridges and buildings. There were also some who reflected more broadly to their wider cultural context and noted engineering examples from books/stories, games, and movies. This highlights the point that there are many different ways to see engineering as part of our lives, either through what we physically do and/or what is around us.

> *"The Burj Al Kalifa has a great design to combat wind." – Twitch chat comment*

"This is making me think this is the science behind 'twisters' (great movie!)" – Twitch chat comment

Survey results also support that many *Building Stuff* with NOVA stream viewers were able to connect stream content with additional content relevant to them and their lives. For the following points, we will be discussing the proportion of survey respondents who selected a 4 or a 5 on a 5-point Likert scale asking them how true a statement is for them. Therefore, we are sharing those who described each statement as true or very true for them. 69% said it was true or very true that they have found relationships between what on the stream and what they already know. 58% said it was true or very true that they see how what was discussed in the stream would apply to their everyday lives. And lastly, 53% said it was true or very true that they can find practical applications for the material on the stream.

q11: T2B - How true are the following statements about your experience with Building Stuff with NOVA? (All Viewers, n=59)



Top 2 Box: those who selected "True" (4 or 5 on a 5-point scale)

Film Series Mechanisms Toward Affinity

***Building Stuff* film viewers echoed stream viewers in how they viewed science, engineering, and whether they would describe themselves as science people. Similarly, many needed prompting during interviews to reflect on how they engage in everyday science and engineering.** Film viewers referenced similar ideas and reference points when it comes to science and engineering and what they do on a day-to-day basis that could fall into either of those

categories. Also, much like the stream viewers, recruited viewers in particular referenced thinking of science and engineering as difficult and/or topics they were not confident in.

> *"When I think of "science" I think "oh, gosh, I am not going to understand it". I had a lot of trouble with it in school. But it's part of what makes us, the fundamentals of life." - Interview quote: Film recruited viewer*

> *"Tinkering with Christmas lights. We build things all the time. Whether you go to Ikea to buy furniture or putting together bicycles or a toy. Even buying a new media, Amazon Fire Stick, you got to know how to put everything together." – Interview quote: Film recruited viewer*

> *"On a deeper level, everything is kinda science in a way. I don't regularly think about science when I'm doing stuff, but it is cool to think that everything we do involves some sort of science." - Interview quote: Film recruited viewer*

Seeing variety, within the film series was also seen as valuable by some, many older female interviewees compared the presence of women to what they remembered in their youth. Much like the stream, film viewers found the presence of a variety of speakers y as an important moment of representation and demonstrates how everyone belongs in scientific and engineering careers.

> *"It reminded me of going back up to labs where I used to work, where the people were so excited about research they were doing. I loved seeing women and minorities as science experts, covering building to launching rockets, showing people working in their labs."– Interview quote: Film organic viewer*

> *"When I first started watching it, I was impressed with the breadth of things. I don't know how you found all of these people that do all of this stuff. This was amazing to see. I really appreciated the focus on people of color, and women – that was noticeable and notable. When I went to school in the late 80s and early 90s, there weren't women or people of color in my engineering classes. I think it's huge to see yourself in that. I look back and I didn't have that as any kind of mentor or image to make it into the field without seeing myself in it. To have people like yourself in it is huge, to say 'Ok, I belong in this field.'"- Interview quote: Film organic viewer*

Also, for the film in particular we saw that standout moments for many viewers were moments of seeing engineering in unexpected places, yet this was not true for all. For some, they had these "aha!" moments of interest and connection with engineering during the film segments that pushed people to think more critically about engineering's role across an array of typical human activities.

Yet others, who were unable to move outside of their more rigid concepts of engineering, had trouble understanding why these segments were included, and consequently would appreciate them the least of all.

> *"The Double Dutch portion, I really resonated with that one. Taking a topic that people wouldn't necessarily put them together. The last section, I didn't care for as much. It comes to relatability. I think I just didn't really... it didn't catch my eye. It just wasn't for me." – Interview quote: Film recruited viewer*

> *"Some of the stories were more obviously significant in how they relate to the larger planet. Some seemed trivial – like the physics of Double Dutch. I didn't get the scientific point or implications." - Interview quote: Film organic viewer*

> *"I thought it was very interesting. I loved not every story – some I liked more than other, but I thought overall it was tremendously informative. I think that's fascinating. I also really liked the piece where they tried to use electro sensors to create devices to help people control their movements. I thought that was great. I didn't see the point in the one about a dancer – I can't imagine why anybody would want to feel the same things a dancer feels when they're dancing, the same reason I wouldn't want to feel what a marathon runner feels when they're running. I'm not a dancer, maybe that's why. I'm not sure it's worth that investment." - Interview quote: Film recruited viewer*

Detailed Findings

6. Facilitating Scientific Thinking

DETAILED FINDINGS: FACILITATING SCIENTIFIC THINKING

This section explores learning strands related to facilitating scientific thinking for both the Twitch/YouTube stream and the film series. It directly relates to Inquiry Area 3 and its related research questions.

➔ **Inquiry Area 3**: *What lessons around **learning and engagement** are there for informal science communicators regarding community-centered streaming, with focus on qualities that are most conducive toward learning, both related to pre-defined objectives and emergent areas?*

- Do we see evidence of learning on Twitch and YouTube through Building Stuff with NOVA? What type of learning is most prevalent?
- How do different engagement styles (e.g. active, passive, light responder, contributing member, community leader, troll) impact engineering and science-related learning outcomes?

For relevant sources refer to the following thematic areas listed under Literature Review Sources in the Appendix: *General, Learning through livestreaming.*

Mechanisms toward Scientific Thinking

We developed learning metrics to explore *Building Stuff* impacts, and for facilitating scientific thinking we identified three mechanisms, or learning strands, that we have focused our attention on in this section:

A	B	C
Engaging in Scientific Reasoning (Strand 3)	**Engaging in Engineering / Collaborative Practice** (Strand 5)	**Understanding Engineering Knowledge** (Strand 2)

To see more details on the specific components we identified for each learning strand and how we utilized them in our observations, please see the Appendix.

A. Engaging in Scientific Reasoning (Strand 3)

There is importance in seeing imperfection in the problem-solving process, as stream viewers discussed how it made engineering feel real and attainable. Managing challenges and mistakes also brings out the humanity in the engineer identity for those involved. It shows that normal people engage in these activities, and that the crucial component is not perfection but rather dedication to solving the issue. The Escape Room in particular was a format dedicated to seeing people fail and try again until they succeeded.

> *"What's fun about it is that I was seeing myself reflected in the engineers. Watching people struggle is kind of fun. I appreciate realness and people. There's three people [and] they're interacting and talking and trying to figure it out." – Interview quote: Twitch organic viewer*

> *"From my perspective, as being a somewhat older person, you still have to press through, and NOVA shows that. I mean you can't avoid it because it's live. And it's nice to see that things come up, and it's fine, and people are not losing their minds. So, it was really comforting to watch them do this."- Interview quote: Twitch organic viewer*

Building Stuff stream viewers also mentioned how seeing people engage in scientific reasoning and make mistakes also helps the concepts resonate more than they might if the correct answer is just laid out in a book. Also, interestingly, the act of directly engaging and going through the reasoning process with the stream, and watching it play out with others both allowed people to see the "why." So, watching problem solving take place was also valuable.

> *"Watching them be hands-on helped a lot. Like I said, I like to read to get more in-depth information, but when I read it doesn't always stick. So, seeing them actually do the things, talk to themselves throughout the missions, even though we're in the science field, it doesn't mean we always get things right on the first try. There's nothing wrong with getting things wrong. I'm that kind of person, if I get things wrong, I'll beat myself up over it." - Interview quote: Twitch organic viewer*

B. Engaging in Engineering / Collaborative Practice (Strand 5)

The live nature and interactivity of the Twitch chat format also appears to facilitate this kind of group reasoning and seeing the fallible, iterative nature of science. The chat analysis demonstrated how the *Escape Room* and *Interview* streams showed approximately 30% higher

potential for generating substantive STEM discussions. However, because of small sample sizes, we need to consider this a promising trend rather than a firm conclusion. More research with a larger sample would be needed to definitively confirm whether this trend holds true.

Most other science learning formats do not include question and answer, group discussion, and informal building/design as central. Therefore, the *Building Stuff* with NOVA stream maximizes some of the benefits of engaging in problem solving. Some felt as if the iterative and interactive engagement of the stream contributed to their learning.

> *"I can remember one moment very clearly, when the contestants had to be able to produce a very specific amount of fuel to put on the rocket. It was very clever, because all the containers they had didn't have the correct volume they needed. I added a suggestion on chat, and everyone else commented too. And they were a few steps ahead, and came up with a solution that didn't involve repeating the same thing over and over again, and I kept that solution with me because that kind of problem happens in real life. I have tons of technical knowledge, but I still learnt something practical and new, and I believe other people with less technical knowledge did as well." - Interview quote: Twitch organic viewer*

> *"I wasn't trying to solve any of the problems, but one of them – probably the easiest one – I was like "Oh I know this one". I watched them try to solve it, watched the Twitch comments show up on screen and try to communicate that with the participants. I felt like I was more engaged with that one." - Interview quote: YouTube recruited viewer*

Some interviewees were able to explicitly describe how the group problem solving helped viewers to see that engineering is collaborative. In part, the *Building Stuff* with NOVA was very transparent in showing how many people were involved in the creation of these engineering experiences shown on screen, whether that was the field trips, guests, or creation of the Escape Room. Even those who maybe didn't participate in the joint problem solving witnessed it and benefited from seeing engineering in this light.

> *"I was on one of the first calls ideating how to do the Escape Room. So, this is amazing, this is fascinating, to see three camera people there, the production, pulling it off live." - Interview quote: Twitch organic viewer*

> *"When I think about science, I think about precision. And that's my idealization, [though now] I understand that science is collaboration, even though my goal is working by myself." - Interview quote: Twitch organic viewer*

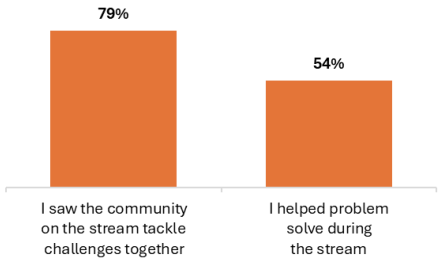
The problem solving tended to take place during the streams that showcase gameplay, builds, and escape room development or play. People built on the ideas of others more easily in these formats,

often with the encouragement of the host. Both chat observations and the interviews affirmed that these formats promoted this kind of thinking. Problem solving often looked like chatters offering up suggestions and solutions related to their own experiences or knowledge, and even simply asking questions to better clarify the problem/solution.

> *"Maybe instead of a chess behind the coal inserter you can put a conveyer belt." – Twitch chat comment*
>
> *"Can we have salt-water batteries?" – Twitch chat comment*

Survey responses additionally reinforce that the majority of stream participants saw problem solving happening and about half thought they contributed personally to finding solutions. Focusing on organic respondents who often spent more time on the stream and had more interest in the topics at hand, 79% agreed that they saw the community on the stream tackle challenges, 54% agreed that they helped solve problems during the stream.

q9: T2B - Please rate how much you agree or disagree with the following statements about the Building Stuff with NOVA stream.
(Organic Twitch Viewers, n=28)



Top 2 Box: those who selected "Agree"
(6 or 7 on a 7-point scale)

Similarly, chat analysis demonstrates the power of collaboration in the *Building Stuff* with NOVA stream, including that streams with more collaborative learning moments aligned with triple the odds of high chat engagement. In the context of the stream, moments of collaboration appear to be enticing and bring others in to contribute. Also, regular viewers outpaced NOVA team members in STEM discussions (16.9% versus 11.3%), with a notable 0.59 correlation in collaborative learning moments. Statistical analysis uncovered powerful engagement dynamics: viewer questions increased the odds of above-average STEM engagement by 28%. Collaborative learning moments made high-engagement discussions 2.6 times more likely. Shared experiences boosted STEM

conversations by 31%. Host interaction messages trended toward increasing STEM discussions by 67%.

C. Understanding Engineering Knowledge (Strand 2)

Twitch/YouTube participants often used fairly sophisticated scientific terminology—they not only had positive identifications with engineering but seemed well versed and comfortable with details. In the stream chat, viewers expressed their knowledge in several ways, such as identifying very specific machinery in videos, knowing details about how buildings/infrastructure are put together, understanding technical tools, and asking questions that seem more sophisticated (e.g., asking about the particulars of physics or chemistry being discussed) than a novice might have the foundation to ask.

> *"I think Frank Lloyd Wright one designed a 520-story building with 10' floors; I don't know whether he had access to a structural engineer of David Field's caliber." – Twitch chat comment*

> *"With such high energy needed how is the heat going to be contained when energy levels are scaled up?" – Twitch chat comment*

> *"The third option is to use a 3d printer to make some 1 mm extruded plastic letters, but it would be super slow. I suppose also you could print a plastic stencil and cut many things from the vinyl yourself." – Twitch chat comment*

Viewers discussed knowledge gained from the stream either as knowledge they once knew that they were reminded of, the expansion of existing knowledge, or even the introduction of entirely new concepts. It was useful to see that even the engineering savvy viewers (both organic and recruited) still learned new things, as learning wasn't always about completely novel ideas but could also build upon what the viewers already knew. Moreover, as the stream covered such a wide array of topic areas, even those immersed in STEM often were exposed to new content. And once again, we see additional harmony with Strand 4 in this section, as recognizing engineering in the day-to-day and applying it in different contexts is in and of itself a way of expanding one's engineering knowledge and viewing the world in a new way. Educators in particular often discussed how they liked taking what they learned from the stream to use in the classroom.

"I am curious about these things. They are interesting to me. I can pick up tidbits here and there to help me with my job [as a teacher]. If I keep vacuuming in everything, I can pick up enough to help me build something or come up with an idea for a student. Anything that is science and engineering related has a lot of merit even if it is motivational. That didn't work. Now what are we going to do?" - Interview quote: YouTube organic viewer

In the chat, explicit signs of learning happened for people watching the stream often in the form of having absorbed fun trivia or bite-sized nuggets of information, through direct answers to specific circumstances or questions asked by the host, a stated sense of curiosity or desire to learn more, or just a general feeling of having made some intellectual "gains" while watching a stream.

"Mnemonic unlocked! – Twitch chat comment

"I learned a lot today!." – Twitch chat comment

On site locations and hands on activities were often stand out opportunities for people to both gain and express engineering knowledge. The Escape Room also involved both of those components, which was a big opportunity for people to build their knowledge because it was all about solving engineering-related puzzles.

"Build your own light up shoes. I did learn a few things there – it was about sensors. I always thought it had to be something motion activated. I never thought about how it was made or how simple it was made, with a spring. Never would have thought of something like that. Credit card, with a wire in there." - Interview quote: Twitch recruited viewer

"I liked that they have sensors that detect overheating, and it was a savior because if something was going bad and was overheating, they could notice it and they wouldn't need to buy another robot. And it took 4 hours to build. And he was able to build the arm right in front of us, that was pretty cool. I like the whole thought process, of the joints having tension to see if they're not connected." - Interview quote: YouTube recruited viewer

We saw willingness for those engaging in chat to demonstrate their engineering knowledge on the stream, yet we also heard in the interviews that some did not engage in chat for fear that they did not know enough to contribute effectively. There did not seem to be any hesitancy about whether engineering knowledge would be appreciated on the stream, as it was often prompted and congratulated. Yet, some viewers (more often recruited viewers and/or those with less STEM education) were concerned that they would either embarrass themselves or not aid in the

issue being tackled in the stream. Anxiety about "getting it wrong" was a hindrance, especially in the fast-paced environment of the Escape Room, where contributions from chat did matter as far as solving the necessary puzzles.

> *"I was in chat a little bit. It's just that I'm just so slow. I did try to figure out the rocket. If you have anxiety about being put on the spot. I said at least two things. I'm a nervous person. I didn't say too much the last one." - Interview quote: Twitch recruited viewer*

Survey results reinforce that the majority of *Building Stuff* with NOVA viewers felt as if they learned from their experiences in the stream. 71% said it was true or very true that they learned something new from their time on the stream.

Film Series Mechanisms

The film series also fostered curiosity and interest in the content through covering a range of topics and highlighting challenges and feasibility of different endeavors. The fact that the films were constructed of several segments each allowed for many entry points to interest and curiosity in engineering for viewers. If one segment was not as interesting, the next might be what draws them in. Also, the changing topics demonstrated the vast nature of the field and kept people's brain engaged by bringing them along on several different journeys per film.

> *"I liked the variety. Instead of having one subject, it had a range of different topics. It was amazing. It made me want to learn a little bit more. Like the one about imaging technology, the eyes, was pretty amazing. The one about architecture and high-rises... Anything about architecture is something I'll watch. So those kinds of shows are amazing to me. Amazing stuff. Space travel, underworld travel, underwater travel. A good variety of shows, many things you wouldn't know or come across in daily life." - Interview quote: Film organic viewer*

> *"I enjoyed that because that made me think critically about the feasibility of being able to do that, and I never thought the biggest hurdle that they had was to be able to manufacture the rocket in a way that could support the G forces that we're going to be exposed to before being thrown into the air. That was fascinating." - Interview quote: Film organic viewer*

Demonstrating learning from failure also stood out to a few film viewers as a way to see and understand the realities of engineering. Managing challenges and mistakes also brings out the humanity in the engineer identity for those involved. It shows that normal people engage in these

activities, and that the crucial component is not perfection but rather dedication to solving the issue. The Escape Room in particular was a format dedicated to seeing people fail and try again until they succeeded.

> *"Something that really resonated with me in the video was going through fails. They said, "we are trying to get this to fail", and when you teach, you try things and they fail. But you don't get better if you don't try it and fail." - Interview quote: Film organic viewer*

Those who watched the *Building Stuff* film series also acknowledged that they learned new things and/or had their knowledge expanded by watching. For recruited viewers who were not often as connected to NOVA or PBS, this learning was sometimes a surprise, though definitely a welcome one. People referenced holding on to some of the knowledge they gained from the films and at times even investigating it further.

> *"There was a lot I didn't know before. I didn't know those things were being done and was not familiar with some of the human-boosted stuff. I really like the one about the building. I know that for earthquakes they use heavy steal balls, but for wind they need to use water, so I thought that was pretty crazy. They all had a 'oh that's cool someone is doing that.'"- Interview quote: Film organic viewer*

> *"Like I said, I didn't know what to expect on the video. But I thought it was very engaging to know about the summaries, blow up buildings, I was like wow. It wowed me. I didn't even know we could do that now. That's also why I didn't see myself as a science person because how come I didn't know? I definitely learned from it." - Interview quote: Film recruited viewer*

> *"I learned a lot of things, but did I keep one? It's so crazy that a fabric can be so resistant and sustain so much. I never thought that a natural fabric could do that and be so much better than other materials. The artificial nose was cool, because I didn't realize there was so much food waste. I knew it, but not to that extent. So, it's great if we could reduce food waste." – Interview quote: Film organic viewer*

The documentary film style was also a plus for some as far as learning format, though the static and non-interactive nature of the film was noted by some viewers as a potential challenge as far as learning. The need for visual learning content, especially among young people, was referenced repeatedly, along with how short people's attention spans are these days with the dominance of social media.

> *"Students do not read. I think it's a time thing. A documentary is one hour. I think it's how they see it. Our students are very busy, they work full-time in addition to school. I try to assign them books, and they find the video. It's not the same, but it's better a video than not learning at all." - Interview quote: Film organic viewer*

Yet it was also acknowledged by a few that with the film format there was no opportunity for discussion, no one to ask or answer questions, and no one to follow up with on the content. Several mentioned a desire to know what happened (or will happen) next with different segments and yet there is no ongoing dialogue to engage with and no avenues to find out more because films are inherently snapshots from a specific period of time.

> *"Documentaries work really well for me. They hold my attention better than a book does. They're not nearly as good as classroom learning. A fairly good documentary makes an excellent classroom resource. A really good documentary might make a good resource for a college resource or seminar. But when they get that polished, they strike me as making less room for conversation, with people who I hope would be questioning the observations. Everything comes off as authoritative, already figured out. A documentary that uses high production values to show progress that is less polished strikes me as a new balance that I see very little of. It has the potential to be much more useful in a learning environment." - Interview quote: Film organic viewer*

Appendix

Appendix: Research Activities

Phase 1 Research Activities

Consultant Engagement: We started with a kickoff workshop via videoconference with our core subject-matter advisor/partner Dr. Jessica Hammer, Associate Professor of Learning Sciences and Director of the Center for Transformational Play at Carnegie Mellon University. In this session, the core NOVA team and Dr. Hammer identified key open questions, refined our research goals, and set clear expectations for future work.

Literature Review: We supported Dr. Lisa Leombruni (GBH's expert consultant) in reviewing a wide range of documents—including research and creative materials from the 2019 WGBH Escape Lab and insights—and systematically analyzed 48 sources (2011–2023), organizing them into six themes covering topics from livestreaming learning to moderation techniques.

Advisory Committee Involvement: An advisory group of additional subject matter experts reviewed our interview guide and survey questionnaire, further enriching our methodology with their specialized insights. Dr. Kishonna Gray is an Associate Professor in Writing, Rhetoric, & Digital Studies and Africana Studies at the University of Kentucky, Dr. Katie Salen Tekinbas is a game designer, animator, educator, and Professor at the University of California, Irvine, and Dr. TL Taylor is a Professor of Comparative Media Studies at MIT and Director of the MIT Game Lab. We also regularly met with Dr. Jessica Hammer throughout each phase of the research to ensure platform-related rigor.

Twitch Streamer Interviews: We conducted in-depth interviews with 6 Twitch streamers specializing in STEM content, which helped us understand practical engagement strategies and informed our overall research design.

Metrics Development: A crucial early step was developing a comprehensive matrix to track individual and community-level variables related to engagement and learning outcomes on Twitch. This matrix guided the design of our interview guide, observations, and data analysis and was pivotal in updating our IRB protocol and refining our research design for the later phases. Please see the Appendix for more details on metrics framework components.

Phase 2 Research Activities

Twitch/YouTube Stream Interviews with Organic and Recruited Participants: We use semi-structured, qualitative interviews to capture how participants make meaning of their experiences on interactive streaming channels featuring STEM content. Our interview guide was adapted for different recruitment approaches. Some participants were recruited via a professional vendor (and asked to watch a stream before the interview) while others were recruited directly from the live stream through a survey link shared in the chat. We conducted 16 interviews with recruited participants (8 on Twitch, 8 on YouTube), with each participant viewing two episodes (one regular stream and one Escape Room finale). Of those 16 participants, 11 were interviewed twice (a 60-minute interview after the first stream and a 30-minute follow-up after the second) and 5 were interviewed once while discussing both episodes. We also conducted 16 interviews with organic participants recruited directly from the stream. All quotations from interviewees are presented without attribution to protect participant anonymity and encourage candid, in-depth responses.

Twitch/YouTube Stream Survey: Our survey—distributed via live stream announcements, the NOVA newsletter, and directly to interviewees—captured quantitative data on viewership habits, engagement styles, and perceptions of STEM content across both interactive streaming and documentary formats. We received 59 complete and 17 partial responses. The data were analyzed by recruitment method (recruited vs. organic participants) and by platform (Twitch vs. YouTube), helping us identify key differences in engagement behaviors.

Twitch/YouTube Stream Observations: We coded and analyzed chat interactions from streamed NOVA content on Twitch and YouTube. Using an observation spreadsheet and a detailed codebook (developed from our metrics matrix), four researchers collected nearly 300 quotes from 38 regular streams and 4 Escape Room finale streams. We focused on quotes that went beyond surface-level interactions to capture deeper insights into community dynamics.

Social Data Collaboratory Twitch Chat Stream Analysis: Between July 22 and October 30, 2024, we collected data from 66 Twitch videos (VODs) averaging 71 minutes and 15 YouTube videos. Using tools like TwitchDownloader and the chat-downloader Python library, supplemented by quantitative metrics from the NOVA team's analytics, we applied multiple linear regressions in R and Python to examine how content type, timing, audience makeup, and interaction features predicted engagement. Qualitative chat messages were systematically coded using GPT-4, with inter-coder reliability assessed via Gwet's AC1 coefficient (Gwet, 2008). We want to thank the Social Data Collaboratory with their help in this

study, including Simon Page, Data Analyst, Alex Kresovich, Research Scientist and Hy Tran, Senior Data Scientist.

Phase 3 Research Activities

Documentary Series Interviews with Organic and Recruited Participants: In Phase 3, we extended our research to explore how audiences engage with NOVA's documentary film content. The film interviews protocol was designed to compare traditional documentary formats with Community-centered streaming in engaging young audiences with STEM content and promoting inclusive science communication. Our interview guide—developed specifically for the *Building Stuff* docuseries—captured nuanced feedback on participants' impressions of the film, their underlying science and engineering interests, and the extent to which the documentary fostered learning and community connections. We conducted experience sampling interviews with 10 participants (all of whom watched the film on YouTube) and 10 interviews with organic participants recruited directly from NOVA channels. As with the Twitch/YouTube interviews, quotations are presented without attribution to safeguard privacy.

Appendix: Key Metrics

A crucial early step in During Phase 1 project was developing a comprehensive matrix to track individual and community-level variables related to learning and STEM-related engagement outcomes on Twitch. This robust framework strongly influenced the design of our interview guide, observations, and data analysis and was pivotal in updating our IRB protocol and refining our research design for the later phases. It also provided a means for standardizing and prioritizing our observations and analytical process across a multi-member research team.

Strand 1: Sparking Interest & Excitement

Key Metrics

- Engagement & interest with engineering content
- Level of curiosity with engineering topics
- Feeling that they can do engineering (attitudinal shift)
- Desire to learn more

Observation Codes

- Code 1.1. Expressing enthusiasm for the content "I am so excited to hear about bridges." "I love bridges."
- Code 1.2. Expressing curiosity about the content "I wonder if this is also applicable to other large structures."
- Code 1.3. Stating an explicit interest in knowing more about the content/adjacent content "I can't wait to watch the documentary you mentioned about this."

Strand 2: Understanding Engineering Knowledge

Key Metrics

- Recall of critical engineering concepts (TBD)
- Willingness to demonstrate engineering knowledge
- Self-reported feeling that they better understand engineering
- Self-efficacy in engineering in handling novel circumstances
- Knowing the steps in engineering process (e.g. ask, imagine, plan, create, improve)

Observation Codes

- Code 2.1. Referencing personal engineering knowledge (possibly any answer to a question trying to gauge knowledge/engagement) "Tension is important on the top of a bridge, while compression is on the bottom."
- Code 2.2. Stating ones ability and willingness to approach engineering problem 'Yep, I think I could tackle this if I had to"
- Code 2.3. Self-reported feeling that they understand some element of engineering better than they used to "I will always remember that now thanks to that mnemonic device! Thank you!"
- Code 2.4. Demonstrating knowledge of general steps to take when approaching engineering challenge (e.g. ask, imagine, plan, create, improve)

Strand 3: Engaging in Scientific Reasoning

Key Metrics

- Engaging in active problem solving during the stream
- Self-report that they engaged in problem solving during the stream

Observation Codes

- Code 3.1 Engaging in active problem solving (providing answer to issue being tackled in stream) "They should pull the blue string to get the door to open, because the clue said azul."

Strand 4: Reflecting on Engineering

Key Metrics

- Extension of active inquiry to other contexts (e.g., applying the scientific method, understanding process of engineering)
- Feeling that engineering is important/relevant to everyday life

- Self-efficacy: Feeling that engineering is something that they can do

Observation Codes

- Code 4.1 Discussing of method of inquiry in other contexts "My dad uses the same strategy when I gardening in the back yard."

Strand 5: Engaging in Engineering / Collaborative Practice

Key Metrics

- Understanding that engineering is a collaborative process
- Observed participation with Twitch collaborative problem solving

Observation Codes

- Code 5.1 Participating in collaborative problem solving (building off of other's ideas and answers in an issue being tackled in the stream)

Strand 6: Identifying with Engineering Enterprise

Key Metrics

- Self-reported confidence in engaging with engineering topics
- Identity or affinity with engineering
- Identification with / affinity toward with engineers

Observation Codes

- Code 6.1. Stating opinions about engineering as a field and engineers "This is why engineers are just the smartest people." (likely positive but not necessarily so)
- Code 6.2. Identifying with engineering/engineers "This is why I love my job." "I could absolutely see myself doing the same in those circumstances."

Appendix: Literature Review Sources

General

- Bandura, A. (1986). Social foundations of thought and action: A social cognitive theory. Englewood Cliffs, NJ: Prentice Hall.
- Burns, H. D., & Lesseig, K. (2017, June). Infusing empathy into engineering design: Supporting under-represented student interest and sense of belongingness. 2017 ASEE Annual Conference & Exposition.
- Doran, K. & Swenson, J. (2022). 'Do I Belong Here?': Persistence and Retention Implications of Engineering Belongingness and Identity in Academically At-Risk Populations. IEEE Frontiers in Education Conference (FIE), 1-9.
- Duke, B. (2013). Connectivism as a digital age learning theory. The International HETL Review, 2013 (Special Issue), 4-13.
- Elliot, A. J. (1999). Approach and avoidance motivation and achievement goals. Educational psychologist, 34(3), 169-189.
- Flores-Saviaga, C., Hammer, J., Flores, J. P., Seering, J., Reeves, S., & Savage, S. (2019). Audience and streamer participation at scale on Twitch. Proceedings of the 30th ACM conference on hypertext and social media, 277-278.
- Gong, W., Lim, E. P., & Zhu, F. (2015). Characterizing silent users in social media communities. Proceedings of the International AAAI Conference on Web and Social Media, Vol. 9, No. 1, 140-149.
- Gwet, K. L. (2008). Computing inter-rater reliability and its variance in the presence of high agreement. British Journal of Mathematical and Statistical Psychology, 61(1), 29-48.
- Hammad, N., Harpstead, E., & Hammer, J. (2023). The View from MARS: Empowering Game Stream Viewers with Metadata Augmented Real-time Streaming. Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology, 1-13.
- Holmes, J. R., To, A., Zhang, F., Park, S. E., Ali, S., Bai, Z., ... & Hammer, J. (2019, May). A good scare: leveraging game theming and narrative to impact player experience. Extended abstracts of the 2019 chi conference on human factors in computing systems, 1-6.
- Kuindersma, E. C., Pal, J., van den Herik, H. J., & Plaat, A. (2016). Comparing voluntary and mandatory gameplay. International Journal of Serious Games. Vol. 3, No.3, 67-83.

- Lave, J. & Wenger, E. (2001). Legitimate peripheral participation in communities of practice. Supporting lifelong learning, 121-136.
- Sala, G., Aksayli, N. D., Tatlidil, K. S., Tatsumi, T., Gondo, Y., & Gobet, F. (2019). Near and far transfer in cognitive training: A second-order meta-analysis. Collabra: Psychology, 5(1), 18.
- Seering, J., Kraut, R., & Dabbish, L. (2017). Shaping pro and anti-social behavior on twitch through moderation and example-setting. Proceedings of the 2017 ACM conference on computer supported cooperative work and social computing, 111-125.
- To, A., Holmes, J., Fath, E., Zhang, E., Kaufman, G., & Hammer, J. (2018). Modeling and designing for key elements of curiosity: Risking failure, valuing questions. Transactions of the Digital Games Research Association, 4(2).
- Yao, L. (2022). Video Game Livestream Trend Analysis Based on Twitch Livestream Data. 7th International Conference on Financial Innovation and Economic Development (ICFIED 2022), 2890-2895.
- Zimmerman, C. (2007). The development of scientific thinking skills in elementary and middle school. Developmental review, 27(2), 172-223.

Learning through livestreaming

- Chen, X., Chen, S., Wang, X., & Huang, Y. (2021). "I was afraid, but now I enjoy being a streamer!" Understanding the Challenges and Prospects of Using Live Streaming for Online Education. Proceedings of the ACM on Human-Computer Interaction, 4(CSCW3), 1-32.
- Chen, Y., Lasecki, W. S., & Dong, T. (2021). Towards supporting programming education at scale via live streaming. Proceedings of the ACM on Human-Computer Interaction, 4(CSCW3), 1-19.
- Consalvo, M., & Phelps, A. (2021). Game Development Live on Twitch: Observations of Practice and Educational Synergies. Game Production Studies, 123-139.
- Hunt Estevez, C., Jones, J., Shrestha, S., & Vincenti, G. (2021). Serious Games in STEM: Online Collaborative Design of a Lunar Simulator. International Conference on Human-Computer Interaction, 223-235
- Faas, T., Dombrowski, L., Young, A., & Miller, A. D. (2018). Watch me code: Programming mentorship communities on twitch.tv. Proceedings of the ACM on Human-Computer Interaction, 2(CSCW), 1-18.
- Fraser, C. A., Kim, J. O., Thornsberry, A., Klemmer, S., & Dontcheva, M. (2019). Sharing the studio: How creative livestreaming can inspire, educate, and engage. Proceedings of the 2019 Conference on Creativity and Cognition, 144-155.

- Gandolfi, E., Ferdig, R. E., & Clements, R. (2022). Streaming code across audiences and performers: An analysis of computer science communities of inquiry on Twitch.tv. British Journal of Educational Technology, 53(6), 1688-1705.
- Gandolfi, E., Ferdig, R. E., & Soyturk, I. (2023). Exploring the learning potential of online gaming communities: An application of the Game Communities of Inquiry Scale. New Media & Society, 25(6), 1374-1393.
- Gay, P. L. (2017). Moving People from Science Adjacent to Science Doers with Twitch. tv. AAS/Division for Planetary Sciences Meeting Abstracts# 49, Vol. 49, 119-202.
- Hammad, N., Harpstead, E., & Hammer, J. (2021). Towards examining the effects of live streaming an educational game. Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems, 1-6.
- Han, H. K., Huang, Y. C., & Chen, C. C. (2019). A deep learning model for extracting live streaming video highlights using audience messages. Proceedings of the 2019 2nd Artificial Intelligence and Cloud Computing Conference, 75-81.
- Lee, W. H., Shim, H. M., & Kim, H. G. (2022). Effect of game-based learning using live streaming on learners' interest, immersion, satisfaction, and instructors' perception. International Journal of Serious Games 9, no. 2, 3-26.
- Payne, K., Keith, M. J., Schuetzler, R. M., & Giboney, J. S. (2017). Examining the learning effects of live streaming video game instruction over Twitch. Computers in Human Behavior, 77, 95-109.
- Payne, K., Keith, M. J., Schuetzler, R. M., & Giboney, J. S. (2017). Examining the learning effects of live streaming video game instruction over Twitch. Computers in Human Behavior, 77, 95-109.
- Pirker, J., Steinmaurer, A., & Karakas, A. (2021). Beyond gaming: The potential of twitch for online learning and teaching. Proceedings of the 26th ACM Conference on Innovation and Technology in Computer Science Education V. 1, 74-80.
- Rubenking, B. & Strawser, M. (2023). Learning from a live stream: Differences in motivations, psychological needs, perceived learning, and information behaviors across live streaming and nonlive social media video viewing.
- Steinbeck, H., Teusner, R., & Meinel, C. (2021). Teaching the masses on twitch: An initial exploration of educational live-streaming. Proceedings of the Eighth ACM Conference on Learning@ Scale, 275-278.
- Stumpf, C. & Parker, A. (2021). LIVE-STREAMING IN MECHANICAL ENGINEERING: AN INNOVATIVE APPROACH TO REMOTE LAB DELIVERY. Proceedings of the Canadian Engineering Education Association (CEEA).

Livestream theory & commentary

- Anderson, K. E. (2018). Getting acquainted with social networks and apps: streaming video games on Twitch. tv. Library hi tech news, 35(9), 7-10.
- Poirier-Poulin, S. (2020). Watch me play: Twitch and the rise of game live streaming.

Inclusive gaming

- Gao, Z., Yada, S., Wakamiya, S., & Aramaki, E. (2020). Offensive language detection on video live streaming chat. Proceedings of the 28th international conference on computational linguistics, 1936-1940.
- Seering, J., Kraut, R., & Dabbish, L. (2017). Shaping pro and anti-social behavior on twitch through moderation and example-setting. Proceedings of the 2017 ACM conference on computer supported cooperative work and social computing, 111-125.
- Uttarapong, J., Cai, J., & Wohn, D. Y. (2021). Harassment experiences of women and LGBTQ live streamers and how they handled negativity. Proceedings of the 2021 ACM international conference on interactive media experiences, 7-19.
- Zhou, Y. & Farzan, R. (2021). Designing to stop live streaming cyberbullying: a case study of twitch live streaming platform. Proceedings of the 10th International Conference on Communities & Technologies-Wicked Problems in the Age of Tech, 138-150.

Moderator tools, techniques, characteristics

- Cai, J., & Wohn, D. Y. (2019). Categorizing live streaming moderation tools: An analysis of twitch. International Journal of Interactive Communication Systems and Technologies (IJICST), 9(2), 36-50.
- Chung, J. J. Y., Shin, H. V., Xia, H., Wei, L. Y., & Kazi, R. H. (2021). Beyond show of hands: Engaging viewers via expressive and scalable visual communication in live streaming. Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems, 1-14.
- Kim, J., Bae, K., Park, E., & del Pobil, A. P. (2019). Who will subscribe to my streaming channel? The case of twitch. Companion Publication of the 2019 Conference on Computer Supported Cooperative Work and Social Computing, 247-251.

- Seering, J., Luria, M., Ye, C., Kaufman, G., & Hammer, J. (2020). It takes a village: integrating an adaptive chatbot into an online gaming community. Proceedings of the 2020 chi conference on human factors in computing systems, 1-13.
- Woodcock, J. & Johnson, M. R. (2019). The affective labor and performance of live streaming on Twitch. tv. Television & New Media, 20(8), 813-823.
- Zhao, K., Hu, Y., Hong, Y., & Westland, J. C. (2019). Understanding characteristics of popular streamers on live streaming platforms: Evidence from Twitch. tv. Journal of the Association for Information Systems, Forthcoming.

User characteristics & motivation

- Bründl, S., Matt, C., Hess, T., & Engert, S. (2023). How synchronous participation affects the willingness to subscribe to social live streaming services: The role of co-interactive behavior on Twitch. European journal of information systems, 32(5), 800-817.
- Cheung, G. & Huang, J. (2011). Starcraft from the stands: understanding the game spectator. Proceedings of the SIGCHI conference on human factors in computing systems, 763-772.
- De Wit, J., Van der Kraan, A., & Theeuwes, J. (2020). Live streams on twitch help viewers cope with difficult periods in life. Frontiers in psychology, 11, 586975.
- Diwanji, V., Reed, A., Ferchaud, A., Seibert, J., Weinbrecht, V., & Sellers, N. (2020). Don't just watch, join in: Exploring information behavior and copresence on Twitch. Computers in Human Behavior, 105, 1-11.
- Dux, J. & Kim, J. (2018). Social live-streaming: Twitch. TV and uses and gratification theory social network analysis. Computer Science & Information Technology, 47.
- Gros, D., Wanner, B., Hackenholt, A., Zawadzki, P., & Knautz, K. (2017). World of streaming. Motivation and gratification on Twitch. Social Computing and Social Media. Human Behavior: 9th International Conference, Part I 9, 44-57.
- Hamilton, W. A., Garretson, O., & Kerne, A. (2014). Streaming on twitch: fostering participatory communities of play within live mixed media. Proceedings of the SIGCHI conference on human factors in computing systems, 1315-1324.
- Hilvert-Bruce, Z., Neill, J. T., Sjöblom, M., & Hamari, J. (2018). Social motivations of live-streaming viewer engagement on Twitch. Computers in human behavior, 84, 58-67.
- Li, Y., Wang, C., & Liu, J. (2020). A systematic review of literature on user behavior in video game live streaming. International journal of environmental research and public health, 17(9), 3328.

- Radu, I. R. (2023). Learning from Twitch streamers' experience for better online live lessons. Journal of Educational Sciences & Psychology, 13(1).
- Sheng, J. T. & Kairam, S. R. (2020). From virtual strangers to irl friends: relationship development in livestreaming communities on twitch. Proceedings of the ACM on Human-Computer Interaction, 4(CSCW2), 1-34.
- Sjöblom, M., & Hamari, J. (2017). Why do people watch others play video games? An empirical study on the motivations of Twitch users. Computers in human behavior, 75, 985-996.
- Wohn, D. Y. & Freeman, G. (2020). Audience management practices of live streamers on Twitch. Proceedings of the 2020 ACM International Conference on Interactive Media Experiences, 106-116.

Methodology

- Harpstead, E., Rios, J. S., Seering, J., & Hammer, J. (2019). Toward a Twitch research toolkit: A systematic review of approaches to research on game Streaming. Proceedings of the annual symposium on computer-human interaction in play, 111-119.
- Lester, J. N. (2020). Going digital in ethnography: Navigating the ethical tensions and productive possibilities. Cultural studies and critical methodologies, 20(5), 414-424.
- Recktenwald, D. (2017). Toward a transcription and analysis of live streaming on Twitch. Journal of Pragmatics, 115, 68-81.
- Reeves, S., Greiffenhagen, C., Flintham, M., Benford, S., Adams, M., Row Farr, J., & Tandavantij, N. (2015). I'd Hide You: Performing live broadcasting in public. Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, 2573-2582.

Metric Development Matrix

- Mamaril, N. A., Usher, E. L., Li, C. R., Economy, D. R., & Kennedy, M. S. (2016). Measuring undergraduate students' engineering self-efficacy: A validation study. Journal of Engineering Education, 105(2), 366-395.
- Seering, J., Savage, S., Eagle, M., Churchin, J., Moeller, R., Bigham, J. P., & Hammer, J. (2017). Audience participation games: Blurring the line between player and spectator. Proceedings of the 2017 Conference on Designing Interactive Systems, 429-440.

Survey Items and References

- Aikenhead, G. S. & Ryan, A. G. (1992). The development of a new instrument: "Views on science-technology-society"(VOSTS). Science education, 76(5), 477-491.
- Nokelainen, P. (2006). An empirical assessment of pedagogical usability criteria for digital learning material with elementary school students. Journal of Educational Technology & Society, 9(2), 178-197.
- NORC at the University of Chicago (2012). GSS Data Explorer. Available online at: https://gssdataexplorer.norc.org/variables/3528/vshow

Appendix: Twitch/YouTube Initial Interview Discussion Guide

Background Context

This protocol is designed to help the Slover Linett at NORC research team ensure that they are keeping the overall goals of the project in mind when conducting interviews with participants. Some participants will be recruited through a recruiter and asked to watch the stream before the interview. Others will be recruited directly from the stream via a request for participation on the survey instrument being deployed as part of this research. Some questions will be aimed at or adapted to make sense for each group.

PART 1: Introductions and Consent (5 minutes)

The facilitators will introduce themselves and thank the participant for their time. They will then offer a brief orientation to the session and encourage participants to provide their candid feedback. Facilitators will reference and explain the study consent form. The form will have been emailed to participants who have access to email prior to their interview.

Interviewer's introduction and goals:

Thank you so much for sharing your time with us. We appreciate it! I would like to give you a quick orientation to how we will spend the next 60 minutes. Hopefully, this will be the only part in our conversations where one of us is doing most of the talking because we really want to hear your thoughts.

We are from Slover Linett at NORC, an organization based in Chicago that tries to understand how people engage with their interests and connect to others and to their communities. We've been doing this as a company for over 25 years, and we are constantly learning something new during each project we have.

For this project, we are interested in learning about how you spend your time, what topics excite you, and your experiences and perceptions with *Building Stuff with NOVA*.

Is that okay?

Also, we want to confirm that you have watched at least one *Building Stuff with NOVA* stream on either Twitch or YouTube. Is that correct?

Consent and orientation to the session:

To help us remember what you share here today, is it ok if we record this conversation? It will only be used for notetaking, and only the people who are on our research team will have access to it.

Great! I invite you to share as much as you feel comfortable sharing. There are no wrong answers. Your thoughts, feelings, and experiences are all 100% valid. Feel free to choose not to answer any question if it makes

you uncomfortable; again, no judgment. I'll respect your decision. You can also take a break or stop the interview at any time and still get compensated.

Also, I want to emphasize that your identity will be protected. We'll be writing up a report based on discussions with several people. We will not connect your name with anything shared in our report. If you're interested, we are happy to send you an email with a link to the report when it's finished.

We'll keep our conversation to 60 minutes, and as a token of our gratitude, *[for those recruited via third-party recruiters]* we'll send you $150 for your time and expertise / *[for those recruited through the survey on the stream]* we'll send you $100 for your time and expertise.

Any questions before we begin? Can I clarify anything? Anything that concerns you? Anything you'd like to let me know before we proceed further?

Do I have your verbal consent to participate?

OKAY, let's begin!

PART 2: Background and Science/Engineering Interest (10 minutes)

We will get to talking about *Building Stuff with NOVA*, but to start, I'd like to hear more about you. Can you tell me a little about what you enjoy doing when you don't have other obligations like work or caregiving?

Note/probe for:

- Description of their interests and how they spend their time
- Any connection to their work or comparisons to their work
- Role other people/communities play in their chosen activities

[*IF NOT ALREADY DISCUSSED*] When you think about the term "science," what comes to mind?

(Strand 1: Sparking Interest & Excitement/ Strand 6: Identifying with Engineering Enterprise)

Note/probe for:

- Description of what science means to them
- Associations with and relationship to science *(probe for more than just a definition of the word)*

Now what about "engineering," what comes to mind?

- Description of what engineering means to them
- Associations with and relationship to engineering *(probe for more than just a definition of the word)*

Can you tell me about any science or engineering related media or activities that you enjoy?

(Strand 1: Sparking Interest & Excitement/ Strand 6: Identifying with Engineering Enterprise)

Note/probe for:

- Types of content (documentaries, books, podcasts, social media, etc.)
- Perceptions of science/engineering content
- Any differentiation between science and engineering (i.e., do they specifically enjoy engineering-related media or activities?)
- Thoughts on who engages with this kind of content
- Others they may connect with through this content
- What draws them to the content and makes them want to return to it/discover more

Would you consider yourself a "science person"? Why or why not?

(Strand 6: Identifying with Engineering Enterprise)

Note/probe for:

- Description of who is a "science person" – characteristics that makes a person a "science person" or not
- Perceptions of science/engineering community
- Comfort with and confidence in their knowledge of science and engineering material

Thinking about how you described "engineering" before, can you think of any ways in which you engage in things that might be considered engineering in your day-to-day life? What are some examples?

Note/probe for:

- Any connections between daily lives and engineering (e.g., building with Legos, crafting, playing Minecraft)

PART 3: Experience with and behavior on Twitch or YouTube (15 minutes)

Now let's switch gears a little. Can you tell me some about the time that you spend on [Twitch and/or YouTube]? How often do you spend time there? Which channels do you visit most?

(Comfort with Twitch or YouTube when relevant)

Note/probe for:

- If a user, details about comfort with Twitch /YouTube
- Description of what streams/channels they enjoy

- Description of topic areas they enjoy

[IF RELEVANT/ NOT ALREADY DISCUSSED] What makes a stream or channel worthwhile in your opinion? What gets you to return to participate again?

(Strand 1: Sparking Interest & Excitement, Host/Moderator engagement styles, Stream characteristics)

Note/probe for:

- Desirable characteristics of the host
- Desirable characteristics of the stream/video format
- Desirable characteristics of the community present in the stream/video chat
- Desirable content areas

[IF RELEVANT/NOT ALREADY DISCUSSED] What makes a stream/channel feel welcoming to you?

(Understanding welcoming and belonging, Host/Moderator engagement styles)

Note/probe for:

- Desirable characteristics of the host
- Desirable characteristics of the stream/video format
- Desirable characteristics of the community present in the stream/video chat
- Desirable content areas

[IF RELEVANT/ NOT ALREADY DISCUSSED] How would you describe your typical behavior on Twitch [YouTube]? For example, would you describe yourself as an observer or do you find yourself engaging in chat a lot?

(Individual engagement styles)

Note/probe for:

- Details about how they interact with the platform
- Any differences in behavior based on stream characteristics

PART 4: Experience with and perceptions of *Building Stuff with NOVA* (30 minutes)

Now we would love to talk about the *Building Stuff with NOVA* stream/video that you engaged with.

[RECRUITER INTERVIEW ONLY] Thank you for filling out the questions that we asked you about the stream. Can you talk a little bit more about your response to the first question, which asked you about any first impressions of the stream? You mentioned [ADD IN DETAILS FROM DIARY].

Note/probe for:

- Elaboration on first impressions of stream
- Perceptions of content, format, host, chat etc.

[RECRUITER INTERVIEW ONLY] Can you also discuss the second question you filled out – what were highlights of the stream for you? Anything that stuck with you? You mentioned [ADD IN DETAILS FROM DIARY].

(Possibly Strand 1: Sparking Interest and Excitement, Strand 2: Understanding Engineering Knowledge, Strand 3: Engaging in Scientific Reasoning, or Strand 4; Reflecting on Engineering)

Note/probe for:

- Elaboration on favorite aspects of the stream
- Areas of interest covered in the stream
- Areas of learning for the interviewee

["ORGANIC" PARTICIPANT INTERVIEW ONLY] Can you talk about your experience with *Building Stuff with NOVA*? How often have you watched? When did you start watching?

Note/probe for:

- Time spent with the stream

[ORGANIC PARTICIPANT INTERVIEW ONLY] Can you share any first impressions of *Building Stuff with NOVA*?

Note/probe for:

- Any first impressions of stream
- Perceptions of content, format, host, chat etc.

[ORGANIC PARTICIPANT INTERVIEW ONLY] What have been some highlights of Building Stuff with NOVA for you?

(Possibly Strand 1: Sparking Interest and Excitement, Strand 2: Understanding Engineering Knowledge, Strand 3: Engaging in Scientific Reasoning, or Strand 4; Reflecting on Engineering)

Note/probe for:

- Any favorite aspects of the stream
- Areas of interest covered in the stream
- Areas of learning for the interviewee

[IF NOT ALREADY COVERED] I would also like to hear about your impression of the community on the stream/in the video chat. What was the chat like?

(Possibly Strand 5: Engaging in Engineering Practice, Community connections, discussion of diversity, and/or discussion of welcome and belonging)

Note/probe for:

- Description of the community built through the channel
- Interviewee's own level of participation on the stream
- Perceptions of the activity on chat

[IF NOT ALREADY COVERED] Did you participate in the chat? [If NO] What would have made you want to participate? [If YES] What made you want to participate? [If YES but INFREQUENTLY] What would have made you want to participate more?]

Note/probe for:

- Pathways into chat
- Implied incentives for participation
- Barriers to participation

[IF NOT ALREADY COVERED] Also, what do you remember about the host of *Building Stuff with NOVA*? Any thoughts about how he communicated information or interacted with those in the chat?

(Host/Moderator characteristics)

Note/probe for:

- Perception of host
- Desirable host characteristics generally
- Dynamic between host and community

[IF NOT ALREADY COVERED] Can you also share with me your thoughts on the format of the stream/video you watched? For example, did you see an interview? Or was the host playing a game?

(Stream/video characteristics)

Note/probe for:

- Type of format(s) watched
- Perceptions of format(s)
- [If multiple] Comparisons or preferences between formats

[IF RELEVANT] Can you talk a bit about how *Building Stuff with NOVA* compares to other streams or channels where you spend time? Or other science/engineering media you enjoy?

Note/probe for:

- Ways other streams excel
- Avenues where interviewee likes to get science/engineering content
- Perceived benefits/strengths of media types in comparison to each other

[IF NOT ALREADY COVERED] What would be the best nugget of information that you took away from your time on the stream/watching the video? Have you or would you look into [INSERT TOPIC] outside of the stream or talk about it with others?

(Possibly Strand 1: Sparking Interest and Excitement, Strand 2: Understanding Engineering Knowledge, or Strand 4; Reflecting on Engineering)

Note/probe for:

- Thoughts on what was learned
- Perceptions of most valuable information covered
- Desire (or lack thereof) to deepen or share learning
- Additional interest in other NOVA content

[IF NOT ALREADY COVERED] Were there any other takeaways from your time with the *Building Stuff* stream?

Note/probe for:

- Perceptions of learning, generally
- Sense of science identity and whether that has changed since before watching the stream
- Level of awareness of engineering in their everyday lives

[IF NOT ALREADY COVERED] What kind of person do you think would most enjoy the *Building Stuff with NOVA* channel? Is there anyone in your life you can think of who would like it?

(Possibly Strand 5: Engaging in Engineering Practice, Community connections, discussion of diversity, and/or discussion of welcome and belonging)

Note/probe for:

- Thoughts on who the stream is for
- Perceptions of the community in the stream

[RECRUITER INTERVIEW ONLY] Also, the last question you filled out when you watched the stream asked you about what you might add, change, or adapt about the stream. You mentioned [ADD IN DETAILS FROM DIARY]. Can you talk more about your response?

Note/probe for:

- Aspects of the stream they would change
- More details on characteristics they value in a stream

[ORGANIC PARTICIPANT INTERVIEW ONLY] What might you add, change, or adapt about the stream/video you watched?

Note/probe for:

- Aspects of the stream they would change
- More details on characteristics they value in a stream

Appendix: Twitch/YouTube Second Interview Discussion Guide

Now that you have watched more than one *Building Stuff with NOVA* stream, we are looking forward to hearing your thoughts and we want to hear also any comparisons across the videos.

Any about impressions of the second stream you want to share off the bat?

Note/probe for:

- Elaboration on first impressions of stream
- Perceptions of content, format, host, chat etc.

Any highlights for you from the second stream? Anything that stuck with you?

(Possibly Strand 1: Sparking Interest and Excitement, Strand 2: Understanding Engineering Knowledge, Strand 3: Engaging in Scientific Reasoning, or Strand 4; Reflecting on Engineering)

Note/probe for:

- Elaboration on favorite aspects of the stream
- Areas of interest covered in the stream
- Areas of learning for the interviewee

What was your impression of the community on this second stream/in the video chat? Any different than the first one you watched?

(Possibly Strand 5: Engaging in Engineering Practice, Community connections, discussion of diversity, and/or discussion of welcome and belonging)

Note/probe for:

- Description of the community built through the channel
- Interviewee's own level of participation on the stream
- Perceptions of the activity on chat

[IF NOT ALREADY COVERED] Did you participate in the chat during this second stream? [If NO] What would have made you want to participate? [If YES] What made you want to participate? [If YES but INFREQUENTLY] What would have made you want to participate more?]

Note/probe for:

- Pathways into chat
- Implied incentives for participation

- Barriers to participation

[IF NOT ALREADY COVERED] Anything additional you want to share about the host and how he handled this second *Building Stuff with NOVA* stream? Any thoughts about how he communicated information or interacted with those in the chat?

(Host/Moderator characteristics)

Note/probe for:

- Perception of host
- Desirable host characteristics generally
- Dynamic between host and community

[IF NOT ALREADY COVERED] Can you also share with me your thoughts on the format of this other stream/video you watched? For example, did you see an interview? Or was the host playing a game?

(Stream/video characteristics)

Note/probe for:

- Type of format(s) watched
- Perceptions of format(s)
- [If multiple] Comparisons or preferences between formats

[IF NOT ALREADY COVERED] What would be the best nugget of information that you took away from your time on the second stream/watching the video? Have you or would you look into [INSERT TOPIC] outside of the stream or talk about it with others?

(Possibly Strand 1: Sparking Interest and Excitement, Strand 2: Understanding Engineering Knowledge, or Strand 4; Reflecting on Engineering)

Note/probe for:

- Thoughts on what was learned
- Perceptions of most valuable information covered
- Desire (or lack thereof) to deepen or share learning
- Additional interest in other NOVA content

[IF NOT ALREADY COVERED] Were there any other takeaways from your time with the *Building Stuff* stream?

Note/probe for:

- Perceptions of learning, generally
- Sense of science identity and whether that has changed since before watching the stream
- Level of awareness of engineering in their everyday lives

[IF NOT ALREADY COVERED] After having seem more than one, any addition a thoughts on you think the stream is for or who would most enjoy the *Building Stuff with NOVA* channel? Is there anyone in your life you can think of who would like it?

(Possibly Strand 5: Engaging in Engineering Practice, Community connections, discussion of diversity, and/or discussion of welcome and belonging)

Note/probe for:

- Thoughts on who the stream is for
- Perceptions of the community in the stream

Also, the last question, anything else you might add, change, or adapt about the stream now that you have seem more than one stream? You mentioned [ADD IN DETAILS FROM DIARY]. Can you talk more about your response?

Note/probe for:

- Aspects of the stream they would change
- More details on characteristics they value in a stream

Interview Conclusion

To complete the session, we will present the interviewees with a chance to ask questions, offer any final insights and feedback, inform them of process for receiving their thank you gift, ask them if they want to receive a link to the final report, and thank them for their participation.

Appendix: Film Series Interview Discussion Guide

Background Context

This protocol is designed to help the Slover Linett at NORC research team ensure that they are keeping the overall goals of the project in mind when conducting interviews with participants. Some participants will be recruited through a recruiter and asked to watch the film series before the interview. Others will be recruited directly from NOVA sources via a request for participation. Some questions will be aimed at or adapted to make sense for each group.

PART 1: Introductions and Consent **(5 minutes)**

The facilitators will introduce themselves and thank the participant for their time. They will then offer a brief orientation to the session and encourage participants to provide their candid feedback. Facilitators will reference and explain the study consent form. The form will have been emailed to participants who have access to email prior to their interview.

Interviewer's introduction and goals:

Thank you so much for sharing your time with us. We appreciate it! I would like to give you a quick orientation to how we will spend the next 60 minutes. Hopefully, this will be the only part in our conversations where one of us is doing most of the talking because we really want to hear your thoughts.

We are from Slover Linett at NORC, an organization based in Chicago that tries to understand how people engage with their interests and connect to others and to their communities. We've been doing this as a company for over 25 years, and we are constantly learning something new during each project we have.

For this project, we are interested in learning about how you spend your time, what topics excite you, and your experiences and perceptions with the *Building Stuff* documentary series.

Is that okay?

Also, we want to confirm that you have watched at least one *Building Stuff* episode. Is that correct?

Consent and orientation to the session:

To help us remember what you share here today, is it ok if we record this conversation? It will only be used for notetaking, and only the people who are on our research team will have access to it.

Great! I invite you to share as much as you feel comfortable sharing. There are no wrong answers. Your thoughts, feelings, and experiences are all 100% valid. Feel free to choose not to answer any question if it makes you uncomfortable; again, no judgment. I'll respect your decision. You can also take a break or stop the interview at any time and still get compensated.

Also, I want to emphasize that your identity will be protected. We'll be writing up a report based on discussions with several people. We will not connect your name with anything shared in our report. If you're interested, we are happy to send you an email with a link to the report when it's finished.

We'll keep our conversation to 60 minutes, and as a token of our gratitude, *[for those recruited via third-party recruiters]* we'll send you $150 for your time and expertise / *[for those recruited through NOVA channels]* we'll send you $100 for your time and expertise.

Any questions before we begin? Can I clarify anything? Anything that concerns you? Anything you'd like to let me know before we proceed further?

Do I have your verbal consent to participate?

OKAY, let's begin!

PART 2: Background and Science/Engineering Interest (10 minutes)

We will get to talking about the *Building Stuff* documentary series, but to start, I'd like to hear more about you. Can you tell me a little about what you enjoy doing when you don't have other obligations like work or caregiving?

Note/probe for:

- Description of their interests and how they spend their time
- Any connection to their work or comparisons to their work
- Role other people/communities play in their chosen activities

[*IF NOT ALREADY DISCUSSED*] When you think about the term "science," what comes to mind?

(Strand 1: Sparking Interest & Excitement/ Strand 6: Identifying with Engineering Enterprise)

Note/probe for:

- Description of what science means to them
- Associations with and relationship to science *(probe for more than just a definition of the word)*
  Now what about "engineering," what comes to mind?
- Description of what engineering means to them
- Associations with and relationship to engineering *(probe for more than just a definition of the word)*

Can you tell me about any science or engineering related media or activities that you enjoy?

(Strand 1: Sparking Interest & Excitement/ Strand 6: Identifying with Engineering Enterprise)

Note/probe for:

- Types of content (documentaries, books, podcasts, social media, etc.)
- Perceptions of science/engineering content
- Any differentiation between science and engineering (i.e., do they specifically enjoy engineering-related media or activities?)
- Thoughts on who engages with this kind of content
- Others they may connect with through this content
- What draws them to the content and makes them want to return to it/discover more

Would you consider yourself a "science person"? Why or why not?

(Strand 6: Identifying with Engineering Enterprise)

Note/probe for:

- Description of who is a "science person" – characteristics that makes a person a "science person" or not
- Perceptions of science/engineering community
- Comfort with and confidence in their knowledge of science and engineering material

Thinking about how you described "engineering" before, can you think of any ways in which you engage in things that might be considered engineering in your day-to-day life? What are some examples?

Note/probe for:

- Any connections between daily lives and engineering (e.g., building with Legos, crafting, playing Minecraft)

PART 3: Experience with and behavior on social media (15 minutes)

Now let's switch gears a little. Can you tell me some about the time that you spend on social media [For example: YouTube, Twitch, Instagram etc.]? How often do you spend time there? Which channels do you visit most?

(Comfort with Twitch or YouTube when relevant)

Note/probe for:

- If a user, details about comfort with Twitch /YouTube
- Description of what streams/channels they enjoy
- Description of topic areas they enjoy

[IF RELEVANT/ NOT ALREADY DISCUSSED] What makes a content creator, stream or channel worthwhile in your opinion? What gets you to return?

(Strand 1: Sparking Interest & Excitement, Host/Moderator engagement styles, Stream characteristics)

Note/probe for:

- Desirable characteristics of the host
- Desirable characteristics of the stream/video format
- Desirable characteristics of the community present in the stream/video chat
- Desirable content areas

[IF RELEVANT/NOT ALREADY DISCUSSED] What makes a content creator, stream or channel feel welcoming to you?

(Understanding welcoming and belonging, Host/Moderator engagement styles)

Note/probe for:

- Desirable characteristics of the host
- Desirable characteristics of the stream/video format
- Desirable characteristics of the community present in the stream/video chat
- Desirable content areas

[IF RELEVANT/ NOT ALREADY DISCUSSED] How would you describe your typical behavior on social media? For example, would you describe yourself as an observer or do you find yourself engaging in the comments or chat a lot?

(Individual engagement styles)

Note/probe for:

- Details about how they interact with the platform
- Any differences in behavior based on social media characteristics

PART 4A: Recruited Experience with /perceptions of *Building Stuff with NOVA* (30 minutes)

Now we would love to talk about the *Building Stuff* docuseries episode that you engaged with. Thank you for filling out the questions that we asked you about the episode you watched. Can you talk a little bit more about your response to the first question, which asked you about any first impressions of the film? You mentioned [ADD IN DETAILS FROM DIARY].

Note/probe for:

- Elaboration on first impressions of film
- Perceptions of content, format, etc.

Can you also discuss the second question you filled out – what were highlights of the episode for you? Anything that stuck with you? You mentioned [ADD IN DETAILS FROM DIARY].

(Possibly Strand 1: Sparking Interest and Excitement, Strand 2: Understanding Engineering Knowledge, Strand 3: Engaging in Scientific Reasoning, or Strand 4; Reflecting on Engineering)

Note/probe for:

- Elaboration on favorite aspects of the film
- Areas of interest covered in the film
- Areas of learning for the interviewee
- Which of the film segments did they like the most and why
- Which segment did they like the least and why
- What do they think about all different people that appear in the film – including guest speakers, experts, engineers and others

Is there anything about the episode that you didn't like, or things that you wish had been different?

Note/probe for:

- Any ways that they didn't connect with the documentary
- Aspects of the episode they would change
- More details on characteristics they value in a docuseries

[IF WATCHED ON YOUTUBE] I would also like to hear about your impression of the community response to the episode. Did you happen to notice/read the chat/comments? Or participate yourself?

(Possibly Strand 5: Engaging in Engineering Practice, Community connections, discussion of diversity, and/or discussion of welcome and belonging)

Note/probe for:

- Description of the community built through the channel
- Interviewee's own level of participation on the stream
- Perceptions of the activity on chat/comments
- Pathways into chat
- Implied incentives for participation
- Things that may have gotten to participate or participate more
- Barriers to participation

Now that you've watched the documentary, has anything changed for you? For example, did you think about anything differently, or feel differently, do something differently. Have you talked to someone about something that you wouldn't have done otherwise?

Note/probe for:

- Thoughts on what was learned
- Perceptions of most valuable information covered
- Desire (or lack thereof) to deepen or share learning
- Additional interest in other NOVA content

Can you talk a bit about how the *Building Stuff* docuseries compares to other science/engineering media that you may have seen elsewhere?

Note/probe for:

- Ways other media excel
- Avenues where interviewee likes to get science/engineering content
- Perceived benefits/strengths of media types in comparison to each other
- Additional interest in other NOVA content

[IF NOT ALREADY COVERED] What kind of person do you think would most enjoy the *Building Stuff* docuseries? Is there anyone in your life you can think of who would like it?

(Possibly Strand 5: Engaging in Engineering Practice, Community connections, discussion of diversity, and/or discussion of welcome and belonging)

Note/probe for:

- Thoughts on who the docuseries is for
- Perceptions of the community surrounding the docuseries

[IF NOT ALREADY COVERED] Can you talk a little bit about what you think of documentaries as a mode for learning. How might it feel different than a classroom, a book? Or even perhaps different than getting the same information via a Twitch stream or YouTube video?

(Possibly Strand 5: Engaging in Engineering Practice, Community connections, discussion of diversity, and/or discussion of welcome and belonging)

Note/probe for:

- Thoughts different avenues for informal science learning

- Ways social media may differ in particular from a more traditional documentary

I'd like to show you another format that the Building Stuff team created in addition to the documentary. [Facilitator shares description below and then opens the page and shares screen.] I'd like to hear about your impressions of the things on this page. I'll scroll down slowly for about 20 seconds. Don't share your thoughts right away, just take things in for a moment. [Facilitator slowly scrolls through at least 10-15 videos. If participant speaks, remind them to just take things in first before you talk.]

OK, thanks for looking through some of the things on this page. What stands out to you about what you see here?

Note/probe for:

Description to share: *Building Stuff* with NOVA's Twitch stream featured live interactive episodes showcasing Science, Engineering, Technology and Math (STEM) content in summer and fall 2024. Each episode explored the world of engineering through either gameplay, interactive expert interviews, builds, or virtual field trips. Former NASA engineer Dr. Nehemiah Mabry, also known as Dr. Nee, hosted the series. The series culminated in four-night series of a virtual collaborative Escape Room game.

Page: https://www.twitch.tv/novabuildingstuff/videos?filter=all

Overall impressions and anything that is of interest to them (e.g., tone, content of interest, range of content, how people are featured)

KEY: how this content might compare (similar/different) from the documentary they watched

Who they think this content might be for, compared to the documentary film

PART 4B: Organic Experience with /perceptions of *Building Stuff with NOVA* (30 minutes)

Now we would love to talk about the *Building Stuff* docuseries episode that you engaged with. Can you talk about your experience with NOVA' three-part *Building Stuff* docuseries? How often have you watched? When did you start watching?

Note/probe for:

- Time spent with the film series
- Awareness of the different parts and which parts watched? (Boost it! Reach it! Change it!)
- Where they watched

Can you share any first impressions of *Building Stuff docuseries*?

Note/probe for:

- Any first impressions of film series
- Perceptions of content, format, etc.

What have been some highlights of *Building Stuff* with NOVA film series for you?

(Possibly Strand 1: Sparking Interest and Excitement, Strand 2: Understanding Engineering Knowledge, Strand 3: Engaging in Scientific Reasoning, or Strand 4; Reflecting on Engineering)

Note/probe for:

- Elaboration on favorite aspects of the film
- Areas of interest covered in the film
- Areas of learning for the interviewee
- Which of the film segments did they like the most and why
- Which segment did they like the least and why
- What do they think about all different people that appear in the film – including guest speakers, experts, engineers and others

Is there anything about the episode that you didn't like, or things that you wish had been different?

Note/probe for:

- Any ways that they didn't connect with the documentary
- Aspects of the episode they would change
- More details on characteristics they value in a docuseries

[IF WATCHED ON YOUTUBE] I would also like to hear about your impression of the community response to the episode. Did you happen to notice/read the chat/comments? Or participate yourself?

(Possibly Strand 5: Engaging in Engineering Practice, Community connections, discussion of diversity, and/or discussion of welcome and belonging)

Note/probe for:

- Description of the community built through the channel
- Interviewee's own level of participation on the stream
- Perceptions of the activity on chat/comments
- Pathways into chat
- Implied incentives for participation
- Things that may have gotten to participate or participate more
- Barriers to participation

Now that you've watched the documentary, has anything changed for you? For example, did you think about anything differently, or feel differently, do something differently. Have you talked to someone about something that you wouldn't have done otherwise?

Note/probe for:

- Thoughts on what was learned
- Perceptions of most valuable information covered
- Desire (or lack thereof) to deepen or share learning
- Additional interest in other NOVA content

Can you talk a bit about how the *Building Stuff* docuseries compares to other science/engineering media that you may have seen elsewhere?

Note/probe for:

- Ways other media excel
- Avenues where interviewee likes to get science/engineering content
- Perceived benefits/strengths of media types in comparison to each other

[IF NOT ALREADY COVERED] What kind of person do you think would most enjoy the *Building Stuff* docuseries? Is there anyone in your life you can think of who would like it?

(Possibly Strand 5: Engaging in Engineering Practice, Community connections, discussion of diversity, and/or discussion of welcome and belonging)

Note/probe for:

- Thoughts on who the docuseries is for
- Perceptions of the community surrounding the docuseries

[IF NOT ALREADY COVERED] Can you talk a little bit about what you think of documentaries as a mode for learning. How might it feel different than a classroom, a book? Or even perhaps different than getting the same information via a Twitch stream or YouTube video?

(Possibly Strand 5: Engaging in Engineering Practice, Community connections, discussion of diversity, and/or discussion of welcome and belonging)

Note/probe for:

- Thoughts different avenues for informal science learning
- Ways social media may differ in particular from a more traditional documentary

I'd like to show you another format that the *Building Stuff* team created in addition to the documentary. [Facilitator shares description below and then opens the page and shares screen.] I'd like to hear about your impressions of the things on this page. I'll scroll down slowly for about 20 seconds. Don't share your thoughts right away, just take things in for a moment. [Facilitator slowly scrolls through at least 10-15 videos. If participant speaks, remind them to just take things in first before you talk.]

OK, thanks for looking through some of the things on this page. What stands out to you about what you see here?

Description to share: *Building Stuff* with NOVA's Twitch stream featured live interactive episodes showcasing Science, Engineering, Technology and Math (STEM) content in summer and fall 2024. Each episode explored the world of engineering through either gameplay, interactive expert interviews, builds, or virtual field trips. Former NASA engineer Dr. Nehemiah Mabry, also known as Dr. Nee, hosted the series. The series culminated in four-night series of a virtual collaborative Escape Room game.

Page: https://www.twitch.tv/novabuildingstuff/videos?filter=all

Overall impressions and any thing that is of interest to them (e.g., tone, content of interest, range of content, how people are featured)

KEY: how this content might compare (similar/different) from the documentary they watched

Who they think this content might be for, compared to the documentary film

Age and race/ethnicity

Interview Conclusion

To complete the session, we will present the interviewees with a chance to ask questions, offer any final insights and feedback, inform them of process for receiving their thank you gift, ask them if they want to receive a link to the final report, and thank them for their participation.

Appendix: Survey Instrument

Intro and Consent Language

"Thank you for your time! Before we get started, we just wanted to remind you that this survey is part of a study on the experience with Building Stuff with NOVA . You will be asked questions about your experiences and how it felt to be a part of Building Stuff with NOVA community. Your responses will help us create more fun and engaging engineering content in the future!

The survey should take no more than 5-7 minutes, and there is no risk involved—other than reflecting and briefly sharing your experiences with science, engineering, and the NOVA Stream/videos. If at any point you don't wish to complete the survey, you may end it at any time, without any consequence, as it is voluntary. Your data will also remain strictly anonymous and confidential.

If you have any questions about this research study, please contact Bayaz Zeynalova from the research team (zeynalova-bayaz@norc.org)

Also, we are recruiting a few people to be interviewed about their experience watching Building Stuff with NOVA. At the end of the survey there will be an opportunity to provide your contact information to potentially be chosen to participate in an interview and receive $100 compensation for your time and expertise. Providing your information is completely voluntary and will only be used for the purposes of this study.

If you consent to this process and to participating in this survey, please click "I consent" below:

C1. I consent to participating in this research study on the [Building Stuff with NOVA Stream/Building Stuff documentary] experience.

1. *I consent to participating in this research study on the [Building Stuff with NOVA Stream/Building Stuff documentary] experience.*
2. *I do not consent to participating in this study.*

Thank you for your interest in our survey! This study is intended for participation by people 18 years of age or older. If you are not 18+, please answer "No" to the following question.

1. Are you 18 years old or older?

1. Yes
2. No

Section 1: Background and Experience with the *Building Stuff with NOVA* stream and Twitch

[If Q1=2] Thanks again for your interest, but we have to keep participation open to those 18 years of age or older only – Please continue to enjoy the stream anyway and we're happy to still have you as part of the community!!

2. **In the last month, how often did you spend time on Twitch?**

    1. Every day
    2. A few times a week
    3. Once a week
    4. A few times a month
    5. Only once this month
    6. I don't spend time on Twitch
    7. I don't know/don't remember

3. **Is this your first-time watching *Building Stuff with NOVA*?**

    1. Yes
    2. No, I have watched before

4. **In which way(s) have you watched *Building Stuff with NOVA*?** Please select ALL that apply.

    1. Live on Twitch
    2. Pre-recorded videos on Twitch
    3. Live on YouTube
    4. Pre-recorded videos on YouTube
    5. Live on Facebook
    6. Pre-recorded videos on TikTok
    7. Other (please specify):_____
    8. I am not sure/I don't know

5. **[IF Q3 = 2] In the last month, how often did you spend time with the *Building Stuff with NOVA* stream (on any platform)?**

    1. Every day they've streamed
    2. A few times a week
    3. Once a week
    4. A few times a month
    5. Only once this month
    6. I don't know/don't remember

6. **How did you first find out about *Building Stuff with NOVA*?**

    1. Mention from a streamer I follow
    2. Twitch promotion / front page
    3. Science / tech tabs in Twitch
    4. NOVA YouTube channel
    5. YouTube suggested the video to me
    6. Other social media platforms (e.g., TikTok, Reddit)
    7. Other NOVA social media
    8. Family and friends
    9. Professor / educator
    10. Community members in a different Twitch chat
    11. Other: please specify_____
    12. I don't know/don't remember

Section 2: Perceptions of and experiences with *Building Stuff with NOVA and similar STEM content*

7. [IF Q4 = 1 or 2] **Please rate how accurate the following statements are about what brings you to the *Building Stuff with NOVA* stream.** *(Engagement style/type of user)*

    [7-point-scale: 1/left = Not at all like me, 7/right = Very much like me)

    1. To be social with others in the stream
    2. To engage with interesting content in the stream
    3. Because I like the host
    4. To support people I know working on the stream
    5. Because of guests on the stream

8. [IF Q4 = 1 or 2] **Please select whether the following statements are True or False based on your typical behavior on the *Building Stuff with NOVA* stream.** *(Engagement style/type of user)*

    [True/False]

    1. I tend to participate a lot in chat
    2. I enjoy the sense of community built in the stream
    3. I tend to have the stream on in the background while I do other things
    4. I just watch the stream and don't tend to chat
    5. I consider myself a Building Stuff with NOVA community leader

9. [IF Q4 = 1 or 2] **Please rate how much you agree or disagree with the following statements about the *Building Stuff with NOVA* stream.** *(Engagement style/type of user)*

[7-point-scale: 1/left = Strongly disagree, 7/right = Strongly agree)

1. I helped problem solve during the stream (Strand 3:Engaging in Scientific reasoning)
2. I saw the community on the stream tackle challenges together (Strand 5: Engaging in engineering practice)
3. I feel my chat contributions are valuable to the community (Welcome and Community Building)

10. **Which types of *Building Stuff with NOVA* content have you watched?** Please select ALL that apply. [RANDOMIZE]

1. Video game play
2. An interview
3. Model building
4. Field trips
5. Escape Room planning and design
6. Escape Room game play (October 27th 2024 – October 30th 2024)
7. Other (please specify):_____
8. None of the above

11. **How true are the following statements about your experience with *Building Stuff with NOVA*?** [5 point scale: 1 = Not at all true, 5 = Very true] [RANDOMIZE]

1. I have found relationships between what was on the stream/video and what I already know (Strand 4: Reflecting on Engineering)
2. I see how what I was seeing discussed would apply to my everyday life (Strand 4: Reflecting on Engineering)
3. I can find practical applications for the material on the stream/video (Strand 4: Reflecting on Engineering)
4. I learned something new from my time on the stream/video. (Strand 2: Understanding Engineering Knowledge)
5. I feel connected to the other people watching/engaging in chat (Welcome and Community Building)
6. I feel welcome when engaging with the Building Stuff with NOVA (Welcome and Community Building)
7. I believe that Building Stuff with NOVA has its own community (Welcome and Community Building)
8. I think that Building Stuff with NOVA celebrates diversity in engineering (Diversity/Inclusivity)
9. I feel safe in the Building Stuff with NOVA community.

12. **[IF Q4 = 1 or 2] To what extent do you agree or disagree with the following statements about *Building Stuff with NOVA*?** [7 point scale: 1 = Strongly disagree, 7 = Strongly agree, with N/A option] [RANDOMIZE]

    I feel motivated to join in the chat and participate when the host or moderators do the following

    1. Prompt the viewers to comment or answer a question
    2. Like or openly appreciate a comment in the chat
    3. Ask people to elaborate on or expand something they said in the chat
    4. Ask community members to reflect on prior learning/experiences
    5. Connect people in the chat with each other
    6. Remind those in the stream of any rules and/or expectations
    7. Ask community members to share information about themselves
    8. Act on information provided by the community in the chat
    9. Shut down inappropriate behavior
    10. Give shout outs to community members they remember in chat
    11. Give shout outs for subscribing or donating

13. **After engaging with *Building Stuff with NOVA*, I have done or want to do the following.** Please select ALL that apply. [RANDOMIZE] *(Strand 1: Sparking Interest and Excitement)*

    1. Explore more similar Twitch streams
    2. Explore more similar YouTube videos/channels
    3. Watch science and nature documentaries
    4. Play engineering games
    5. Build models
    6. Find out more information on something I learned during the stream
    7. Talk with friends or family members about something discussed on the steam
    8. Talk with others about science and technology more generally
    9. Visit science and tech museums
    10. Visit engineering marvels in person (i.e., bridges, towers, rockets)
    11. Explore possible engineering related careers
    12. Read something discussing the same content
    13. Look up the host or a guest to learn more about them
    14. Something else (please describe): _____
    15. None of these [EXCLUSIVE]

Section 3: Personal Background and Demographics

You are almost done! We have a few important questions about you that will help NOVA understand the *Building Stuff* community better. Your answers will be kept anonymous and will never be used outside of this research study. If there is anything you do not wish to share, please select "Prefer not to answer" or skip the question.

14. **We would also like to hear about any science, technology, engineering, or math (STEM) related experiences you may have had.** Please select ALL that apply. *(Familiarity with STEM)*

    1. I studied in a STEM field in college or graduate school
    2. I took some STEM courses in college or graduate school, even if it was not my major
    3. I went to a STEM camp or out of school program
    4. I am a STEM educator
    5. A family member works in STEM
    6. I work as an engineer
    7. I work in another STEM field more generally
    8. Other (please specify): _____
    9. None of the above

15. Do you live in the US? [REQUIRED]

    1. Yes
    2. No

16. **What state do you live in?** [DROPDOWN OF STATES]

17. Please select your age category:

    1. 18-24
    2. 25-34
    3. 35-44
    4. 45-54
    5. 55-64
    6. 65 or older

18. **Which of the following races/ethnicities do you identify as?** Please select ALL that apply.

    1. American Indian or Alaska Native
    2. Asian or Asian American
    3. Black or African American
    4. Hispanic or Latina/Latino/Latinx

5. Native Hawaiian or other Pacific Islander
6. White or European American
7. If you don't see yourself in the list provided, please describe: _____
8. Prefer not to answer

19. **What is your gender?** Please select all that apply.

1. Female
2. Male
3. Non-binary
4. Prefer to self-describe: _____
5. Prefer not to answer

20. **What level of education have you completed?**

1. Some high school
2. High school graduate (high school diploma or the equivalent GED)
3. Some college/Associates degree
4. Bachelor's degree
5. Master's degree
6. Professional or doctorate degree (e.g., J.D., M.D., Ph.D.)
7. Prefer to self-describe: _____

21. **Do you identify as someone with a disability?**

1. Yes
2. No
3. Prefer not to answer.

22. **Do you identify as part of the LGBTQ+ (Lesbian, Gay, Bisexual, Transgender, Queer) community?**

1. Yes
2. No
3. I don't label myself as anything
4. Prefer to self-describe: _____
5. Prefer not to answer

Section 4: Follow-up Interview

We are also recruiting people who are interested in being **interviewed about their time watching B*uilding Stuff* with NOVA!** It is ok if you have only watched a little (or have watched a lot); we want to know about a range of experiences. The interview would be 60 minutes long and take place via Zoom. You will receive **$100 for your time and participation**.

Please note that if you choose to participate, you will be sent to a new web page where we will collect your name and contact information. Your responses here will remain anonymous and confidential.

CLICK HERE TO PROVIDE INFORMATION TO PARTICIPATE IN AN INTERVIEW